Growth and Transition in the Cleveland Iron and Steel Industry, 1850 to 1914.

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Abstract

The dramatic expansion of the iron industry in Cleveland from 1850 propelled the district briefly to the position of the world's largest iron-producing centre and brought about the formation of a major industrial cluster in a previously unindustrialised area. By the end of the 1870s, however, its prosperity was threatened by developments in steel-production technology and the growth of iron and steel output in the US and Germany. The first part of this thesis examines the initial development and early expansion of the industry. Using a data set of firms that entered the iron and related sectors between 1850 and 1880, the study assesses the contribution of business networks to growth. It is suggested that an important part was played by an existing network of Darlington-based Quaker business interests, and that development may have taken a different form without the presence of the network. The second part investigates the transition of the industry from the 1870s to 1914 to determine how effectively the district's firms responded to significant changes in technology, international competition, corporate legislation and financial markets. The study finds that some firms did adapt and grow, and the district made the transition to steel successfully. Steel technology was adopted when technical and commercial circumstances allowed, and in particular the basic open hearth process was actively investigated from an early stage. Flexible use was made of the free availability of incorporation and of access to securities markets. An extended case study of one company, Dorman Long, illustrates the beginnings of the development of corporate enterprise in the industry.

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Abbreviations

AGM	Annual General Meeting
BBA	Bell Brothers Accounts
BBAR	Bell Brothers Annual Report and Accounts
BBDM	Bell Brothers Directors' Minutes
BH	*Business History*
BHR	Business History Review
BS	Teesside Archive British Steel Collection
BSDM	Bowesfield Steel Company Directors' Minutes
BVAR	Bolckow Vaughan Annual Report and Accounts
BVDM	Bolckow Vaughan Directors' Minutes
CIE	*Cleveland Institution of Engineers Proceedings*
DLAR	Dorman Long Annual Report and Accounts
DLDM	Dorman Long Annual Directors' Minutes
EcHR	*Economic History Review*
HWDM	Head Wrightson Directors' Minutes
ICE	*Institution of Civil Engineers Proceedings*
ICTR	*Iron and Coal Trades Review*
IME	*Institution of Mechanical Engineers Proceedings*
JISI	*Journal of the Iron and Steel Institute*
NER	North Eastern Railway
NESAR	North Eastern Steel Company Annual Report and Accounts
NESCo	North Eastern Steel Company Limited
NESDM	North Eastern Steel Company Directors' Minutes
S&DR	Stockton and Darlington Railway

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Chapter 1: Introduction

1.1 Aims and background

Of the many examples of a district's development being founded on a single industry, Britain's industrial history offers few better than Teesside. Here growth was driven by the dramatic expansion of the Cleveland iron industry after 1850.[1] It transformed the undeveloped marshy lower reaches of the River Tees, with its two coal shipping ports – Stockton and Middlesbrough – and the largely agricultural surrounding area into the largest iron-producing centre in the world in less than twenty-five years. By 1873 over 10 per cent of the world output of pig iron was smelted in Cleveland, and a cluster of iron-based industries had become established in the towns and along the banks of the river.

There is little dispute that the district's industrialisation was based on natural resources: the conjunction of coal, limestone and especially iron ore close to the Tees. Indeed, the 'event' that triggered expansion was the discovery of a rich, thick bed of iron – the Main Seam – a few miles from Middlesbrough. Locating this ore bed, which had been known about and used, but which was under-utilised as it was either inaccessible or because only the poor, thin seams had been identified, made commercial exploitation viable. But while natural resources, and the presence of a railway system that had been built to link the coalfields to the ports, were necessary, they were not in themselves sufficient. One of the principal aims of this thesis is to consider other factors that contributed to the nature of development in Cleveland. Specifically, the role of business networks is examined to determine whether and how the connections between businesses and entrepreneurs influenced the process and pattern of expansion.

Areas based on a single or narrow range of industries tend to expand rapidly but then contract just as quickly. The extreme example is a gold rush town, and it is no coincidence that Briggs called Middlesbrough, the town at the centre of the Cleveland iron industry, the 'British Ballarat'.[2] Yet Cleveland's industry did not evaporate almost as quickly as it had appeared. In part this was due to the abundance of the iron and coal resources, but it was more than this. Industrial districts are often seen as passing through a life cycle in which, after the initial take-

[1] Cleveland and Teesside are often used interchangeably. In this study Cleveland will normally refer to the iron and steel industry that initially developed from, and depended on, Cleveland ironstone. Teesside will usually be used for the geographical area where the industry developed, including the towns of Middlesbrough, Stockton and Hartlepool. Darlington is not taken to be part of Teesside.
[2] A. Briggs, 'Middlesbrough: the growth of a new community', originally published in *Victorian Cities* (London, 1963) and reprinted in A.J. Pollard (ed.), *Middlesbrough: Town and Community, 1830-1950* (Middlesbrough, 1996), p. 10.

off and rapid expansion stages, the growth trajectory levels off as districts mature. Maturity may then give way to decline as changes in supply conditions, technology or demand shift the balance of advantage to other districts. Similarly, there may be non-economic factors that have economic effects, including legal changes or shifts in attitudes towards business that affect entrepreneurial effort. But decline is not inevitable. Thus the other principal aim of the thesis is to consider whether and how well Cleveland's iron and steel industry made the transition to a more mature sector after the early stages of development and initial prosperity had passed. That is, it is proposed to examine how Cleveland's firms responded to changing external circumstances and how the responses extended the district's life cycle.

1.2 Relationship to previous studies

This examination of Cleveland's iron and steel industry draws on three discernible but overlapping areas of research. First is the work on the importance of networks and clusters to the history of industrial districts, as exemplified by the studies in Wilson and Popp's *Industrial Clusters and Regional Business Networks in England*.[3] Second, and closely related, are the histories of local and regional economic development in north east England, such as those by Kirby, Orde, Cookson, Yasumoto and Milne.[4] The third area is the extensive and long-standing debate on the performance of Britain's iron and steel sector, an issue that is almost as old as the industry itself.[5]

Many network and cluster studies emphasise agglomeration economies and the importance of trust, and both aspects are prominent in this work.[6] A more general framework for analysing networks, proposed in a series of articles by Wilson, Popp, Toms and Filatotchev, relates network features to two underlying factors.[7] One is the degree of openness and hence

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[3] J.F. Wilson, and A. Popp, (eds.), *Industrial Clusters and Regional Business Networks in England, 1750 – 1970*, (Aldershot, 2003).
[4] M.W. Kirby, *Men of Business and Politics* (London, 1984); M.W. Kirby, *The Origins of Railway Enterprise* (Cambridge, 1994); A. Orde, *Religion, Business and Society in North East England: The Pease Family of Darlington in the Nineteenth Century* (Stamford, 2000); G. Cookson, 'Quaker families and business networks in nineteenth-century Darlington', *Quaker Studies*, 8 (2004); G. Cookson, 'Quaker networks and the industrial development of Darlington, 1780-1870', in Wilson and Popp, *Industrial Clusters*, pp.155-73; M. Yasumoto, *Victorian Ironopolis: Middlesbrough and Regional Industrialization* (Woodbridge, 2011); G.J. Milne, *North East England, 1850-1914:the Dynamics of a Maritime-Industrial Region* (Woodbridge, 2006).
[5] For full references see notes 14 to 16 below and Chapter 4.
[6] For agglomeration economies see Yasumoto, *Victorian Ironopolis*, pp. 41-51; on trust see M.C. Casson, 'An economic approach to regional business networks' in Wilson and Popp (eds.), *Industrial Clusters*, pp. 19-43.
[7] Wilson and Popp (eds.), *Industrial Clusters*; A. Popp, S. Toms and J. Wilson, 'Industrial districts as organizational environments: resources, networks and structures', *University of York Department of*

accountability of firms to outsiders, principally investors, which in turn is determined by firms' dependence on external resources; in general, the higher the degree of dependence, the more transparent and accountable the network. The second factor is the resource base of firms. This may be extensive, where there are technologically determined internal economies of scale and economies of scope; or narrow, where specialised firms benefit from external economies as a result of geographical proximity. Both factors can vary along a continuum, giving rise to networks with different characteristics and with developments in either or both producing changes in the nature of the networks. The framework is therefore dynamic and has implications for economic performance; it may be used to explain the evolution of industries and districts over time and to investigate whether networks facilitate or impede transition and adaptation. Using this approach, Toms and Filatotchev have provided a cogent analysis of the rise and slow decline of the Lancashire cotton industry.[8] The present study concentrates on the contribution of networks to the early stages of an industrial cluster's development, emphasising the importance of networks for the transmission of information and incentives and their relationship to trust and to family and religious groups. But it may also be seen as another case study that provides further evidence on whether it is possible to explain the workings of networks in a general model.

As a case study, this investigation also adds to the work of Kirby, Cookson and Orde on the contribution of Quaker business-cum-family networks to the development of industry in north east England.[9] By contrast with the earlier studies, with their concentration on family businesses and on early railway development, this case looks at the growth of a staple industry in a new industrial district. Moreover, the area and period under consideration are extended beyond those investigated in Yasumoto's recent examination of Middlesbrough to encompass the wider district of Teesside as well as to incorporate the transition to steel after the ending of the dominance of iron in the 1880s.[10]

In another recent study Milne combined the approaches of maritime with industrial and regional history to consider whether the North East – defined as stretching from the southern edge of urban Teesside to the northern limit of the Northumberland coalfield, and from the coast to the

Management Studies Working Paper no. 22, (York, 2006); S. Toms, S. and I. Filatotchev, 'Networks, corporate governance and the decline of the Lancashire textile industry' in Wilson and Popp (eds.), *Industrial Clusters*, pp. 68-89; S. Toms, S. and I. Filatotchev, 'Corporate governance, business strategy, and dynamics of networks: a theoretical model and application to the British cotton industry, 1830-1980', *Organisation Studies*, 25 (2004), pp. 629-51.

[8] Toms and Filatotchev, 'Networks', pp. 76-89; Toms and Filatotchev, 'Corporate governance', pp. 637-46.

[9] Kirby, *Men of Business*; Kirby, *Origins*; Orde, *Religion, Business and Society*; Cookson, 'Quaker families'; Cookson, 'Quaker networks'.

[10] Yasumoto, *Ironopolis*.

western edge of the Durham coalfield – constituted a cohesive and identifiable region.[11] Unsurprisingly, Milne stressed the importance of the port districts on the three principal rivers – Tees, Wear and Tyne – and of Hartlepool, as separate foci of economic activity rather than the region being an integrated maritime-industrial complex: '(the) individual riparian districts seem… to have offered sufficiently effective and coherent clusters for the purpose of the maritime-oriented economy…Those centres of activity …(were) "meso"-spaces, far more important than the North East as a whole'[12] A detailed investigation of one of these (Teesside) through one industry (iron and steel) contributes additional detail to Milne's broader approach, not least because Milne's emphasis was on shipbuilding and coal. An analysis of the early formation of the Cleveland cluster also offers an opportunity to identify the balance of influence between local, regional and wider national networks in establishing the new industrial district, and thus determine whether there were any identifiable North East regional networks operating at that time. And by considering the later transition, it is possible to evaluate Milne's claim that it was 'riparian geography' that drove the merger movement among iron and steel companies at the turn of the century.[13]

In fact, Milne, like Yasumoto, had little to say about the transition from iron to steel and from small to large firms in the Cleveland iron and steel cluster. It is through an examination of changes such as these that the current study aims to extend earlier work and in doing so explain how an industry's and thus an industrial district's prosperity may be sustained in the face of external and internal challenges. The challenges, which came after about twenty-five years of growth, were primarily due to the combined technological and market pressures that arose from advances in bulk steel production. In addition there was growing international competition along with considerable change in the inter-related areas of the legal, financial and organisational framework within which business operated. By investigating the responses of Cleveland's iron and steel firms to these changes the study addresses some of the recurring issues both in the performance of Britain's iron and steel industry, and more generally in Britain's economy in the last quarter of the nineteenth and first decade of the twentieth centuries. In particular these include the impact of changes in corporate legislation and in the financial markets; the widespread, but not unanimous, view that technologically Britain's firms lagged behind their German and US rivals; and the more general proposition that there was a decline in the 'industrial spirit' which was reflected not only in technological backwardness, but also in a failure to make the organisational and market-orientated adjustments necessary to modernise business.

[11] Milne, *North East England*, p. 7.
[12] Ibid., p. 202.
[13] Ibid., pp. 196-7.

The approach here relies on a detailed investigation of the technological knowledge available to, and decisions made by, firms rather than neoclassical economics-based international productivity comparisons. It complements, but also questions, the earlier industry-wide studies, such as Burn's and Allen's damning judgements on entrepreneurial performance, and the highly critical firm-based research of Boyce and Abé.[14] By looking at Cleveland, the study adds a district dimension to the reappraisals of the industry by McCloskey, Tolliday and Wengenroth, and one that is broadly supportive of their revisionist conclusions, i.e. entrepreneurialism had not deserted the most important Teesside firms in the years before 1914.[15] It is not suggested that a study of Cleveland iron and steel is able to provide definitive answers to all aspects of industrial performance; after all, it was just one part of a major national industry, albeit a large one accounting for between one-fifth and one-quarter of the bulk iron and steel output. Nevertheless, an examination of a segment of the industry offers additional evidence with which to make a more detailed and balanced assessment of its performance.

1.3 Plan of the work

Following the two main aims, viz. to examine the contribution of business networks to the early growth of the Cleveland iron industry, and then the transition the industry made from the last quarter of the nineteenth century, the thesis is divided into two parts. The chapters in Part 1 look at the role of networks in the process of industrial growth and clustering. Chapter 2 briefly reviews the explanations for the initial development of the industry in Cleveland. Earlier studies have tended to emphasise the locational advantages of the proximity to natural resources and the availability of railway transport and harbour facilities that were enhanced by the effects of clustering as firms in closely related industries benefitted from agglomeration economies. These were, and are, powerful forces, but in the chapter it is suggested that Cleveland's development could have taken a different course. What underlay its particular path were the pre-existing business networks in the region and it was these that encouraged the clustering of the industry. The concepts of networks and clusters, how they contribute to growth and how they are related to cluster formation are examined in the rest of the chapter. It is proposed that

[14] D. Burn, *The Economic History of Steelmaking, 1867-1939: A Study in Competition* (Cambridge, 1961), first published in 1940; R. Allen, 'International comparisons in iron and steel, 1850-1913', *Journal of Economic History* 39 (1979), pp. 911-37; G. Boyce, 'The development of the Cargo Fleet Iron Company, 1900-14: entrepreneurship, costs, and structural rigidity in the Northeast coast steel industry', *BHR*, 63, (1989), pp. 839-75; E. Abé, 'The technological strategy of a leading iron and steel firm, Bolckow Vaughan & Co Ltd: late Victorian industrialists did fail', *BH*, 38 (1996), pp. 45-76.
[15] D. N. McCloskey, *Economic Maturity and Entrepreneurial Decline: British Iron and Steel, 1870-1913* (Cambridge MA, 1973); S. Tolliday, 'Competition and maturity in the British steel industry', in E. Abe and Y. Suzuki (eds.), *Changing Patterns of International Rivalry: Some Lessons from the Steel Industry* (Tokyo: 1991); U. Wengenroth, *Enterprise and Technology* (Cambridge, 1994).

although clustering can generate growth that is self-sustaining, there needs to be some means through which signals about opportunities are transmitted and resources made available. It is the linkages between entrepreneurs and businesses, i.e. the networks, that provide the essential information channels.

Chapter 3 applies these ideas to the growth of Cleveland's iron industry up to 1880 by investigating the characteristics and backgrounds of the investors and entrepreneurs who entered the district during this period. The data is drawn from a sample of firms that is as close as possible to the population of iron and engineering businesses. In total, useable data have been identified for 130 firms, and by examining the nature of the firms setting up in Cleveland, it is possible to provide a measure of the clustering process in the industry based on business formation. The data also indicates that most of the new entrants were linked to at least one of four groups. Foremost among these was the railway, coal, banking and Middlesbrough Estate interests of two Darlington-based Quaker families, the Peases and Backhouses. These connections are further illustrated by a series of short histories of some of the firms and ironmasters who set up in Cleveland. How effective these networks were in promoting expansion through attracting new entry is almost impossible to measure as it is not possible to predict what would have happened in their absence. However, an attempt is made to assess the contribution of networks indirectly. To do this the final section of Chapter 3 tests a logistical regression model that relates business survival to Quaker network membership and other characteristics. On the assumption that longer-lived firms contribute more to growth than short-lived ones, the results offer some evidence that Quaker-linked firms had a distinct and positive impact. The test, however, is not able to distinguish efficient from inefficient firms, and thus not able to determine the impact of the network on overall efficiency.

In Part 2 the focus switches from growth and development to the transition of a mature industry and district. To set the context for Cleveland, Chapter 4 reviews and assesses the literature on the performance of Britain's iron and steel industry as a whole. The sector is often seen as a prime example of relative industrial decline, exhibiting the effects of a waning in entrepreneurial vigour or the outcome of an inappropriate institutional structure in the industry – relatively small, family-owned firms in a highly competitive market.[16] The effect was to produce either a resistance to, or a constraint on, the adoption of new technology, business methods and organisational forms that were more readily embraced in the US and Germany. With lower productivity and the wrong technology – mainly the failure to exploit the basic Bessemer steel process as in Germany and hard-driving and mechanisation in America –

[16] For example see B. Elbaum, 'The steel industry before World War 1', in B. Elbaum and W. Lazonick (eds.), *The Decline of the British Economy* (Oxford, 1986), pp. 51-81.

Britain's industry lost its lead to its two larger rivals. However, as is pointed out, there is some disagreement over such highly critical judgements, especially over the reasons for thinking that the technological choices were entirely inefficient or unjustifiable. Comparative studies of relative productivity levels and growth often show a lag in British performance, with the effect of ever-rising imports. But when the trade data is measured in value rather than volume terms, it is clear the industry's position remained strong and the balance of trade healthy in a difficult international environment characterised by protection and dumping.

Chapter 5 assesses the effects of changes in corporate legislation on the organisation and financing of firms. The freer access to incorporation and to launching joint stock companies that followed the Joint Stock Acts of 1855, 1856 and 1862 is often associated with providing firms with an improved means of raising finance for capital investment. Indeed, in some explanations, it was the pressure for greater funds as capital requirements of industry increased that supplied the impetus for the changes. In Cleveland, however, there were a variety of reasons for incorporation, ranging from the need to raise funds for capital projects, to re-floating failed businesses, or more basically obtaining the protection of limited liability. And for some, a public flotation enabled the original partners to liquidate their capital without losing control of the business, as is illustrated in the case of Bolckow Vaughan. Detailed studies of two of the industry's largest incorporated firms also investigate how use was made of the developing equity and debt securities markets. It is therefore possible to consider whether capital investment, and thus the adoption of new technology, modernisation and expansion were constrained by restricted access to sources of finance. In this way, the study adds some additional evidence to the role of the financial system in promoting or retarding economic growth.

It was the failure to adopt new technology that is the focus of much of the criticisms of the British iron and steel during this period. Chapter 6 therefore looks at one aspect of the debate – the choices Cleveland producers made as steel began to replace wrought iron from the 1870s. The aim is to assess whether, and if so why, iron and steel firms were slow to adjust to major shifts in production technology, and whether this hampered transition in Cleveland. Problems of using Cleveland pig iron in steel production hindered the changeover to steel considerably as the presence of impurities in the iron, especially phosphorus, made both acid Bessemer and acid open hearth processes infeasible. Cleveland's firms, however, were quick to respond using imported hematite ore for acid open hearth furnaces and also in developing the basic Bessemer process. Nevertheless, these were essentially temporary solutions; it was the development of the basic open hearth method that provided the longer-term answer. The chapter demonstrates that far from being neglectful, or tardy in their decision to adopt it, there was interest across the

British steel industry in applying the basic process to the open hearth furnace from an early stage. Some of Cleveland's firms not only made a contribution to the developments that enabled Cleveland iron to be used in the process, they also invested in large scale production as soon as it became technically feasible and profitable.

An important aspect of the transition of the Cleveland's iron and steel industry was the increasing concentration of the sector into fewer, larger firms, either through internal growth, acquisition, or a combination of the two. Chapter 7 presents a case study of Dorman Long, which became not only one of the largest firms in Cleveland, but also in Britain. Its growth was part of the combination movement of the 1890s and early 1900s, the effect of which has been subject to considerable criticism as many of the businesses that were formed out of the mergers were neither reorganised nor restructured. In some cases the resulting companies were almost a haphazard collection of independent firms lacking strategic direction. The examination of Dorman Long, however, indicates there were strategic elements to its growth. Part of this was to integrate operations vertically as the original steel company acquired iron smelting capacity and mineral resources; it also diversified its final output from girders and steel plate to wire, construction and bridge building. But alongside the expansion there were organisational and managerial changes put in place to control the larger and more diverse enterprise. These marked the beginnings of a group identity among the three main component companies of Dorman Long even though the subsidiaries remained nominally separate. Moreover, there were considerable advances in the firm's approach to marketing, with the company taking steps to exert increasing control over the distribution of its products and obtain direct access to customers. Before 1914 these organisational developments were not on the scale or of the scope of the Chandler-type strategy that occurred in American manufacturing, but they marked a shift to a more corporate form of enterprise among a number of Cleveland's iron and steel firms.[17]

The concluding chapter (Chapter 8) proposes a way of looking at the clustering and growth process that gives a central role to business networks. There is also an assessment of the performance of Cleveland's iron and steel firms and their contribution to the transition and sustainability of the industry in the district. It is suggested that rather than marking the beginnings of decline, the evidence from a number of firms shows that there was a willingness to adopt new technology and methods of production when appropriate, to look for new markets and products, to expand businesses through acquisitions and internal growth, and to make organisational changes. In short, while the vitality of the early iron industry may have faded in

[17] A.D. Chandler, *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge Ma., 1990).

some firms, there remained plenty of entrepreneurial vigour in others to maintain the dynamism of the sector; in general the industrialists had not failed.

1.4 Limitations and omissions

The history of an industry or district is the product of many influences, but it is not possible or necessary to include all aspects of Cleveland's development in this thesis. Four major areas have been omitted from consideration. First, there is the labour market. Owing to the newness and rapid growth of Cleveland's industry, there was no pre-existing pool of labour on which firms could draw. Consequently, labour supply was closely associated with substantial population movements and is therefore most appropriately analysed by the methods of demographic historians. Yasumoto for instance, using record linkages to follow population movements between censuses, has demonstrated the substantial turnover levels in Middlesbrough as a result of high rates of both in- and out-migration.[18] The effect, while beneficial in the expansionary stage, may have been deleterious for longer-term growth as there was a reduced incentive for workers to acquire skills and for firms to provide training. On the other hand, with a Board of Arbitration and Conciliation established in 1869 and the introduction of a sliding scale for the determination of wages, the industrial relations system in the district gave rise to relative industrial peace for much of the period.[19]

Second, the discussion of technological advance in Chapter 6 focuses on the development of the processes for bulk steel production, especially by the basic open hearth method. There were, of course, many other technical changes in the industry, ranging from blast furnace design and practice to the mechanisation and electrification of production, and the rate at which these were adopted had a substantial impact on the relative performance of firms in Cleveland. However, as a principal aim of the thesis is to investigate the transition of Cleveland's industry from iron to steel that was so crucial to the district's continued prosperity after the 1870, it is the technology of steel production that warrants special attention.

Third, there is no analysis of the extent and effects of collusion or cartel agreements. There were many attempts to control prices and production, but as McCloskey has noted, these were largely short-lived and unsuccessful, and the industry was 'substantially competitive' at the

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[18] M. Yasumoto, *Victorian Ironopolis*, Chapters 2 and 3.

[19] Yasumoto, *Victorian Ironopolis*, pp. 146-56; Geoffrey Owen, *From Empire to Europe* (London, 2000), p. 19. For a more critical view of the industrial relations system, see Elbaum, 'Steel industry', pp. 69-71.

regional and national level.[20] For the purposes of the present study, therefore, it is assumed that collusive agreements in Cleveland, e.g. by members of the Cleveland Iron Masters Association, or between Cleveland firms and those elsewhere had little overall impact on the district's development.

Fourth, in the analysis of business networks in Chapters 2 and 3 the emphasis is on the *fact* that entrepreneurs, investors and their firms were connected in some way rather than on the *attributes* of any particular network. Thus, when examining the Quaker-based business network centred on Darlington, which it will be argued, played a central role in the early growth of the Cleveland industry, the proposition that there were special Quaker characteristics that made their approach to business particularly efficient or effective is not explored. Indeed, as Cookson has shown, there are good reasons for thinking that '[these attributes] were largely mythical and have been over-rated as a general phenomenon.'[21]

1.5 Sources

As there have been many studies of Britain's and Cleveland's iron and steel industry, some of this thesis is based on a re-examination of previously researched material. For the business records of Cleveland companies the most important source was the British Steel Collection at Teesside Archives, formerly Corus Records and, prior to privatisation, part of BSC's Northern Records Centre. The collection contains extensive records of the companies based on Teesside, principally Dorman Long and South Durham Steel, when the industry was nationalised (1967), along with the firms' subsidiaries and the businesses acquired since the beginnings of the industry. Recent re-cataloguing (2007-11) has made access to the archive easier and revealed some previously un-investigated or overlooked material.

The data on business formation, entry into Cleveland, incorporation and failure used in Chapters 3 and 5 have been assembled from a variety of sources. In addition to the British Steel Collection, archival sources include Teesside Archives' Index of Teesside Businesses, the Industrial and Engineering Company Records collection also at Teesside Archives and the National Archives Records of Defunct Companies (BT31). However, the surviving records of many of the smaller firms are limited, especially those that were partnerships, but also for most of the larger companies before incorporation. The archival sources therefore have been

[20] D. N. McCloskey, *Economic Maturity*, pp. 28-33.
[21] G. Cookson, 'Quaker families and business networks in nineteenth-century Darlington', *Quaker Studies*, 8 (2004), pp. 127-33 and p. 135.

supplemented by business directories, previously (often privately) published company histories and local newspaper reports available from the 19th Century British Library Newspapers and Middlesbrough Central Library's newspaper collection. As a result the data posed a number of significant difficulties including: the identification of partners; the formation and closure dates of businesses; and even the precise nature of firms' output. This was often made more difficult as iron firms were frequently referred to by the name of the works rather than the business operating them, a problem that was exacerbated when works changed hands or businesses changed names as new partners were taken on, or old ones retired and the partnership reconfigured. There are also inaccuracies over, and confusion between, firms and plants with similar names in both newspaper reports and earlier histories. Consequently, much of the data have been pieced together from several sources and is often incomplete, especially in the case of small businesses' financial details. Even for incorporated and the larger businesses, there is considerable variability in detail available. As Cookson has recorded, the files for some dissolved companies in BT31 no longer exist.[22] Where annual reports, directors' minutes and other company files are accessible, they are more detailed for some companies than for others, and there are often significant differences in the type of information that has survived. For Bell Brothers, for instance, detailed cost and output data for iron production are available from the 1870s but there is no equivalent for Dorman Long's steel production. For these reasons it has been impossible to obtain a consistent sample, and the composition of the samples of firms analysed and included in the tables and graphs varies throughout the study. A list of firms with the data sources is provided in Appendix 1, including those that have been identified but for which there are no records available.

Technical details on the development of steel processes and statistics on production and plant have been drawn from the publications of the iron and steel and engineering industry organisations. Chief among these are the journals of the professional institutes, the Iron and Steel Institute (ISI), Cleveland Institution of Engineers (CIE), Institution of Civil Engineers (ICE) and Institution of Mechanical Engineers (IME), as well as the publications of the trade organisations, the British Iron Trade Association (BITA) and the National Federation of Iron and Steel Manufacturers (NFISM). For some products, notably iron, a complete set of output data are available at regional and national level, and are subdivided by product type – hematite, Cleveland and basic pig iron. For manufactured iron and for steel, however, variations from year to year in the level of detail that was published has meant that it has not been possible to construct a series disaggregated by region and process over the period studied. Lastly, the other

[22] G. Cookson, 'The Public Record Office and the record of limited companies: some problems and issues', *Association of Business Historians website*: http://www.abh-net.org/archive9.htm (last accessed: 12 Mar. 2013).

major sources drawn on include the weekly trade journal *Iron and Coal Trades Review* (*ICTR*), published from 1868 and several official reports into the industry, e.g. *Royal Commission into the Causes of the Depression in Trade* (1886).

Part 1: Growth and Development

Chapter 2: Conceptual Issues in Business Networks and Industrial Clusters

2.1 Introduction

The discovery of the main ironstone seam in the Eston Hills in 1850 marks the beginning of the startling and dramatic growth of the Cleveland iron industry. By the mid-1860s pig iron output on Teesside was almost half a million tons, 10 per cent of the UK's total (1865). Just eight years later, in 1873, the district was the country's largest producer, with production of 1.2 million tons, 17 per cent of UK output, and by the end of the decade it had risen to one-fifth.[23] With some 46 blast furnaces and 160 puddling furnaces spitting sparks and flames, and belching smoke and fumes along the banks of the River Tees and almost into the towns, it was with good reason that Gladstone, on his visit in 1861, referred to Middlesbrough as the 'infant Hercules'.[24] Indeed, in barely 25 years the area had seen not only the creation of a major new iron producing centre, but also a significant local cluster of iron related industries including railway engineering, shipbuilding, bridge building and design, and other engineering trades. Table 2.1 and Figure 2.1 provide two basic measure of the expansion – the output of the pig iron and the populations of the two major towns on Teesside.

This rapid acceleration stands in sharp contrast to the district's early development. The town was the focus of industrialisation, Middlesbrough, was established in 1830 as a port for shipping coal brought down from the South Durham coalfield by the Stockton and Darlington Railway (S&DR).[25] Concerned about the navigational problems of the river to Stockton, some of the main investors in the railway, led by the Quaker businessman and banker Joseph Pease, along with a group of other Quaker investors, bought the 520 acre Middlesbrough estate for £30,000. On the land located downstream from Stockton on the south bank of the river, the Owners of the Middlesbrough Estate, as they named their firm, established a port – Port Darlington – with coal

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[23] G.A. North, *Teesside's Economic Heritage* (Middlesbrough, 1975), p. 206; B. Mitchell, *British Historical Statistics* (Cambridge, 1988), pp. 281-3; 'Statistics of the iron and steel trades', *JISI,* 2 (1871), p. iii.

[24] I.L. Bell, 'On the manufacture of iron in connection with the Northumberland and Durham coalfield', *Transactions of the North of England Institute of Mining Engineers*, XIII (1864), pp. 109-55. The figures refer to 1863 and 1862 respectively. For Gladstone's speech see *Daily News*, 11 Oct. 1862.

[25] W. Lillie, *The History of Middlesbrough: An Illustration of the Evolution of English Industry* (Middlesbrough, 1968). North, *Economic Heritage*; M.W. Kirby, *Men of Business and Politics* (London, 1984); Briggs, 'Middlesbrough', pp. 2-4; D. Taylor, 'The infant Hercules and the Augean stables: a century of economic and social development in Middlesbrough, c1844-1938', in Pollard, *Middlesbrough: Town and Community*, pp. 53-4.

staithes to load the coal onto the ships. At the same time the railway, bridging the Tees at Stockton, was extended to terminate at the new the town of Middlesbrough. What had been a collection of no more than four houses before 1830 became a hamlet of 383 people by 1831, expanding to a small town a decade later, with a population of 5,709 (1841).[26] This new town, sited on slightly higher ground above the marshes that lay along the banks of the river as it looped through several large meanders down the Tees valley towards the sea, was initially planned and laid out on a symmetrical grid. Later development took a rather haphazard form as industry spread out along the river both to the east and west, and the town itself expanded southwards. Other early industries besides the coal trade included a pottery (1834), a brickworks and some businesses associated with shipping (e.g. rope makers), along with a variety of local traders that might be expected to be found in a nascent town with a growing population.[27] Iron and related industries such as engineering, particularly those connected with the railways, appeared in Middlesbrough from about 1840. One of the most notable, at least with regard to future developments, was the partnership between Henry Bolckow and John Vaughan, who opened a malleable ironworks in 1841. Development remained relatively slow and narrowly focused, however, and it was not until the Bolckow and Vaughan partnership started to exploit the ironstone deposits near Middlesbrough, blowing-in their first blast furnace in 1851, that Cleveland's growth finally took-off.

In 1850 therefore there was a sharp improvement in Cleveland's fortunes. The standard interpretation is that it marked a distinct break with the immediate past, or as Bullock put it, 'a major historical discontinuity'.[28] This chapter briefly reviews the explanations that have been put forward to account for the development of Cleveland's iron industry (Section 2.2), and it argued that some important aspects of the growth process have been omitted from earlier accounts. In particular it is suggested that industrialisation of the district was not solely a product of its resource endowments, but that pre-existing business networks guided and coordinated development. The notion that business networks make an essential contribution to economic activity has become increasingly widespread. They have been used to explain the success or otherwise of anything from individual entrepreneurs and businesses to the growth and development of industrial sectors, districts and regions.[29] The main conceptual issues in business networks and the relationship with industrial clusters are set out in Sections 2.3 to 2.6 as a prelude to a fuller examination of Cleveland's growth in the next chapter. Section 2.7 offers a brief conclusion.

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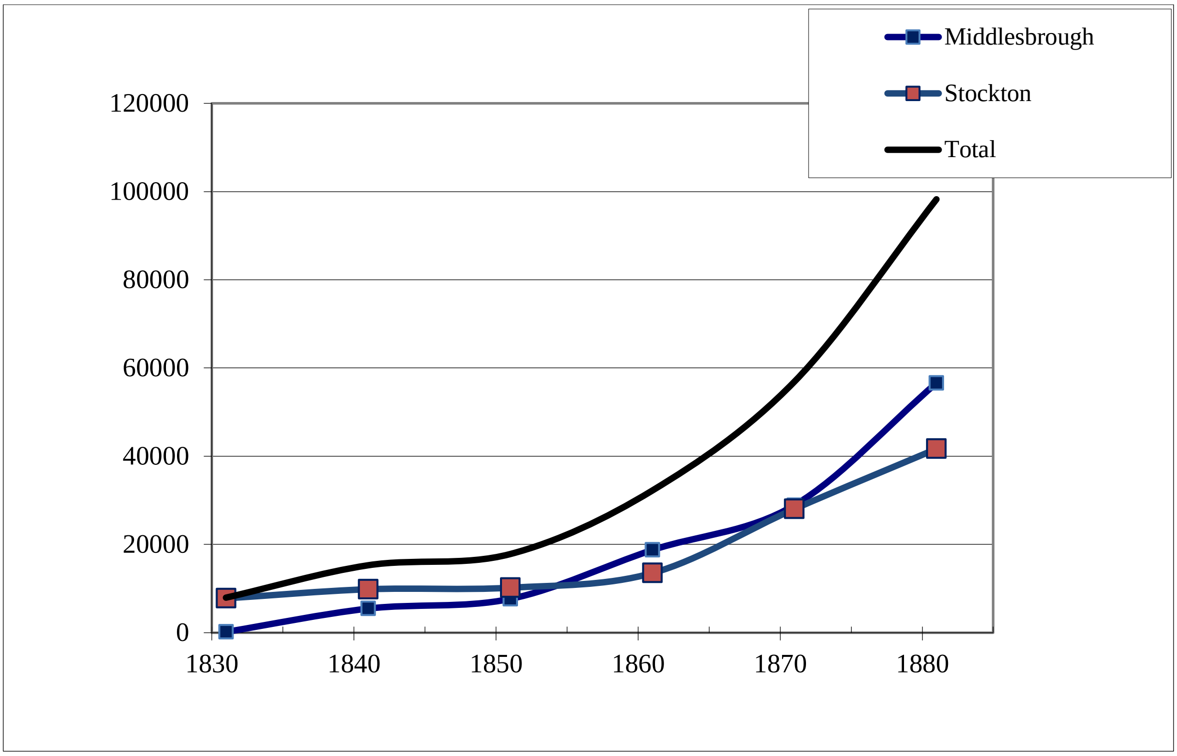
[26] North, *Economic Heritage*, Statistical Appendix, pp. 147-53.
[27] Lillie, *Middlesbrough*; M. Yasumoto, *Victorian Ironopolis*, pp. 1-11.
[28] I. Bullock, 'The origins of economic growth on Teesside', *Northern History*, (1974), p. 94.
[29] Wilson and Popp, *Industrial Clusters*.

Table 2.1: Pig Iron Output, 1854-84 (thousand tons)

	North Riding of Yorkshire	UK	NRY per cent of UK	NRY percentage change	UK percentage change
1854	101	3,070	3.3	-	-
1859	216	3,713	5.8	113.9	20.90
1864	409	4,768	8.6	89.4	28.40
1869	766	5,446	14.1	87.3	14.20
1874	1,158	5,991	19.3	51.2	10.00
1879	1,210	5,995	20.2	4.5	0.07
1884	1,729	7,812	22.1	42.9	30.30

Note: As some of County Durham's production can be classified as part of the Cleveland district, North Riding of Yorkshire (NRY) data tend to understate the output for Cleveland.
Source: Mitchell, *Historical Statistics*, pp. 281-3.

Figure 2.1: Population of Middlesbrough and Stockton, 1831-81



Source: Census data from North, *Economic Heritage*, pp. 147-64.

2.2 Explanations

A standard supply-side explanation for Cleveland's development is that it was an inevitable consequence of the geological and geographical conditions that gave iron production in the district a significant cost advantage over other areas. The presence of a vast and easily workable deposit of ironstone so close to the Tees was a 'geological accident', which, in conjunction with a easily accessible sources of coal and limestone provided the essential ingredients for an iron industry.[30] In addition, by the mid-nineteenth century the usual economic-cum-geographical factors associated with industrialisation were in place: the railway network, a growing coal trade based on a well-established mining industry, port facilities, a few local iron and engineering firms and a rapidly growing town with space for industry and population to expand. That the development of Cleveland was entirely predictable is a far from uncommon view and one with a long history, as shown by Frey (1929), Gleave (1938) and Isard (1948) among others.[31]

A complementary explanation emphasises demand conditions. Iron, as the fundamental material of mid-Victorian industry, faced high and rising demand, especially as the railway systems in Britain and abroad were initially developed and then extended. Thus for Bullock growth was essentially export-led, sustained by the expansion of both home and overseas markets.[32] Putting supply and demand together, the development of Cleveland can be seen as a serendipitous co-incidence, both temporally and spatially, of natural locational advantages, transport infrastructure and the necessary demand conditions.

In the mid-nineteenth century, however, there were numerous disadvantages to siting an iron industry in the lower Tees valley. The river was shallow and difficult to navigate; the land marshy and unsuitable for building without reclamation; there was no labour force to speak of; and the railway infrastructure was limited. It is possible therefore to argue that the development of a major industry in the district was far from inevitable. Indeed, following the discovery of the ironstone there were other possible routes for the exploitation of Cleveland's resources. One was for the ore to be exported and processed elsewhere. This was the approach adopted by Palmers, the Jarrow shipbuilders when they built Port Mulgrave to ship ore to their blast furnaces on the Tyne.[33] Bell Brothers similarly transported Cleveland ore to their furnaces at Walker on the Tyne and at Washington on the Wear.[34] Another possibility was to smelt and export pig iron from Teesside without the corresponding development of iron processing and

[30] Cookson, 'Quaker families', p. 121.
[31] J.W. Frey, 'Iron and steel industry of the Middlesbrough district', *Economic Geography*, 5 (1929), pp. 176-82; J.T. Gleave, 'The Tees-side iron and steel industry', *The Geographical Journal*, 91 (1938), pp. 454-67; W. Isard, 'Some locational factors in the iron and steel industry since the early nineteenth century' *Journal of Political* Economy, 56 (1948), pp. 203-17; D.C.D. Pocock, 'An urban geography of selected steel towns' (PhD thesis, University of Nottingham 1968); A. Nicholson, '"Jacky" and the Jubilee: Middlesbrough's creation myth', in Pollard, *Middlesbrough: Town and Community*, p. 44.
[32] Bullock, 'Origins', p.87.
[33] J.S. Jeans, *Pioneers of the Cleveland Iron Trade* (Middlesbrough, 1875).
[34] See Chapter 3.

other ancillary industries. A contrast can be made here between Cleveland and the early Lincolnshire iron industry that developed after 1864. Because of institutional factors and a lack of an extensive network of interrelated business interests, a substantial iron and steel using industry failed to take root in Lincolnshire in the way that it did on Teesside.[35] Most of the output of the Scunthorpe-based industry was exported out of the region as semi-manufactured goods – pig iron and steel ingots – for finishing elsewhere. This also occurred at Whitby, where there were two iron smelting works inland at Glaisdale and Grosmont. These plants produced pig iron only and exported their output through the port, and later by rail.[36] A third possibility is that there was at least one alternative site for the industry to develop – Hartlepool. At the time of the discovery of the main iron deposits, the coal trade in Middlesbrough was under significant challenge from Hartlepool; the town had just as good railway links to the coalfields and superior harbour potential. The riverside sites at Middlesbrough and along the Tees were therefore not necessarily the obvious local choice for the industry.

An additional supply-side element in the industry's and district's growth was needed and one explanation that has been offered is that it was provided by the entrepreneurial efforts of a few men of great energy and vision who encouraged or set up their businesses in the new industrial area. This 'industrial heroes' interpretation in the Samuel Smiles vein is exemplified by J.S Jean's *Pioneers of the Cleveland Iron Trade* (1875) and H.G. Reid's *Middlesbrough's Jubilee* (1881), and in the twentieth century by Gott's biography of Henry Bolckow.[37] And once the development began, Cleveland benefitted from the effects of clustering as firms in the same and related industries located close together. As Yasumoto has shown, this was not just a result of the duplication of iron smelting capacity, although there was that; it also occurred through the specialisation of firms in different stages of the production of iron goods, some (limited) diversification, the creation of supporting institutions – the warrant stores, the iron exchange, technical institutes and ironmasters' organisation – and the dissemination of technical advances between firms in the area.[38] The benefits, stemming from the resulting agglomeration or external economies, meant that the (cost) advantages of the location were cumulative; as Teesside grew it developed the conditions necessary for the sustained expansion of an integrated and interdependent group of industries and firms.

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[35] P. Wardley, 'The Lincolnshire Iron Industry, 1859-1914' (PhD thesis, University of Wales, 1983).
[36] Part of the reason why ancillary industries failed to develop in the Whitby area is that in comparison to Teesside, output volumes were low.
[37] Jeans, *Pioneers*; H.G. Reid, *Middlesbrough and its Jubilee* (Middlesbrough, 1881); R. Gott, *Henry Bolckow: Founder of Teesside* (1968, Private Publication).
[38] Yasumoto, *Victorian Ironopolis*, pp. 41-58.

The combination of locational advantages, clustering and astute entrepreneurial decisions offers a cogent explanation for the creation of Cleveland's iron industry and its subsequent expansion. This chapter and the next, however, suggest that these factors miss some important aspects of the development process and that neither impersonal market forces nor the vision of a few businessmen can fully account for the pattern of expansion. It is argued that the reason why Cleveland's industrial history did not take one of the alternative courses was primarily because of the entrepreneurial decisions made at the time, but that it was not so much the individual entrepreneurs who were important, but how their activities were guided and coordinated through the linkages that existed, and which were later created, in the industry. That is, central to the investment decisions that led to industrial development was the operation of the business networks. These networks stimulated development by transmitting information and incentives that at first drew the iron firms and entrepreneurs to the district and later provided the mechanism for the creation of a more diversified and sustainable industrial cluster.

The remainder of this chapter examines some of the underlying analysis of business networks and how they contribute to economic activity. In particular it considers the role networks play in the process of growth, and most especially in the development of industrial clusters. It is suggested that networks are an important aspect of the growth of an industrial cluster as they act as the channels through which information about business opportunities are disseminated, incentives transmitted and resources organised. Understanding the role of business networks therefore adds the detail to the explanations of what triggers the start of a cluster, what causes it to grow and whether it survives and adapts or declines.[39]

2.3 Networks and Theory

A business network is essentially a description of the connections between businesses, the people in businesses, or between individual entrepreneurs who are known to each other. What is important is not so much the connections *per se*, but the nature of the connections, how and why these arise, and the underlying theoretical explanations of what benefits networks provide their members and the wider economy. A useful starting point is to consider the nature of impersonal market transactions.

All traders incur costs in market transactions as they can never be certain that counter-parties will honour their side of contracts. Prior to entering a contract it may be difficult to determine

[39]See Wilson and Popp, *Industrial Clusters* for other studies of networks and clusters.

the reliability or honesty of counter-parties or to distinguish the reliable, high quality ones from the unreliable. After contracts have been signed it may also be costly to monitor and enforce their terms in order to ensure that goods are delivered, repayments made or the terms of the contract are not changed. In other words, it is costly to eliminate the potential for opportunistic behaviour. It is the existence of these transactions costs that has been used to explain why some activities are organised within firms rather than through market transactions.[40] Although internalisation of market activities does not eliminate transactions costs, the relative costs of organising production through market exchanges compared to internal, bureaucratic organisation can be thought of as a major determinant of the boundaries of a business organisation.

A business network can be seen as a way of organising transactions that lies somewhere along a spectrum between impersonal market exchange at one end and internal transactions within a firm at the other. The central element, by definition, is that economic agents in the network are known to each other, or are at least closely connected to a member of the network, i.e. there is a 'web of relationships'.[41] This reduces the cost of market transactions as the information on which decisions about trade are made is both easier to obtain and more reliable. As Casson has emphasised, however, it is also crucial that members of the network trust each other.[42] This can be defined more precisely as 'warranted mutual trust' – the trust that each member invests in others is justified and reciprocated. The effect is to produce a 'high trust' equilibrium in which there is no incentive for anyone to change their beliefs about the trustworthiness of others in future dealings. Consequently, each transaction confirms agents' expectations about others in the network and this creates a climate in which further transactions are encouraged.

The sources of trust are to be found in the social institutions and relationships that determine the interaction between members of a network. These may be formal or informal. Commonly cited examples include kinship groups, co-religionists, and the membership of other organisations and clubs, which may be connected with business (e.g. trade associations, chambers of commerce) or not, or at least not directly (e.g. freemasons, charities, fraternities, scientific, literary and philosophical societies and the like). From a sociological perspective economic activity is embedded in the social structure, thus what is important in networks is how codes of behaviour and shared backgrounds, attitudes and values generate trust, and therefore influence the nature

[40] R.H. Coase, 'The nature of the firm', *Economica*, 4 (1937), pp. 386-405; O.E. Williamson, *The Economic Institutions of Capitalism* (London, 1985); O.E. Williamson, *Economic Organizations* (Brighton, 1986).
[41] R.C. Michie, 'The social web of investment in the nineteenth century', *International Review of Investment*, (1979).
[42] M.C. Casson, 'An economic approach to regional business networks' in Wilson and Popp, *Industrial Clusters*, pp. 19-43.

and direction of business activity.[43] Where there is a high degree of shared values and common identity, and the ties are close, then a high-trust culture is more likely to develop. In turn, this is conducive to a greater frequency and variety of business transactions, and thus more economic activity, within the network than with outsiders.

The importance of cultural and institutional factors for the operation of business networks and their effects on reducing transactions costs has been applied to a wide variety of cases. It is especially powerful in finance, and this is easy to see why. Moral hazard and adverse selection are potential problems in finance as the normal market mechanisms such as raising price (interest rates) to ration credit can have perverse effects. Higher interest rates for example may induce hazardous behaviour by borrowers or make it more difficult to identify borrowers' creditworthiness. As a result lenders and investors may well look to non-market means of allocating funds, including giving preference to known customers, business associates, family members and so on. For borrowers it may also be difficult to signal creditworthiness to lenders, and thus tapping funds through a network of family members or members of the same social group may often be the sole source of finance. This is especially so in economies and financial systems at relatively early levels of development where there are no sophisticated or systematic ways of assessing credit risk.

Two classic examples of the importance of social relationships that underpinned the provision of finance are the Lancashire cotton and West Riding of Yorkshire woollen textile industries in the late eighteenth and early nineteenth centuries.[44] In both of these there was a 'web of credit' connecting merchants and manufacturers that was cemented by inter-marriage, often membership of the same sect (e.g. the Unitarian church in Manchester) and other civic organisations. Similarly, Prior and Kirby, and also Cookson, emphasise the importance of extended family contacts – the Quaker 'cousinhood' – as a source of credit for the financing of the Stockton and Darlington Railway (S&DR) and later the purchase of the Middlesbrough estate.[45] This credit was not only highly personal, coming from family contacts within the Quaker community, but also geographically spread, stretching from Darlington to Norwich and London. Another example is Lamoreaux's study of banking in New England at the end of the

[43] M. Granovetter, 'Economic action and social structures: the problem of embeddedness', *American Journal of Sociology*, 91 (1985), pp. 481-510; M. Granovetter, and R. Swedburg, *The Sociology of Economic Life* (Boulder, 1992).
[44] P. Hudson, *The Genesis of Industrial Capital: a study of the West Riding wool textile industry c.1750-1850* (Cambridge, 1986); M.B. Rose, *Firms, Networks and Business Values: The British and American Cotton Industries Since 1750*, (Cambridge, 2000).
[45] A. Prior and M.W. Kirby, 'The Society of Friends and business culture, 1700-1830', in D.J. Jeremy (ed.), *Religion, Business and Wealth in Modern Britain* (London, 1998), pp. 116-36; Kirby, *Men of Business*; M.W. Kirby, *The Origins of Railway Enterprise* (Cambridge, 1994); G. Cookson, 'Quaker networks', in Wilson and Popp, *Industrial Clusters*, pp.155-73; Cookson, 'Quaker families'.

eighteenth century.[46] She shows how early corporate banks were effectively 'the financial arm of kinship groups', with the major shareholders related by blood and marriage. The banks raised funds for their owners (shareholders) to invest in their own industrial enterprises, often by selling stock to insurance companies and savings banks controlled by other family members.

Although emphasis is often placed on transactions costs, i.e. the costs of opportunistic behaviour, these are not the only costs associated with market activity.[47] More generally there are information costs, of which transactions costs are a subset. These include the costs of collecting, monitoring and analysing market information, and are the basis for making decisions on investments, production, suppliers, pricing and so on. One way of looking at the economy is to see it as a cybernetic system, that is, as a system of information flows.[48] Successful entrepreneurs and firms are those who make the best use of the information available, spotting and acting on opportunities as they arise. Indeed, Casson suggests that entrepreneurs can be regarded as specialist intermediaries in information.[49] They link buyers with sellers, not just as brokers or market makers, but as organisers of finance, production and sales and even innovation. Applying conventional economic reasoning, their success is ultimately dependent on minimising information costs without reducing the quality of decisions. Alternatively, this could be restated as increasing the quality of information and decisions without raising costs; or, more generally, increasing the former greater than the latter.

Business networks are important in this scheme since it is through the connections between businesses, customers, suppliers and others that information about profitable opportunities flows. Information is not floating around somewhere in the ether, ready to be tapped, but generated as a result of contact between economic agents. For an individual entrepreneur, success depends on how the information is used, but before that, how it is obtained or created; this is the familiar idea of networking to develop contacts and generate useful information. The connections between people may well already exist, as in the membership of a religious group or part of an extended family, but these connections have to be developed and exploited if the information, and with it the flow of resources, are to result in an effective business network and successful enterprise. In this view social connections are important not because they determine the nature of economic activity, the form of business organisation or the relationships between

[46] N. Lamoreaux, 'Banks, kinship and economic development', *Journal of Economic History,* 46 (1986), pp. 647-67.
[47] M.C. Casson, 'Institutional Economics and business history: a way forward?', *BH,* 9 (1997), pp. 150-171.
[48] Casson, 'Institutional Economics'; J. Marschak, *Economic Information, Decisions and Prediction,* (Dordrecht, 1974).
[49] Casson, 'Institutional Economics', p. 155.

them, as the sociological approach would suggest. It is because they provide lower cost, more reliable and trustworthy sources of information. As in the case of transactions costs, greater quantity and improved quality of information at lower cost raises the level of economic and business activity.

From the perspective of the individual entrepreneur, business connections within a network are developed and used for private gain. Social structures and institutions, however, exist independently of entrepreneurs and their businesses, and the strength of social ties within them is not dependent solely on the networking efforts of entrepreneurs. Similarly, trust in such groupings is an attribute of the community and its benefits are available to all members. For this reason, networks – defined as high trust linkages– and the formal and informal institutions that support them can be regarded as the social capital, social infrastructure or cultural assets of an economy.[50]

There has been considerable research on the beneficial effects of social capital on business performance, economic growth and development, but there seem to be few satisfactory explanations of the precise link between them. Zak and Knack have emphasised the impact of trust. Higher levels of trust reduce the likelihood of opportunistic behaviour which, by lowering transactions costs, generates a greater flow of savings and investment, and hence more growth. A simple cause and effect model is shown in Figure 2.2.[51] Casson characteristically adopts a much more comprehensive model, suggesting that that there are beneficial effects both on economic efficiency (allocative) and on equity. As in other approaches, however, the stress is more on the details of the connection between trust and economic behaviour than on the precise mechanism by which this produces faster growth.[52]

One possible way of looking at the network – trust – growth link is to view social capital as akin to the physical capital infrastructure of an economy – its roads, railways, power supplies, communication systems and similar assets. In a sense, these infrastructure investments are all networks, with the important common feature that there are major indivisibilities in setting them up. Consequently, there are high fixed costs, but low operating costs. The effect is that once established these assets exhibit significant increasing returns and thus reductions in unit cost as the number of users rises. There are therefore network externalities in infrastructure investments: the more users there are in the network, the lower the cost not just to the marginal

[50] Casson, 'An economic approach', pp. 28-31; M.C. Casson, 'Culture as an economic asset' in A. Godley and O.M. Westall, *Business History and Business Culture,* (Manchester,1996), pp. 48-76.
[51] P.J. Zak and S. Knack, 'Trust and growth', *Economic Journal*, 111 (2001), pp. 295-321.
[52] Casson, 'Culture'.

user, but to existing users as well. The same is also the case as regards the benefits to users of networks as is clear from telephone systems, the internet or any other system. The benefits rise as the number of users rises.

In an analogous way to physical capital infrastructure, a business network in which there is a high degree of trust (high-trust culture or equilibrium) is accessible to all entrepreneurs and investors connected to the network. And since the benefits of the network are available to all, it can be regarded as providing a positive externality or as having public goods attributes. The better the network functions in terms of providing information, the greater the degree of trust; and the wider the set of linkages, the greater the will be the benefits to each individual member and to the wider economy. These come in the form of the familiar benefits of: lower information costs; increased information flows about investment opportunities; improved access to resources, including finance to fund investment; easier coordination of inputs and economic activities; more risk taking; potentially greater commitment to risky ventures from partners in the network; and a greater ability to draw in new investors and entrepreneurs. These benefits improve the quality of entrepreneurial decisions-making and produce higher levels of investment; therefore, rather like a physical infrastructure, the positive externalities associated with a business network can give rise to increasing returns. Once given an initial trigger to start the investment process, further entrepreneurial activity can be induced and coordinated through the network, giving rise not only to initial economic development, but also to self-sustaining growth. This process is represented in Figure 2.3; it shows a more complex explanation of growth than the simple trust model of Zak and Knack in Figure 2.2. The network provides, a greater amount, better and more trustworthy information than is available through impersonal market signals. Feedback effects that stimulate further growth occur as the industrial district develops and the network of interconnected businesses and entrepreneurs expands, generating both more investment opportunities and stimulating supply. Furthermore, institutions develop to support the effectiveness of the networks' operation, thus adding to the increasing returns effects. It is precisely because of these increasing returns characteristics of networks that they are able to produce growth that results in more growth or, in other words, endogenous growth.[53]

[53] On endogenous growth models see N. Crafts, '"Post neoclassical endogenous growth theory"; what are its policy implications?', *Oxford Review of Economic Policy,* 12 (1996), pp. 30-47; C.I. Jones, *Introduction to Economic Growth* (New York, 1998), pp. 88-113, 147-89.

Figure 2.2: Trust, transactions costs and growth (following Zak and Knack).

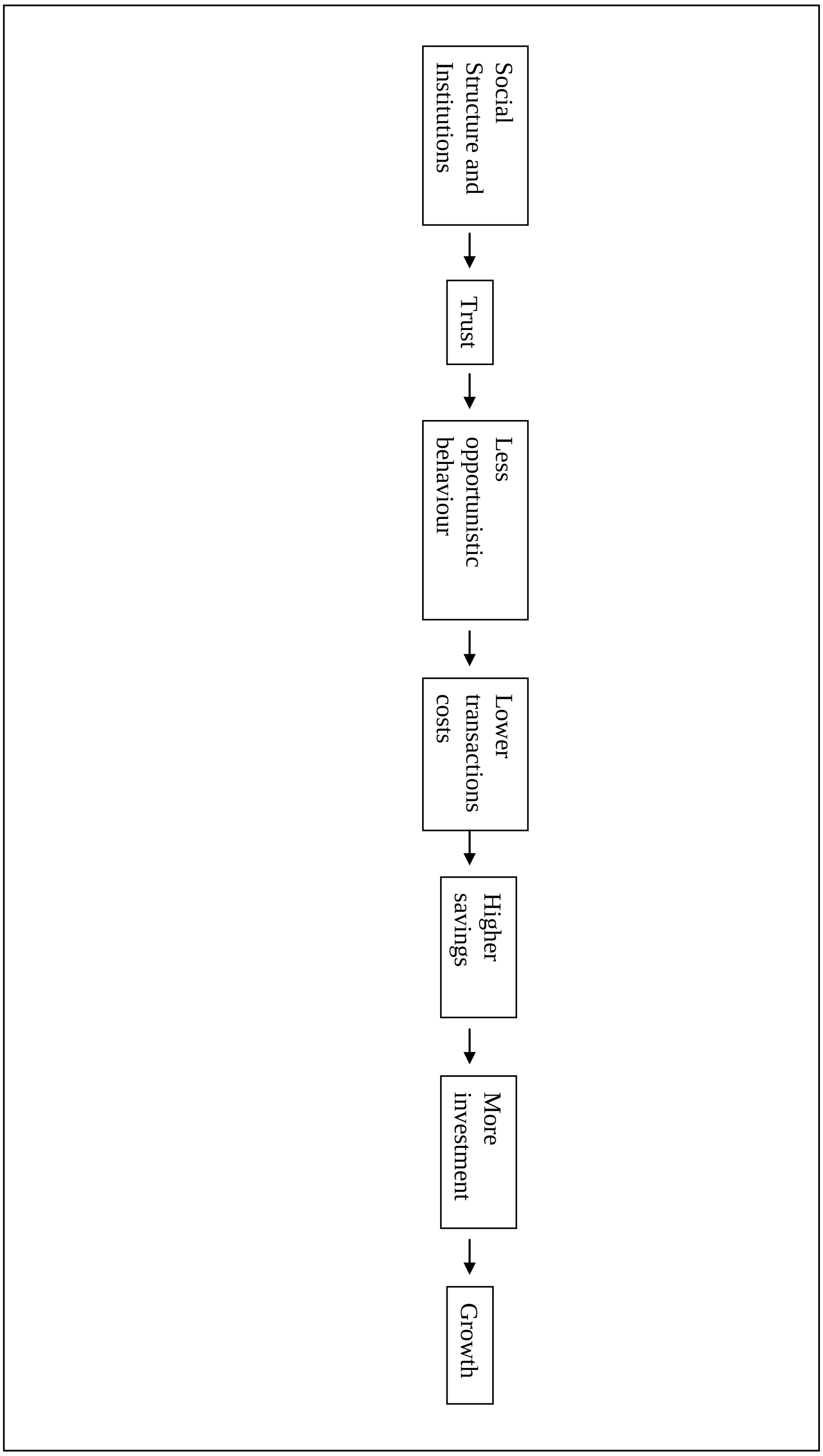
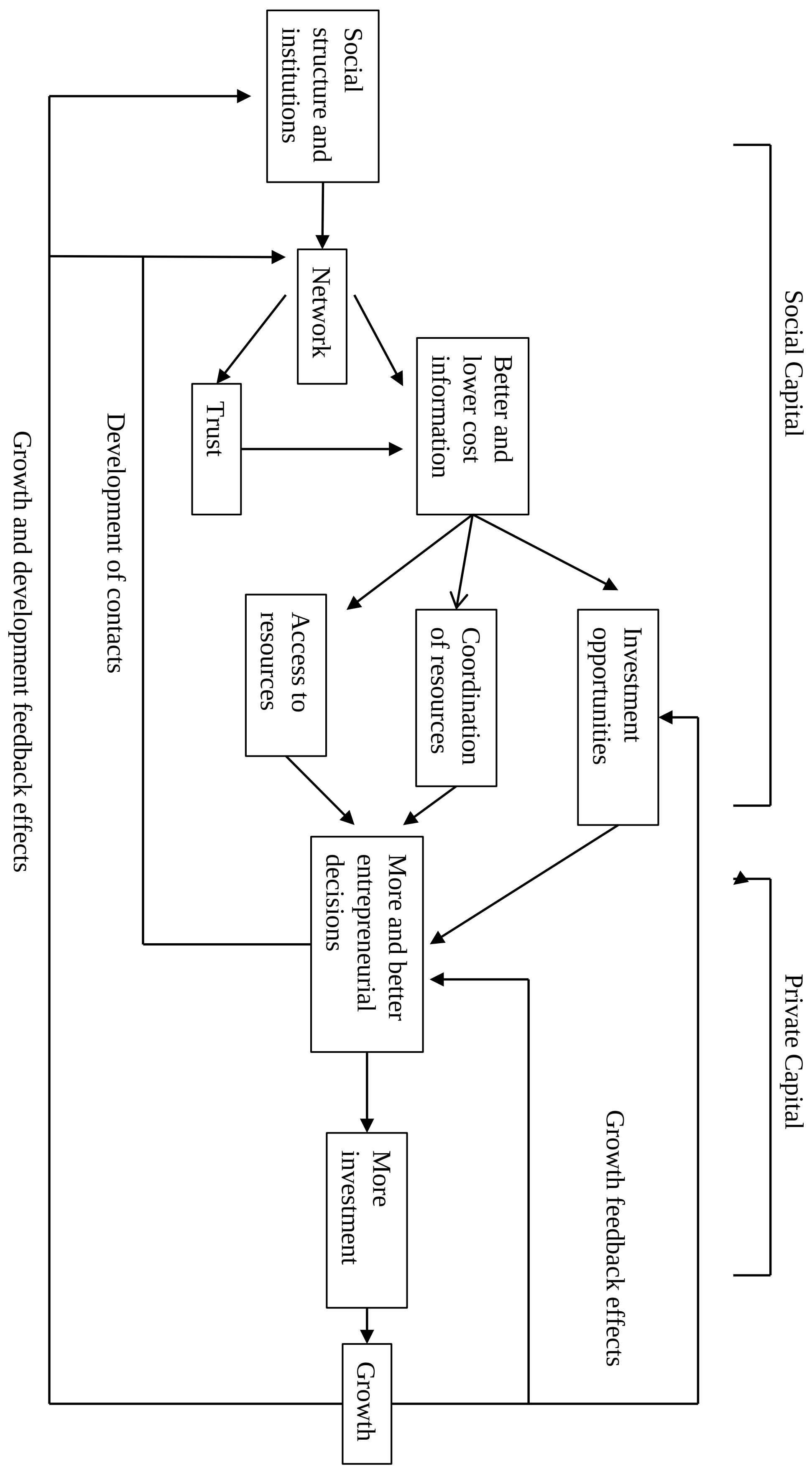


Figure 2.3: Business networks, social capital externality effects and growth



In short, business networks are of central importance as a conduit for the information flows that help in the organisation of production, and in entrepreneurial activity as a whole. The nature of networks is such that as they grow and are accessed by more entrepreneurs then information costs fall and the benefits rise. They are, however, essentially a supporting structure; the presence of a network does not explain fully the mechanism by which localised or regional economic development takes place or what may have provided the initial trigger.

2.4 Location and Agglomeration Economies

Why and how a localised industry grows in the first place to form an industrial district or cluster of firms specialising in related products can be explained by the particular advantages of the location. In terms of basic economic theory, the region may have a *comparative* advantage in the production of certain goods, or in broader terms, a *competitive* advantage. In general these advantages may stem from one of two sources: the first is that the location possesses specific natural resource advantages; and the second arises from the fact that when firms in an industry locate in close proximity there are additional advantages for all firms in the locality. These are considered in turn.

The traditional explanation for the location of industry, and indeed its localisation, is the presence of special natural resources or other natural conditions that are site-specific. The common reasons include: mineral wealth and energy supplies; natural geographical features (a harbour); and the pre-existence of transport and communications systems. In the economic geography approach to location, decisions are made principally with regard to minimising transport costs[54]. A firm will choose to locate at a site where the overall costs resulting from the transport of inputs to the firm and outputs to the markets are at their lowest. Clearly transport costs are not the only factor, and decisions will therefore take into account other costs that are affected by, or dependent on, location. These will include such factors as the availability of low wage labour, land costs and the nature of the market, that is, whether it is spatially dispersed or concentrated.[55] The degree of competition and the potential to exploit market power in the local market is another.[56]

[54] A. Weber, *Theory of the Location of Industry* (English translation, Chicago: 1929), W. Isard, *Location and Space Economy*, (Cambridge Ma., 1956).
[55] J.H. von Thunen, *Isolated State* (1875, English translation by C.J. Fredrich, Oxford, 1966).
[56] H. Hotelling, “Stability and competition”, *Economic Journal,* 39 (1929), pp. 41-57; M. Maggioni, ‘The location of high-tech firms and the development of innovative industrial cluster: a survey of the literature’, *Progetto di Ricera di Interesse Nazionale*, AT2 1/2002.

At root, the site specific factors explanation is cost-based (with the exception of the Hotelling effect), since costs are determined by locational features specific to the site. Given that all firms in an industry face similar requirements and costs, it is possible to explain the specialisation of a region in a particular industry or range of industries by these factors. There are numerous examples of this; for instance shipbuilding on the Clyde, Tyne and Wear can be explained at least in part by the need for a sufficiently large river to site the shipyards and dry docks.

Not all industrial clusters can be explained by these factors, however. Some industries are footloose and not dependent on naturally occurring or pre-existing advantages, and rather than a single optimum site there may be numerous ones that provide equivalent benefits, i.e. there are multiple equilibria. Also as more firms are drawn to an area to take advantage of special factors, costs begin to rise. The most obvious example of this is the cost of land, particularly in city centres, although the same effect can apply to suitable industrial sites. Finally, clusters often persist long after the initial benefits of the site have disappeared. These points suggest that rather than firms being drawn to a location by special external factors, there are benefits to be derived from the very fact of being located in close proximity to one another. The clustering of industry at a particular location produces its own benefits; that is there are agglomeration or external economies.

Agglomeration economies arise when unit costs of production fall as the scale of an industry increases. The cost reductions or what effectively amount to the same thing, productivity increases, are external to each firm but are internal to the industry because they occur as there are more firms often in the same industry at a specific location. Much of the analysis of agglomeration economies follows Marshall and has been applied widely to the explanation of local and regional specialisation, and to the formation of clusters.[57] They can be divided into localisation externalities – the benefits from the local concentration of firms in the same industry and – urbanisation economies – the benefits arising from firms in different industries locating together, and thus from the growth of diversified cities and urban areas. Four main sources of these external economies have been identified: intra-industry specialisation; labour

[57] A. Marshall, *Principles of Economics* (London, 1961); A. Marshall, *Industry and Trade,* (London, 1920); J.V. Henderson, 'Efficiency of resource usage and city size', *Journal of Urban Economics,* 19 (1986), pp. 47-70; J.V. Henderson, *Urban Development: Theory, Fact and Illusion* (New York, 1988); P.A. David and J.L. Rosenbloom, 'Marshallian factor market externalities and the dynamics of industrial localisation', *Journal of Urban Economics,* 28, (1990), pp. 349-370; P. Krugman, *Geography and Trade* (Cambridge, 1991); Maggioni, 'Location of high-tech firms'; Wilson and Popp, *Industrial Clusters,* pp. 4-5.

market economies (or 'pooling'); information and communication economies; and economies from public or shared infrastructure.[58]

Intra-industry specialisation: the spatial concentration of industry allows greater specialisation by firms which can raise efficiency and reduce costs. By specialising in one part of the production process firms will form part of a localised, vertically linked network of suppliers feeding the industry. In addition, because there are many firms in the same industrial sector there is a greater incentive for specialist business services to develop, e.g. marketing, legal work, specialist finance, design, maintenance and stock holding.

Labour market economies: the presence of a large number of firms means that there will be a pool of skilled and experienced workers available to all firms. This can reduce the search and training costs for each firm. From the workers' point of view, the large number of potential employers in the industry is likely to make the district attractive to immigrant workers with the appropriate skills. Furthermore, the attraction will be even greater as there will be increased chances of finding a job should a worker be laid-off. Consequently, firms may be able to pay lower average wages as workers do not need to be compensated if are lower risks unemployment.[59] Of course, the effect is most likely to be felt in diversified urban economies than in specialised industrial districts where layoffs are likely to be highly correlated between firms.

Information and communication economies: the location of firms in close proximity is likely to improve both the quality and quantity of information passed between them, especially if communication costs are sensitive to distance. Not only can this improve the coordination of production between supplier and user firms, but also give access to better information about markets and consumers on one side, and about suppliers of inputs on the other. On the demand side, this helps firms identify and respond to changes in consumer tastes and preferences. In addition, the clustering of suppliers reduces the search costs for customers, stimulating industry demand, e.g. the clustering of antique shops or estate agents.[60] On the supply side it enables a better assessment and monitoring of the quality of inputs. Finally, there is the possibility that in spatially concentrated industries there will be a more effective transmission of information about new ideas and innovations between firms (knowledge spillovers). The result is a faster rate of innovation and adoption of new technology. This is one interpretation of Marshall's

[58] Henderson, 'Efficiency of resource usage'.
[59] David and Rosenbloom, 'Marshallian factor markets', pp. 351-2
[60] , G.M. Peter Swann, M. Prevezer, and D. Stout, *The Dynamics of Industrial Clustering* (Oxford, 1998), pp. 56-58.

famous statement about industrial districts – or at least workers and entrepreneurs in them – having a collective understanding of an industry, with the 'mysteries of the trade being no mystery; but are as it were in the air'.[61]

Economies of public infrastructure refer to the local facilities and infrastructure that are available and of benefit to all firms. These assets are usually indivisible and unit costs fall as they are used more intensively. Examples include physical assets such as transport networks or a central meeting place for trade as in the case of an exchange, and intangible assets, e.g. educational institutions and local industry associations. They are often financed collectively by public funds, although this is not necessarily the case. The private provision of some collective assets is often feasible and it provides an important incentive to suppliers to encourage their use. As will be discussed below, this was an important element in Cleveland.

In each of these cases increased efficiency and reduced costs for each firm arise from a pooling of resources. An individual firm located on its own away from the main centre of the industry would face considerable cost increases, putting it at a serious competitive disadvantage. In short, agglomeration economies confer advantages on all firms located in close proximity and they can explain why certain regions specialise in particular industries and may retain a competitive advantage even when the original reasons for location, say, in the form of natural resource availability, have been exhausted.

This idea of competitive advantage and how it relates to agglomeration economies has been further developed by Porter.[62] He has provided a comprehensive and all-inclusive framework for analysing why some nations and regions have successfully specialised and maintained an economic lead in certain sectors. It has been used by Tweedale, for example, to explain the development of the steel industry in Sheffield 'in what...seems a somewhat unpromising locality' by a process that 'transformed ...a small, but vigorous working town into an industrial player of the first rank'.[63] The approach incorporates both the site-specific locational benefits and the effects of agglomeration economies along with other aspects of industrial structure. Porter identifies four broad groups of contributory factors, which together determine competitive advantage. First are the factor conditions. These refer to the resources available including natural resources, capital stock, human capital, and the physical infrastructure. Second are the home demand conditions. This includes the size, growth and specialisation of

[61] See for example Krugman, *Geography*, pp. 36-38.
[62] M.E. Porter, *The Competitive Advantage of Nations* (New York, 1990); M.E. Porter, 'Clusters and competition', in M.E. Porter, *On Competition*, (Harvard, 1998), pp. 197-287.
[63] G. Tweedale, *Steel City: Entrepreneurship, Strategy and Technology in Sheffield, 1743-1993* (Oxford, 1995), p. 28.

the home market as well as the degree of segmentation in the market. This last quality allows a high level of specialisation by firms, which will contribute to efficiency and help firms find niche markets. Third, there is the presence of supporting and related industries. This refers to the interdependencies between firms, and in particular whether they are vertically linked in the supply chain. Close linkages between clustered firms help to create the benefits of agglomeration economies. Fourth, there is the structure of industry and the strategy and rivalry of firms. Porter stresses the need for an industrial structure that promotes rivalry and competition between firms in order to promote efficiency and innovation. However, competition must be balanced by enough cooperation to encourage the spread of innovations across the industry and to provide an incentive for firms to invest to upgrade the factor conditions.

This is a considerable list of attributes that a region would have to attain if it is to achieve and maintain an advantage over competing regions. In fact, in some interpretations, the sources of advantage have been reduced to two crucial conditions: a high degree of specialisation in a geographically concentrated industry, as this facilitates knowledge spillovers; and a competitive environment to stimulate innovation.[64] This interpretation suggests that Porter's scheme provides an explanation of the dynamics of the development of a successful locally concentrated industry. But while there are clearly dynamic elements embedded in it, it is in many ways a static view. Indeed, it is essentially a stylised description – albeit an all-encompassing one – of a region that has achieved a competitive advantage; it does not say much about what started it off or how it got there. In a similar way, agglomeration economies are also a static explanation of the advantages of locational specialisation. They can explain what determines the *pattern* of industry location and regional specialisation, but on their own say little about the dynamics of why a cluster forms, grows and whether it survives or declines.[65]

Naturally, the pattern of specialisation and localisation of industry at any one time is the outcome of past growth, and therefore agglomeration economies and Porter's competitive advantage conditions are still relevant to explaining the dynamics. After all agglomeration economies are the product of the past accumulation of economic activity at a particular locality: today's pattern is yesterday's growth. But to understand how an industry-region reaches a particular point it is necessary to explain how the advantages were initiated and then how they build up over time – they need to be placed in a dynamic framework.

[64] E.L. Glaeser, H.D. Kallal and J.A. Scheinkman, 'Growth in cities', *Journal of Political Economy*, 100 (1992), pp. 1126-52.
[65] Glaeser et al, 'Growth'.

2.5 Dynamics of Clusters

A commonly observed feature of clusters is the tendency for them to pass through a series of stages, initially growing rapidly before slowing, stagnating and ultimately entering a decline during which the industry at the centre of the district contracts. A common approach to analysing this apparent regular pattern is to use the framework of a lifecycle or stages of growth model. It is one that has been widely applied to whole economies, industries, technologies and individual products.[66] Swann for example has applied the life cycle scheme to the investigation of high-technology industries (computing and biotechnology), but it can be applied more generally to other industries and in different time periods.[67] The model has four stages: initial growth up to a critical mass; take-off when growth accelerates; maturity (or saturation or peak entry) when growth slows; and finally decline.

The initial growth of an industry up to a critical mass is the outcome of 'natural' factors that makes one district more attractive as a location than others. They arise as a result of climate, the presence of natural mineral or energy resources, infrastructure or any of those that are considered to be locational factors in traditional economic geography. These initial attractors are what may be called fixed effects as they are independent of the strength of the cluster, i.e. the number of firms, employment or output of the cluster. Once the number of firms (or output or employment) at the location reaches a certain size – the critical mass – then the cluster moves to the take-off stage of growth.

During the take-off stage growth accelerates as a result of positive feedback effects. That is, as new firms enter and existing firms grow, further growth is promoted by more new entry or incumbent growth. The feedback mechanism operates through agglomeration economies, with the increasing size of the industry adding to the benefits of agglomeration producing further growth. And as in the static analysis of agglomeration economies, the benefits come from the usual sources. Swann provides a useful classification of the demand and supply side benefits (and costs) of agglomeration, but the analysis of growth is too aggregative and lacks the detailed explanation of the process by which a district and industry expands.[68]

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[66] W.W. Rostow, *The Stages of Economic Growth: a non-communist manifesto* (Cambridge, 1960); 1960: R. Vernon, 'International investment and international trade in the product lifecycle', *Quarterly Journal of Economics*, 81 (1966), pp.190-207; J.F. Wilson and J. Singleton, 'The Manchester industrial district, 1750-1939: clustering, networking and performance', in Wilson and Popp (eds.), *Industrial Clusters*, pp. 60-5.

[67] See for example G.M.P. Swann, 'Towards a model of clustering in high-technology industries', in Swann et al, *Dynamics*, pp. 52-5.

[68] Swann, 'Model of clustering', pp. 56-7.

It is possible to investigate the process of cluster development in more detail by noting that there are essentially two dimensions to the growth. First it may be through the growth of incumbent firms or the entry of new ones; and second, it may result from the expansion of the existing industry or by diversification into different, though often related products. The importance of distinguishing cluster growth in this way is that it helps to identify those features that may lead to rapid expansion that soon peters out or a more sustainable growth that results in a longer lasting cluster and a local or regional economy that is able to adapt to changing external circumstances.

In the case where growth is through the duplication of the existing industry, whether it is by increasing the size of incumbent forms or the replication of production facilities by new entrants, the increasing size of the industry is built primarily on the pre-existing advantages – the fixed effects. Larger production units may give rise to internal economies of scale, and for a time the industry expands. There may even be some cooperation between firms to solve common problems in order to improve competitive advantage, e.g. over transport systems. Nevertheless, the industry and the district is vulnerable on three counts. The first is to technological change. Large investments in existing (old) technology are costly to replace before they are fully depreciated and firms will often resist premature scrapping even if there are technological developments that undermine competitive advantage. Consequently, the industry will at some point be overtaken by those located in newer districts that have been built on the later technology. Second, the industry is at risk from shifts in demand towards new products, and the same inertia may apply to the choice of products as it does to the technology of production.[69] Third, the initial reasons for an industry's location may soon become exhausted, undermining any advantage of the site of the industry. The classic case of this is gold mining. A further problem arises when the growth is mainly the result of the expansion of the early entrants to the industry rather than through the entry of new businesses. These old firms can become inflexible and unable to adapt to changing economic or other external circumstances, especially when they have a dominant local or regional market position.

By contrast, where expansion is through diversification, the cluster will be more soundly based. This form of expansion may take various forms, such as diversifying into related products; supplying the main industry with inputs such as components or capital equipment; the development of supporting businesses; and extending production downstream into user and processing industries. As Jacobs has shown so convincingly, expansion of this nature is much

[69] Of course, the shift in production technology and product demand may be linked, as was the case in the shift to steel from iron after the 1870s. See Chapter 6.

more sustainable.[70] It is likely to result in the agglomeration economies that produce the feedback effects on growth, especially through the creation of interrelated specialist supplier and user firms between which there is close communication and coordination and clear incentives for the development and use of innovations.

The process of diversification may involve a narrow or a broad range of activities and products. In the take-off stage this is most likely to be concentrated in those areas fairly close to the principal industry of the cluster, for example on the immediate further processing of its output, and in the development of specialist supplying and supporting businesses. Some of this growth will be stimulated by the replacement of previously imported goods, services and expertise. And as local expertise and activities develop, additional exports from the district are generated adding impetus to the expansion. Growth proceeds by adding new work to existing work, and although Jacob's description of the process principally applies to the rise of cities, it seems just as applicable to industrial clusters. Thus the take-off stage involves much more than replication of existing production; it entails the expansion of economic activity by adding new products and services to existing ones: 'new goods and services...do not come out of thin air. New work arises upon existing work; it requires 'parent work.'[71]

At some point the growth of the industry slows as the sector becomes saturated. This arises partly because of congestion effects. Increasing demand for land, labour and other inputs drives up costs and this in turn reduces the attractiveness of the cluster to new entrants as well as putting a break on the growth of incumbents by reducing their competitive advantage. Additionally, it may be that the technology of the industry matures and begins to be replaced by new technologies. Where these are not developed within the cluster, but by firms in other locations, then the adoption is likely to be slower, if it occurs at all, further undermining the competitive position. Market demand factors may also be a contributory factor. It is unlikely that the initial rate of expansion in the use of a product will be maintained, and as demand slows then so too will the growth of output. This effect may be further heightened if the expansion of capacity has run ahead of market growth. With excess capacity, competition increases, there is downward pressure on prices and ultimately profitability is undermined.

Finally, the industry-district may enter the decline stage. Having lost its original advantages to new technologies and new areas producing better products more efficiently, production shifts away and firms close. The industry begins to contract and just as expansion had positive cumulative effects, contraction has similarly cumulative effects, this time negative ones. This

[70] J. Jacobs, *The Economy of Cities* (London, 1972 edition).
[71] Jacobs, *Cities*, p. 60

decline is often accentuated by the nature of the firms and the industry. If firms are large and the district is highly specialised, then it is likely that fewer technological spillovers will be generated, both because there is not the diversity of producers ready to take up the new ideas and because the existing firms tend to be more introverted. Moreover, the infrastructure is likely to be highly specialised and less useful to newer industries. Consequently, new entrants are unlikely to be attracted to the region and there will be no new industry to take the place of the declining old one, resulting in serious decline.

Terminal decline, however, is not a foregone conclusion; there are many areas originally built on the strength of one industry that maintain their prosperity and growth by developing others. There is evidence that the ability of a cluster to revive and generate a new growth industry depends on the degree of diversity in the local economy.[72] A highly specialised industrial district that has been built on the duplication of a narrow range of products, while often highly efficient in its heyday, will find it difficult to adapt to changing circumstances. Jacobs contrasts the experience of the specialised cotton textile economy of Manchester with that of the more diverse Birmingham. The diversity of Birmingham, with its 'fragmented and inefficient little industries kept adding new work and splitting off new organisations ... some of which became very large', ensured that the city retained its economic vigour and prosperity into the 1960s – the time of Jacobs' study. Manchester on the other hand stagnated as it had lost its advantage in cotton production to other centres and had little to replace it. Detroit similarly became excessively specialised and reliant on the motor industry from the early twentieth century, but found its economic fortunes on the wane by the 1960s in the face of growing competition from new centres of production.[73]

Jacobs explains this relationship between the ability to adapt and the diversity of the economy by reference to the way in which new ideas and innovations are initiated and taken up. In many cases (most, in Jacobs' view) new innovations are not directly related to existing industries, even if they emanate from them; they tend to be offshoots into new areas. In a specialised cluster there is little interest or incentive to take these up as the focus of firms is on maintaining and improving their current position. New products are unlikely to fit with the existing range or the demands of current customers. New processes require costly adjustments to existing ones. And firms are too large and too bureaucratic to finance highly uncertain new ventures.[74] It is in the diversified and fragmented industrial districts where there are more opportunities for the new ideas that cut across existing industries' interests to be taken up and developed. In such

[72] Glaeser et al, 'Growth in cities', pp. 1140-8
[73] Jacobs, Cities, pp. 120-2; Wilson and. Singleton, 'Manchester industrial district', pp. 60-5.
[74] For example, see Jacobs, *Cities* , pp. 79-81 on IBM

economies firms are also likely to be smaller and more entrepreneurial, and with the pressures of competition and survival, may well be more open to adopting, or imitating, new innovations. Swann also identifies these cross-sectoral effects, where an older industry attracts a newer one, the result of what he calls technological convergence.[75] Effectively, this is where there is close technological complementarities between the sectors, such as between computing and publishing or biotechnology and pharmaceuticals.

The development and adoption of new ideas and innovations is the key to cluster growth and to sustainability and rejuvenation in the face of a decline in the primary industry. And the basis of this is a diverse and competitive economy. There is, however, and alternative view. Porter for example suggests that innovation will be greater in a highly specialised cluster.[76] An intense focus on developing an industry generates innovations that are rapidly taken up and passed on from one firm to another in the cluster, thus improving the overall efficiency and competitive advantage of the cluster's industry and raising its growth rate. In fact it is fairly straightforward to reconcile these two views, i.e. whether it is specialisation or diversity in the industrial district that is more conducive to the development of innovations, by noting that the effects are likely to operate at different stages in a cluster's lifecycle. At the take-off stage in a specialise cluster there is likely to be rapid innovation and the development of a narrow range of products and services around the main industry, while a more diverse economy will experience a slower initial rate of growth. At the mature stage it is likely to be in a diversified economy that innovations will find sponsors and thus produce new industries to replace the ailing one. In other words, there is something of a trade-off between specialisation and diversity. The former promotes rapid early growth, but an early decline; the latter slows initial development but ensures that the industrial district is more sustainable.

2.6 Networks, Knowledge Spillovers and Cluster Development

One explanation of how the development of new innovations produces growth in clustered industries is that within clusters there are greater knowledge spillovers between firms.[77] Knowledge can be regarded as having many of the properties of a public good, notably that it is non-rival in consumption and, relatively speaking, it is non-excludable. This 'publicness' by itself means developments in knowledge (and innovations) are likely to have spillover effects, with benefits accruing to others besides the creators. The benefit of clusters is that as firms are

[75] Swann, et al, *Dynamics*, pp. 63-4.
[76] Porter, *Competitive advantage*.
[77] Swann, 'Model of clustering', pp. 43-8; Krugman, *Geography*, is sceptical.

located in close proximity, ideas can flow more easily between them: ‘intellectual breakthroughs … cross hallways and streets more easily than oceans and continents.’[78]

Knowledge, however, does not just enter the ether ready to be tapped by anyone, or, like a radio transmission, ready to be picked up by all with receivers. It needs to be communicated between members of different firms. There is, therefore, a more fundamental condition for knowledge to be spread: it is that it requires a network of linkages between firms to act as a channel through which the knowledge and information can pass from person to person. This has been demonstrated clearly in Saxenian’s comparative study of the US computer and electronics industry in Silicon Valley and along Route 128 (near Boston, Massachusetts).[79]

In the 1970s both districts were locations for leading firms in the innovative electronics sector, with Silicon Valley specialising in semiconductors (memory chips) and Route 128 a cluster of minicomputer companies. By the early 1980s each had begun to suffer from competition from overseas and new products. In semiconductors Japanese firms had made substantial inroads into the standardised mass-produced chip market, and the route 128 firms saw the minicomputer market decline in the face of competition from the newly developed personal computer. At this point there was a clear contrast in the development of the two regions. In Silicon Valley both start-up businesses and the existing firms developed new high-technology products including specialised, as opposed to standardised, chips, and other computer hardware and software. As a result the district continued to grow and prosper. Route 128 on the other hand, while remaining an important centre for the computer industry, lost its advantage and leadership in terms of the number and size of firms, employment and technological innovations, not only to the Californian centre of the industry, but to other developing districts (e.g. Austin, Texas).

Saxenian has explained this differing experience by reference to the contrasting industrial structures of the two districts. In Route 128 the industry was dominated by a small number of large integrated companies in which secrecy, loyalty and self-reliance were emphasised. Information tended to flow vertically within organisations and therefore the extent to which knowledge spillovers could generate and spread new innovations outside the main businesses was severely limited. Ultimately this reduced the dynamism and flexibility both of the firms and the whole district. In contrast to this ‘firm-based’ industrial system, Saxenian suggests that in the late 1980s and early 1990s Silicon Valley had a ‘regional network-based’ industrial

[78] Glaeser et al, ‘Growth’, p. 1127.
[79] A-L Saxenian, ‘Regional networks and the resurgence of Silicon Valley’, *California Management Review,* 33 (1990), pp. 89-112; A-L Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge Ma, 1994).

system. There were a much larger number of independent specialist firms and even though some were sizeable, or later grew large, there was in general an absence of vertical integration. Instead businesses operated by subcontracting work through networks of interconnected but independent firms. This provided competition – for contracts – but also encouraged cooperation as information for product specifications and the like had to be shared. Moreover, the linkages between firms were reinforced by a high degree of horizontal communication, with companies tied together by teams of innovators and entrepreneurs drawn from the different businesses. The rapid turnover of skilled workers and the high rate of new firm creation, as entrepreneur-innovators with novel ideas left one company to establish their own businesses, also added to the inter-firm linkages as did what Saxenian calls the 'dense social groupings' in the district. The effect was to create a highly flexible industrial system that could not only produce a great number of innovations, but which could also incorporate these quickly into products and processes ready for commercial exploitation. For these reasons the firms in Silicon Valley were able to adapt to changing outside pressures and reinvigorate the growth of the cluster.

In short, it is the flexibility of the business networks that enabled Silicon Valley to maintain its competitive advantage and technological leadership. Similar explanations have been given for the persistence of a number of industrial clusters in continental Europe, including France (mechanical engineering in Lyon), and northern Italy (Prato and Biella: textiles; Bologna: packaging machinery; Sassuolo: ceramic tiles).[80] As with Silicon Valley, these districts all have a large number of specialised, often small, vertically linked firms between which there is considerable degree of subcontracting. As well as formal contracts, much subcontracting work is undertaken on the basis of informal agreements that are based on mutual trust built up over time by repeated contact between businesses. It is also is supported by strong networks of business and social institutions to which employers and employees, and their families, all belong, giving rise to the business relationships being 'embedded' in the Granovetter sense in the social structure of the district. The effect is to create a common business language and purpose in the district and hence improve efficiency and cooperation.

Business networks, however, are important not only for maintaining the effective operation of an existing cluster, as in the European examples, or for the revivification of a mature one. They

[80] B. Harrison, 'Industrial districts: old wine in new bottles?', *Regional Studies*, 25 (1992), pp. 469-83; M.J. Enright, 'Regional clusters and firm strategy', in A.D. Chandler, P. Hagström, and O. Sövell, (eds.) *The Dynamic Firm: The Role of Technology, Strategy, Organisation and Regions* (Oxford, 1992); E. Lorenz, 'Neither friends nor strangers: informal networks of subcontracting in French industry' in D. Gambetta (ed.), *Trust: Making and Breaking Co-operative Relations* (Oxford, 1988); G. Becattini, 'The Marshallian industrial district as a socio-economic notion', in F. Pyke and G. Becattini (eds.), *Industrial Districts and Inter-Firm Co-operation in Italy* (Geneva, 1990).

also play a crucial part in the early stages of cluster development. Indeed, there are close similarities between the critical mass to take-off stage and the process of renewal. As noted above, diversification is central to the acceleration of growth in a cluster, even when it is within a fairly narrow range of goods and services that are closely related to the main industry. But in the same way that knowledge spillovers are not 'in the air', information about business opportunities offered by the process of diversification in a growing cluster need to be communicated through some channel. This is done through the linkages between businesses and entrepreneurs, that is, through business networks. It is only as a result of some form of inter-personal communication that information can be transmitted and economic activity organised and coordinated. Information may be communicated to those currently outside the industry, attracting new entrants into a growing industrial district, or between insiders to stimulate new investment, facilitating the founding of new firms, joint ventures, and re-combinations of existing firms and entrepreneurs. And as well as providing resources for existing firms to expand, the networks will be the means for promoting the development of user and supplier industries and the development of spin-off activities. There is also a need to provide the collective physical infrastructure assets that are useful to all firms. Where these are not supplied collectively by public funds, but as privately owned and financed ventures, then there will be strong incentives for the suppliers to maximise their use. One way to do this is to use contacts through business networks to attract new firms and hence encourage the development of the industrial cluster since the more intensively fixed assets are used, the greater the returns.

2.7 Conclusions

Locational advantages may explain the initial siting of an activity and agglomeration economies how cumulative growth is produced in clustered industries, but they do not explain all the processes and mechanisms behind the industrialisation of a previously economically undeveloped area. There needs to be some means through which new firms are attracted into a district and the resources for investment made available, either by being brought in from outside or developed locally. This process operates through business networks, the links between entrepreneurs through which signals and incentives for new business opportunities are sent. As part of the process there is a powerful incentive for existing businesses to use their network of contacts to attract new entrants in order to maximise the utilisation of the existing infrastructure, to develop the industrial sector further by providing suppliers of inputs and users of outputs, and to take advantage of innovations and spin-off activities. A model to show how the interaction between networks, information and trust can promote development, and how feedback effects arise as a result of growing investment opportunities, more extensive network connections and the development of supporting institutions is outlined in Figure 2.3 (p. 36). These feedback effects support the clustering process to stimulate further expansion.

Although the claims for the importance of networks should not be over emphasised, they provide more than a descriptive tool for illustrating the details of economic development. By documenting and assessing the inter-connections between entrepreneurs, investors and their business, it is possible to use networks as an analytical framework that can help uncover both why development took place and the form it took. In the next chapter this is applied to the early growth of the Cleveland iron industry.

Chapter 3: Networks and the Development of the Cleveland Iron Industry Cluster, 1850 to 1880

3.1 Introduction

An important implication of the analysis of previous chapter is that the process of clustering alone cannot explain the growth of an industry or district. Networks of businesses and entrepreneurs provide crucial channels for the transmission of information about profitable opportunities and the means for coordinating and organising the necessary resources. In this chapter the links between networks and cluster formation are explored through an examination of the beginnings and subsequent expansion of the Cleveland iron industry. It is shown that interconnected business networks made an important contribution to the formation of the iron cluster in the district.

Section 2 examines the expansion of the industry up to 1880 using detailed data on up to 130 iron and engineering firms that were established in the district between 1840 and 1879 and the entrepreneurs and investors involved with them.[81] It offers some basic quantitative measures of the pattern of entry and the connections between firms and between investors. Section 3 complements the numerical data with brief histories of several businesses that were set up in the Cleveland iron industry at this time. Together these sections provide a discussion of the contribution of networks to clustering; it is suggested that central to Cleveland's development were the interconnected networks of business and family – often Quaker – interests, and of north east and national ironmasters. Drawing on the data, Section 4 attempts to test the effects on the performance of firms of connections to the business networks using a logistical regression model. Section 5 offers some conclusions.

3.2 Development of the Cleveland Iron Industry Cluster

Within twelve weeks of Marley's and Vaughan's discovery of the main ironstone seam on Eston Nab, the Middlesbrough iron firm Bolckow and Vaughan had run a tramway down the hillside to carry the bulky rock from the mine. This was to meet a short railway extension running from the Middlesbrough and Redcar Railway at Eston Junction, later to become the site of numerous iron and steel works. It is a measure of their confidence they had struck 'ferric gold' that Bolckow and Vaughan were able to contemplate such capital expenditure on so little

[81] A list of firms and the sources are given in Appendix 1. The sample sizes used in the tables used in this chapter vary according to the data availability as the surviving records of many firms are limited.

evidence of the ironstone's worth.[82] The firm had after all only recently been bailed out by Joseph Pease (in 1847, see below) and a more risk-averse approach might have been expected. Their optimism is also indicated by the celebratory manner in which the first consignment of ironstone was taken by rail to the blast furnaces at Witton Park near Bishop Auckland. The *Mining Journal* described the celebrations at the official opening to include a party of fifty 'gentlemen' who witnessed 'six loaded wagons rushing down the 1,000 yard incline at a fearful rate'. Their contents were then loaded onto a special train and taken to the Witton Park furnaces accompanied by a brass band drawn from Bolckow and Vaughan's workers. There then followed a 'sumptuous repast' for the party at the Globe Inn at which Henry Bolckow gave a speech in the typically hyperbolic terms of a businessman promoting a new venture: he 'looked forward to the time when Middlesbrough would become the second Birmingham.'[83] The feeling of the time is also indicated by the name given to the new hamlet of cottages erected for the ironstone miners – California.

Bolckow's optimism was well-founded as a wave of economic expansion followed the discovery of the main ironstone seam. Iron ore output rose tenfold between 1854 and 1880, from 650,000 tons to 6.5 million tons; pig iron output exceeded 1.2 million tons by 1871 and 2.2 million tons by 1881. Much has been made of the fact that a substantial proportion of the output was shipped out of Teesside, and as Table 3.1 shows, at just short of half a million tons in 1871, exports to other parts of Britain and overseas were considerable.[84] But even though 40 per cent of pig iron was exported this still left 60 per cent processed by firms in Cleveland.[85] Of course, a high proportion of the intermediate and finished iron products were also shipped out, but the important point here is that so much of the processing took place locally. It suggests that there was much more to the district's economic development than is explained by comparative advantage based on factor endowments. As Yasumoto has shown convincingly, clustering explains the growth of the iron industry up to the 1870s.[86] The district benefited not only from the cost advantages of resource availability and transport links, but also from external economies as firms in the same industry located close together, and supply and user industries

[82] It was known from the geological evidence that the deposit was extensive but there were sceptics who doubted that the iron content was sufficiently high to produce pig iron economically or of an acceptable quality. For assessments of the ironstone between the 1820s and 1840s see J. Marley, 'Cleveland ironstone: outline of the main or thick stratified bed, its discovery, application and results in connection with the iron-works in the north of England', *TNEIME*, 5 (1853-7), pp. 172-4, 182.
[83] *Mining Journal*, 18 Jan. 1851, p. 33.
[84] Bullock, 'Origins', p. 87. Bullock's definition of Teesside includes Middlesbrough, Stockton, Hartlepool, Darlington and Guisborough.
[85] Bell states that fifty to fifty-five per cent of Cleveland pig iron was processed into malleable iron. Lowthian Bell, *The Iron Trade of the United Kingdom* (London, 1886), p. 16. Bullock, 'Origins', p. 89 gives a similar proportion for 1872.
[86] Yasumoto, *Victorian Ironopolis*, pp. 41-4.

sprung up. Moreover, the effects were cumulative as local supporting institutions developed and technological advances in blast furnace practice were shared, the latter part of a process Allen identified as collective invention.[87]

Table 3.1: Cleveland Pig Iron Output and Shipments from Teesside (tons)

	1861	1871	1881	1871-81 % change
Output	334,000	1,270,545	2,190,557	72
UK shipments	--	214,000	501,000	134
Export shipments	--	269,000	430,000	60
Total shipments	62,311*	483,000	931,000	93
Shipments % of output	19*	38	43	+5%
Shipments to UK % of output	--	44	54	+10%
Shipments exported% of output	--	56	46	-10%

Source: Bullock, 'Origins', pp. 87-8; author's calculations. *Shipments are the average for 1857 and 1858 (*Mining Journal*, 1, Feb. 1859).
Note: Shipments refer to those from the Port of Middlesbrough; output figures refer to the total for Teesside, including Hartlepool and Darlington.

An indication of how iron processing followed in the wake of the expansion of iron smelting capacity is indicated in Tables 3.2 and 3.3. The number of blast furnaces on Teesside more than doubled in the ten years between 1861 and 1871, and given the increase in the size of furnaces, the growth in capacity was even greater. It was processing, however, that showed an even more dramatic expansion, with the number of puddling furnaces increasing five-fold over the same period. By the peak year for the production of malleable iron in1873, output was in excess of 600,000 tons, the greatest proportion of which was rolled into rails (53 per cent), the rest made up of plates (27 per cent), bars (13 per cent) and angles (7 per cent).[88]

[87] R. Allen, 'Collective Invention', *Journal of Economic Organisation and Behaviour*, 4 (1983), pp. 3-11; J.K. Harrison, 'The production of pig iron in North East England, 1577-1865' in C. Hempstead, (ed.), *Cleveland Iron and Steel: Background and Nineteenth Century History* (Middlesbrough, 1979), pp. 93-107.
[88] Bell, *Iron Trade*, p. 18.

Table 3.2: Blast Furnaces in Cleveland and North East England, 1855-71

	1855	1861	1871	1871*
Teesside	29	49	89	112
Other Cleveland	15	33	27	29
Total Cleveland	44	82	116	141
Darlington	3	3	6	6
Total	47	85	122	147
Other N. East	27	30	15	15
North East Total	74	115	137	162

* Includes furnaces under construction.
Note: 'Teesside' includes Middlesbrough, Stockton, Redcar and Hartlepool; 'Other Cleveland' includes works using Cleveland ironstone, mainly in south Durham and Whitby and on the Tyne.
Sources:
1855: J. Marley, 'Cleveland ironstone', p. 21.
1861: Bell, 'Manufacture of iron', p. 148.
1871: 'Statistics of the iron and steel trades', *JISI*, 2 (1871), p. iii.

Table 3.3: Puddling Furnaces in Cleveland and North East England, 1850-71

	Before 1850	1862		1871		1862-71
	Furnaces	Furnaces	Capacity (tons)	Furnaces	Capacity (tons)	Percentage increase
Teesside	--	143	71,500	881	440,500	516
Other Cleveland	--	135	67,500	187	93,500	39
Total Cleveland	--	278	139,000	1,068	534,000	284
Darlington	--	45	22,500	316	158,000	602
Total	--	323	161,500	1,384	692,000	326
Other North East	--	323	161,500	606	303,000	88
Total North East	300	646	323,000	1,990	995,000	208

Sources:
1850 and 1862: Bell, 'Manufacture of iron', p. 149.
1871: 'Statistics of the iron and steel trades', *JISI*, 2 (1871), p. lxii-iii.

A fuller picture into the process of cluster formation and growth that complements the usual measures (output, employment and capital investment) can be obtained by examining the pattern of business formation. Table 3.4 shows the establishment of new firms in the iron and engineering industry in the three decades following the ironstone discovery, classified according to type of output. In some cases these were completely new firms, while in others they were existing businesses that moved into the district. In a few instances existing local businesses expanded into iron or iron-related production.

Table 3.4: Iron and Engineering Firms Established on Teesside, 1760-1879

Sector	1760-1850	1850-59	1860-69	1870-79	Total 1850-79
Pig iron production	0	10*	13	10	33
Iron processing	3	4	14	29	47
Smelting and Processing	1	3	2	0	5
Engineering	3	4	6	6	16
Iron and Engineering	6	5	2	0	7
Other Metal (non-ferrous)	0	0	2	1	3
Unknown Iron/Engineering+	1	0	4	1	5
Total	14	26	43	47	116
Memo item: Iron Shipbuilding	1	4	1	1	7

* Includes firms already in existence on Teesside that moved into pig iron production after 1850.
+ Iron and engineering firms whose activity has not been precisely identified.
Sources: data for this table are taken from the survey of Teesside iron, steel and engineering firms in listed in Appendix 1. Full references are given in the Appendix.

Table 3.4 reveals that entry rose from the 1850s to the 1860s and again in the 1870s, most notably in the first half of the decade. It indicates a rapid acceleration in growth from the initial stages through critical mass to take-off. Peak entry occurred in the early 1870s with at least thirty-six new businesses entering the industry between 1870 and 1874, all but one of which were new enterprises. As would be expected, in the 1850s entry was largely in the production of the basic iron product – pig iron – especially in the early part of the decade. Entry by specialist smelting firms also continued right through to 1875, although proportionately they became less important, falling from over half of the new firms in the 1850s to a quarter in the 1860s and one-fifth in the 1870s. After this time there were to be no significant new entries by pig iron smelters; increases in output arose mainly from expansions in capacity by existing firms.[89]

[89] Both the number and size of blast furnaces increased. See: J.K. Harrison, 'The development of a distinctive "Cleveland" blast furnace practice, 1866-1875', in C.A. Hempstead (ed.), *Cleveland Iron and Steel*, pp. 93-5; J. Gjers, 'A description of the Ayresome Ironworks, Middlesbrough, with some remarks

There is also a discernible trend to diversification into 'downstream' products in the iron processing and finishing trades. In the 1860s and early 1870s the majority of new entrants specialised in puddling and rolling to produce wrought iron bars and rails, plates and angles. There was a particular emphasis on railway products, especially rails and castings such as fish plates and chairs, but also wire, nails and products for the shipbuilding industry – angles and ship-plate. The latter were to become increasingly important.[90] The process of extending and diversifying the district's industry is also shown by the gradual entry of engineering firms and those with combined iron and engineering interests. This was within a fairly restricted product range as most of the firms concentrated at the heavy end of the engineering trades, notably bridge design and building, marine engineering and shipbuilding. However, it did extend to more specialist aspects of the industry such as marine engines, boilers and pumps (e.g. Blair and Co, established in 1866). Other specialist firms were in wire production (Richard Hill and Co, 1868), tubes and pipes (Cochrane, Grove and Co, 1862; Crewdson, Hardy and Co, 1873) and in the production and maintenance of blast furnace plant. There were also a few specialist businesses not directly in the iron industry, but in non-ferrous metals, notably copper and brass. These firms supplied parts and components to the iron producers (e.g. copper tuyérès for blast furnaces) and fittings for shipbuilders.

Some caution needs to be exercised in interpreting Table 3.4 as the data refer to the establishment of a business and not of a plant. On the one hand there is a tendency for the figures to understate the scale of the transformation in terms of output, employment and investment as no account is taken of the size of firms or the fact that some owned and operated more than one plant.[91] Similarly, no account is taken of internal expansion that occurred after a firm was set up. Both, factors were major contributors to the growth of the district. On the other hand, Table 3.4 may understate the extent to which the district's interests were extended into downstream processing and related activities, and hence the degree of diversification. First, firms have been classified according to their initial or principal activity, which for some changed over the years. Many of the pig iron producers also had processing and finishing plants (e.g. Bolckow Vaughan), and others expanded into processing by setting up their own puddling furnaces and rolling mills for rails or plates (e.g. W. Whitwell & Co.). There were also some firms that extended their interests in the other direction by building blast furnace plants, as in the case of Snowden, Hopkins and Co (later known as Hopkins, Gilkes). Second, the table does

upon the gradual increase in size of the Cleveland blast furnaces', *JISI*, 2 (1871), pp. 206-16; Allen, 'Collective invention, pp. 5-13.

[90] See J.F. Hargrave, 'Competition and collusion in the British Railway Track Fittings industry: the case of the Anderston Foundry, 1800-1960' (PhD thesis, Durham University, 1992).

[91] For example Bolckow and Vaughan had production facilities at Middlesbrough, Eston (Cleveland Ironworks and Eston Ironworks) and Witton Park (Bishop Auckland).

not include the firms and industries that developed from the by-products of the iron and steel industry, such as gas production and especially chemicals. The latter sector started to develop from the 1870s.

In short, the nature of the firms established over the 1850-80 period reveals a local economy that diversified from pig iron production fairly rapidly, as firms looked for profitable ways to process their output. In some cases this was done through internal growth as the larger businesses expanded their interests, but in others it was through the entry of specialists into distinct market segments. This process is a clear example of the creation of a cluster of interrelated firms. Not only were they located in close proximity, but they were also interdependent, supplying inputs, providing a demand for output and developing and sharing technology.

The extent to which the cluster's development was facilitated by the business networks that existed prior to and developed along with the industry can be investigated in more detail by assessing the degree to which the entrepreneurs, investors and firms were connected to each other. The following tables (3.5 to 3.8) provide the results of research into 130 firms and businesses set up in the Cleveland area. 14 existed on Teesside prior to 1850 and 116 entered the district between 1850 and 1879. It includes 126 entrepreneurs and direct investors in the industry.[92]

A starting point is to consider the extent to which investors and entrepreneurs invested in more than one business, that is, the extent to which they were involved in multiple partnerships or there were overlapping directorships. Table 3.5 shows that at the level of the individual entrepreneur involvement in more than one business was fairly limited: only 20 per cent were directly connected to more than one firm in the iron industry as partners or directors. However, when connections to firms in other sectors or other types of relationship besides partnership are considered, there are clearly much closer linkages. These links include: connections between investors in other business sectors, e.g. the railway company; connections with other businesses as an employee (e.g. an employee in one firm was an investor in another); connections through family and religious denomination.

[92] Additional investors (shareholders) when partnerships were floated as limited companies are excluded.

Table 3.5: Connections between Cleveland Investors, 1850-79 (per cent of investors)

Number businesses investors with which are connected	Percentage of investors connected through: Iron and engineering businesses	Iron, engineering and other businesses[1]	Iron, engineering and all other business connection[2]	All connections[3]
1	80	70	64	53
2	15	}	}	}
3	3	}30	}36	}47
4	2	}	}	}

1: Other business connections as investors. 2: All other business connections, includes being an employee. 3. All connections; includes family, co-religionist. Sample size: 126.
Source: Appendix 1.

The degree of interconnection between investors rises to almost 50 per cent when other possible linkages are included: that is, almost half of all investors were linked to at least one other investor in at least one way. This high degree of interconnectedness is confirmed when the linkages between firms are considered (Table 3.6). Over the whole period almost two-thirds of firms setting up in the Cleveland had some connection with another business in the district.

Table 3.6: Connections between Cleveland Firms, 1850-79

	Total number of firms	At least one partner* is an investor in another iron or engineering firm	At least one partner has business connections with other firms	At least one partner is connected to other businesses through family, religion etc.	Total number of firms connected[+]
1850-59	26	11	12	14	16 (62%)
1860-69	43	16	19	18	20 (47%)
1870-79	47	26	28	18	28 (60%)
1850-79	116	53	59	50	64 (55%)

*Partner includes director for limited companies.
[+] Rows do not add up as firms are often connected in more than one way.
Source: Appendix 1.

The significance of these connections is that they reveal the importance of the regional business networks in the development of the Cleveland iron industry. New businesses were formed not just by outsiders spotting an opportunity and moving in, but as a result of existing investors extending their interests, attracting or facilitating and financing the entry of new investors and entrepreneurs, or establishing new enterprises themselves. Often the new investors and entrepreneurs were family members, part of the same religious group, or already connected to the iron and engineering industries in some way. In other words, they were drawn in through the existing business network. Moreover, Table 3.6 may also understate the connections in three ways. First, it does not include the links to secondary financing, i.e. to the source of funds for the new entrants. If these were local or connected in some other way to the entrepreneurs, then the significance of network is reinforced. Second, the table does not indicate the extent to which there were close connections between the entrepreneurs that involved several possible linkages – finance, family, and business partnership – all within the same firm. Third, the table omits the links new entrants already had with other regional or local businesses. There were a number of firms with interests in Durham collieries or railways that moved into iron production, e.g. Carlton Iron Company.

Further detail is revealed by an examination of the backgrounds of investors and entrepreneurs. A common factor in many of these connections is the link with the business and banking interests of Darlington-based Quakers, especially the Pease and Backhouse families. In fact, Quaker-related firms occurred with considerable regularity (Tables 3.7 and 3.8). The data shows that in the 1850s around half of investors and firms entering Cleveland's new iron industry had known Quaker links. These were through family or business interests such as the S&DR, and finance, e.g. banking with a Quaker-owned bank. In many cases the connections were multiple. Even though the Quaker links declined over the following two decades, there were still a significant number of new firms with Quaker connections, over 30 per cent in the 1860s and 1870s.

The other feature of the new firms is that a high proportion had at least one investor (partner or director) who had already been involved in the iron or engineering industries. This is not surprising. The technology of iron production at the time, although essentially practical, was becoming increasingly sophisticated. Any entrepreneur with a financial or merchant background needed the support of an experienced engineer to set up in the industry. Once again the influx of experienced ironmasters and engineers demonstrates that information about the opportunities in Cleveland was filtering out through the network of north east and national iron producers.

Table 3.7: Characteristics of Investors Entering the Cleveland Iron and Engineering Industry, 1850-79

		1850-59	1860-69	1870-79	Total
Total number of new investors		32	49	45	126
Investors with Quaker links	Quaker family	4	2	-	6
	Railway	4	1	-	5
	Finance	2	1	3	6
	Multiple	6	8	6	20
	Total Quaker	16 (50%)	12 (24%)	9 (20%)	37 (29%)
Non-Quaker		6	6	11	23
Unknown		8	31	25	64
Memo item	Previously in iron/engineering	17 (53%)	13 (27%)	18 (40%)	48 (38%)

Notes for Table 3.7 and Table 3.8: the categories are defined as follows.
Investors: sole proprietors, partners and directors of joint stock companies.
Quaker family: a Quaker meeting member or attender or had Quaker parents, wife or in-laws.
Railway: investor or employee of the SDR.
Finance: banked with a Quaker-owned bank.
Multiple: linked in two or more ways
Source: Appendix 1.

Table 3.8: Characteristics of Firms Entering the Cleveland Iron and Engineering Industry, 1850-79

		1850-59	1860-69	1870-79	Total
Total number of new firms		26	43	47	116
Firms with Quaker links	Quaker family	9	14	7	30
	Railway	6	7	2	15
	Quaker finance	9	11	11	31
	Multiple	7	9	5	21
	Total Quaker	13 (50%)	17 (40%)	13 (28%)	43 (37%)
Memo item	Previously in iron/ engineering	21 (81%)	23 (53%)	33 (70%)	77 (66%)

Source: Appendix 1.

3.3 Networks of Firms and Investors

The crucial point revealed by Tables 3.7 and 3.8 is not that the whole development of Cleveland's industry was Quaker dominated; indeed, it was far from that. It is that, at least in the early period, the numbers and influence of Quaker-linked firms and entrepreneurs entering the industry were out of proportion to the size of the group, and they were strategically important.[93] The effect was that the closely connected and coordinated local Quaker business interests, with extensive links to a wider network of potential entrants to the industry, were sufficiently powerful to be able to attract a significant number of businesses and entrepreneurs.

Foremost among the interrelated business networks were the Quaker business and banking interests of the Darlington-based Pease family. As the Peases' businesses interests have been well documented, it is sufficient to outline them briefly.[94] By the 1840s and 1850s these were largely under the control of Joseph Pease (1799-1872), who along with his father Edward Pease (1767-1858) and other Quaker businessmen and bankers had played a leading role in setting up the S&DR. With business interests stretching from a private bank (Pease and Co), railways and coal mines in south Durham to the new town of Middlesbrough (as shareholders in the Middlesbrough estate) and its docks (built in 1846 by the S&DR to improve coal shipping facilities), there was a clear incentive to encourage development. Before 1850 Middlesbrough's and its port were heavily dependent on the coal trade but at that time its position was under threat from at least three sources of competition: the port at Hartlepool; an expanding railway system that could transport coal to the London market along the main North-South route; and from other coal producing areas. A new industry in Cleveland was a timely development.[95] Indeed, an anonymous correspondent from Glasgow, who signed himself 'No Speculator' wrote to the *Mining Journal* at the end of 1851: 'I find the people getting up these joint stock schemes as entirely connected with a certain railway greatly in want of traffic, besides being parties largely interested in collieries on this line [S&DR] in the west of Durham.'[96] The Peases were also linked by marriage and religious denomination to the Darlington-based bank of J. Backhouse and Co, which had been crucial to the financing of the railway. They too had interests in coal in South Durham, and as the only bank in with branches in both Middlesbrough

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[93] There were never more than about 2,000 Quakers in the north east, (Cookson, 'Quaker families', p. 123) and Darlington Monthly Meeting, which covered the Meetings in Darlington and Teesside, had just 907 members and attenders in 1866, Religious Society of Friends, *List of Members and Attenders belonging to Darlington Monthly Meeting*, 1866, (Darlington Friends Meeting House Library).
[94] Kirby, *Men of Business*, pp. 21-46; A. Orde, *Religion, Business and Society in North East England: The Pease Family of Darlington in the Nineteenth Century* (Stamford, 2000), pp. 19-46; Cookson, 'Quaker families'.
[95] Briggs, 'Middlesbrough', pp. 7-8; Kirby, *Origins*, pp. 133-44; Taylor, 'Infant Hercules', p. 54.
[96] *Mining Journal*, 6 Dec.1851.

and Stockton in the late 1840s and early 1850s, clearly had good reason to encourage the development of the district. [97]

How this network of Quaker family and business interests worked to foster the development of the iron industry in Cleveland can be illustrated by considering a number of case histories. The ones outlined below all had particularly strong connections to the business networks in the district and are therefore useful for identifying the multiple linkages that existed between enterprises and between their owners.

Bolckow Vaughan

One of the earliest iron firms linked to the Pease-Backhouse network to set up in Cleveland was Bolckow Vaughan, although it was not a Quaker business by any stretch of the imagination. Its importance lies not just in its rapid expansion after 1850, or that it became one of Britain's largest iron companies, but also in the part it played at the start of Cleveland's industry. Specifically, there are indications that the firm was attracted to Middlesbrough by the Pease-Backhouse-S&DR interests, that Joseph Pease had a role in the formation of the partnership in the first place, and that the firm was supported financially by the Darlington Quaker businessmen during a difficult period in the 1840s and later when it began to exploit the newly discovered ore deposits.

The Bolckow and Vaughan partnership (1840) was a classic example of the combination of a merchant and financier, Henry Bolckow (1806-78), with a practical industrialist, John Vaughan (1799-1868). Prior to their move to Cleveland the partners were also linked to the Newcastle and the north-east networks of iron and other business interests. John Vaughan was associated with Bell Brothers, one of the principal iron firms that moved in to Teesside after 1850. He was the manager of their Walker Ironworks – originally owned by a forerunner to Bell Brothers – from the late 1820s until 1840.[98] The son of an iron worker from Worcester, he had trained at Dowlais in South Wales before running a small ironworks in Carlisle.[99] From there he went on to manage the rolling mills at Walker where he and Lowthian Bell were close colleagues. Bell is reputed to have learnt much from the older man, and in his unfinished family history Hugh Bell quotes his father: 'Often and often did I go down to the mill after supper and sit for hours watching the bars being rolled and listening to John Vaughan talk about mill practice and instruct me in the act.'[100] He also relates a trip that John Vaughan and a young Lowthian Bell

[97] Kirby refers to the Quaker family connections as the 'cousinhood'. Kirby, *Men of Business*, p. xx.
[98] Bell Brothers is considered below.
[99] Jeans, *Pioneers*, pp. 67-70.
[100] T.H. Bell, 'Family History and Autobiographical Notes', (unfinished draft), 1906, North Yorkshire Record Office (NYRO), ZFK, mic002465-002505, p. 25.

made to South Wales to recruit puddlers for the Walker works, which he described as a 'a sort of piratical expedition'. Vaughan left Walker in 1839 or 1840 to found the partnership with Bolckow and establish his own a puddling plant and rolling mills in Middlesbrough.

Bolckow, originally Bölchow, was a German-born, Newcastle-based merchant. He began working in a merchant's office in the Baltic port of Rostock and in 1822 moved to Newcastle with a friend and colleague, Christian Allhusen, to work as a clerk in Allhusen's brother's merchant business.[101] In the 1820s Bolckow and Allhusen formed a partnership as corn merchants (Allhusen and Co) and it appears they successfully speculated in grain. Estimates of the amounts they made vary: for Bolckow, they are put at between £20,000 and £40,000.[102] Hugh Bell suggests that Allhusen's share was £30,000, but gives no indication of Bolckow's.[103] By the end of the 1830s Bolckow, by now a property owner eligible to vote and in his mid-thirties, was looking for a new challenge and ended the partnership with Allhusen.

There are numerous explanations as to why Henry Bolckow should have entered into partnership with John Vaughan in a cyclically unstable business, iron, and in a virtually unknown and underdeveloped town, Middlesbrough. They were brothers-in-law (married to sisters); they may have met during the normal course of business, as both men's firms (Losh, Wilson and Bell and Allhusen and Co) had offices in Newcastle, and discussed new ventures; Vaughan may have wanted to leave Walker if he thought his prospects for further advancement were blocked by Lowthian Bell; and finally, Jeans suggests that Bolckow chose iron as he was looking for 'a business occupation of a more steady character', which is a rather odd description of a trade renowned for its volatility.[104] Irrespective of Bolckow and Vaughan's personal motivation, there does seem to be evidence that Joseph Pease made an attempt to persuade them to establish a works in Middlesbrough, perhaps acting a little like a modern development agency attempting to attract inward investment. Firstly, Pease was at the meeting in Newcastle between Bolckow and Vaughan where the decision to establish their partnership, and for Bolckow to dissolve his with Allhusen, was taken.[105] Secondly, Bolckow and Vaughan, had attempted to buy land for an ironworks in Stockton in 1839, but were persuaded by Pease and John Harris, the chief engineer for the S&DR, that Middlesbrough provided the superior port facilities and generally better prospects.[106] Pease, as a representative of the Owners of the Middlesbrough

[101] Jeans *Pioneers*, p. 49; Gott, *Bolckow*, pp. 19-20.
[102] Gott, *Bolckow*, p. 20.
[103] T.H. Bell, 'Family history', p. 26.
[104] Hugh Bell refers to Bolckow and Vaughan's wives as 'the *causa causans* of the development of Cleveland'. T.H. Bell, 'Family history'. See also Gott, *Bolckow*; Jeans, *Pioneers*, pp. 49-50.
[105] Gott, *Bolckow*, p. 20. For the notice dissolving the partnership between Allhusen and Bolckow, see *London Gazette*, 9 Jan 1841.
[106] Gott, *Bolckow*, pp. 24-5.

Estate, was able to offer land on which to site their works that was close both to the river and railway at a cheap rate.[107] Thirdly, Vaughan is reputed to have received from Joseph Pease a letter of introduction addressed to the Durham colliery owners stating that he 'was likely to become an extensive consumer.'[108] And lastly, Backhouse's bank financed the new firm as a balance sheet for the firm in 1843 contained in a notebook of one of the bankers shows: Bolckow and Vaughan owed the bank £11,500 (a loan or overdraft) and the Middlesbrough Owners £2,700 for coal.[109]

Pease was cautious in the help he provided, and he may have been wary of two independent and experienced businessmen coming to a town dominated at that time largely by Quaker interests. But it was certainly in his own interests and those of his fellow Quaker investors to encourage the new business to Middlesbrough. The iron firm would fit in well, making use of the railway for its coal supplies, the harbour for imports of pig iron and exports of finished products, and providing the railway with a local supply of rails and other iron components from the rolling mill and puddling furnaces. Moreover, there were the benefits of increased business to the local bank.

Although evidence is sparse, there appears to be a continuation of a close financial link between the Quaker businesses and Bolckow and Vaughan into the 1850s that enabled the early expansion of the iron industry. This seems to be implied by an entry in Joseph Pease's diary when he wrote: 'Then to my Counting House. H. Bolckow quite fast in his financing arrangements … liberated by him.'[110] Given that it was in the Peases's interests, it is highly likely therefore that Bolckow Vaughan received some support from the Pease's bank, Pease and Co, and Backhouse's, possibly in the form of short-term loans as the firm expanded rapidly. Apart from the investment required to buy leases and open up the mines, Bolckow and Vaughan had by 1853 built three blast furnaces at their Middlesbrough ironworks, six at the Cleveland works (Eston Junction) and acquired three more from Thomas Elwon (Eston Ironworks).[111] Long-term capital outlay on the works and for new houses for the mine and iron workers therefore would have been substantial, as would short-term working capital. Thus, external financing would have been essential as it is unlikely that the revenue generated from sales was sufficient: the time lapse between the start of construction and the blowing-in of a furnace was

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[107] Jeans *Pioneers*, p. 135.
[108] Jeans, *Pioneers*, p. 72; Gott, *Bolckow*, p. 23.
[109] Memorandum Book of Agreements Regarding Advances on Accounts, pp. 29-30. Barclays Bank Archive, 0388-0472.
[110] Diary of Joseph Pease, 1 May 1855, Teesside Archive, Microfilms 208 and 209. The full entry is difficult to read; there are four illegible words between 'arrangements' and 'liberated'.
[111] The Cleveland and Eston Ironworks were sited at Eston Junction on the Middlesbrough and Redcar Railway.

some months, and while the firm already had four furnaces operating at Witton Park (see below) and the puddling and forge works and rolling mills in Middlesbrough, revenues were low at the time. Iron prices in the early 1850s were below the average for the previous decade; in the 1840-49 period pig iron prices averaged about 60s per ton, but fell to 40s in 1851, although they rose steadily thereafter.[112] In addition, Bolckow and Vaughan's own resources would have been insufficient. These had been depleted in the late 1840s when the business almost failed. Indeed, this earlier incident reveals that some of the financial arrangements between the ironmasters and Joseph Pease, even if sporadic, were long-standing. The collapse of the railway boom in 1847 led to what Jeans called Bolckow and Vaughan's 'most trying crisis.' With falling iron prices and output at 4,500 tons, down from 20,000 in 1846, the business faced financial problems severe enough for the banker's, Backhouse and Co, to send in the bailiffs to take possession of the works in Middlesbrough. It was Joseph Pease who was able to persuade his cousins at Backhouse's not to call in the loans, and either lent the money himself or stood security for the firm.[113]

More generally, if contemporary accounts are to be believed, there was a mutually supportive relationship between the two ironmasters and Joseph Pease. Jeans wrote in the characteristically flowery prose of the day that there was 'reciprocity of feeling and of interest that made the one rely to a large extent on the other', and 'we have heard it said, too, that there were pecuniary transactions carried on that reflected equal credit on both – providing as it did the limitless confidence of the one [Bolckow], and the honour and integrity of the other [Pease].'[114] That there was 'reciprocity of feeling' between the two sides, and particularly between the two financiers Pease and Bolckow, is shown by a note by Pease in his diary later in 1855. He wrote that Bolckow 'stuck up for me and my partners.'[115]

One further aspect of Bolckow and Vaughan's early history that is worth noting is that in 1845 the firm built its own blast furnace plant at Witton Park near Bishop Auckland to smelt the local clayband ore and to take advantages of coal supplied from the local collieries.[116] The plan to supply the works at Middlesbrough with pig iron clearly benefitted from, and would be a source of revenue for, the S&DR, which provided the rail link to the Tees. And for the firm, shipping

[112] Mitchell, *Historical Statistics,* p. 63.
[113] Gott, *Bolckow*, p. 25; D.W. Hadfield, 'Political and social attitudes in Middlesbrough 1853-1889, with especial reference to the role of Middlesbrough ironmasters' (PhD thesis, Teesside Polytechnic, 1981), p. 29; Jeans, *Pioneers*, p. 54.
[114] Jeans, *Pioneers*, p. 138.
[115] Joseph Pease Diary, 12 Oct. 1855. This may be a reference to the discussions concerning the amalgamation of the railway companies that made up the S&DR interests. See Kirby, *Origins*, pp. 167-73.
[116] Marley, 'Cleveland ironstone', p. 169.

pig smelted at Witton Park to the processing plant was likely to be less costly than building blast furnaces at Middlesbrough and transporting all the materials – coal, iron ore and limestone –to Teesside. On the surface therefore the plan seemed logical, and John Vaughan in particular expected to find substantial iron deposits in the local coal measures to make it worthwhile. But this was not a view shared by all. According to Hugh Bell, Lowthian Bell attempted to dissuade Vaughan from the investment, advising him that there was no ironstone in the south Durham coalfield. Bell is supposed to have commented that 'a more crack-brained enterprise was never undertaken.'[117] As it turned out, Bell was absolutely right; the ironstone supplies were insufficient and Bolckow and Vaughan had to look elsewhere. As others firms had done in the past, it was to the nearest and most obvious source that they turned, Cleveland. However, using the poor quality Cleveland ore raised costs substantially because of its low iron content and as it had to be transported in its raw and bulky state, notwithstanding the volume reducing effects of calcining, up to Witton Park for smelting and then as pig iron back to Middlesbrough for finishing. It was this ore shortage that stimulated the search for the richer and thicker main seam of the ore deposit in the hills south of Middlesbrough, a quest that was eventually successful.

In fact, the search for a commercially viable source of iron in Cleveland had been taking place since the early 1800s.[118] Repeated trials and surveys led to an accumulation of knowledge about the properties and possible location of the main deposit of ironstone that would have been transmitted between the iron firms, surveyors and geologists involved in the north east iron industry. Bolckow and Vaughan were part of this network, or set of interconnected networks, and were well aware of the potential offered by Cleveland. Their discovery was far from a chance event; it was the culmination of a collective effort and a gradual homing-in on the most likely location of the iron. It is possible therefore to provide an explanation for the initial 'event' that started the expansion of the Cleveland iron industry that is also consistent with the operation of business networks.

<u>Edgar Gilkes and Isaac Wilson</u>

Edgar Gilkes and Isaac Wilson had both Quaker connections and interests in the S&DR. Gilkes (1821-1894) was from a Quaker family in Nailsworth, Gloucestershire.[119] He trained as an engineer in Berkshire before moving to Shildon, County Durham, to work at the S&DR's

[117] T.H. Bell, 'Family history', pp. 26-7.
[118] The first attempt to smelt Cleveland ironstone in the nineteenth century was between 1815 and 1820 at the Lemington ironworks on the Tyne. There followed a series surveys to identify main seam and unsuccessful attempts to smelt the ore. See Marley, 'Cleveland ironstone'; Bell, 'Manufacture of iron'; Nicholson, '"Jacky" and the Jubilee', p. 43-4.
[119] 1881 Census; Jeans, *Pioneers*, pp. 117-20; Hadfield (thesis), p. 381.

locomotive works in 1839. By 1843 Gilkes had moved to Middlesbrough to manage an engineering works, the Tees Engine Works, mainly to repair rolling stock at the S&DR's Middlesbrough terminus. In the following year he and Isaac Wilson became partners, initially to lease, and subsequently to take over, the works as an independent business – Gilkes, Wilson and Co.[120] Wilson (1822-99) himself was already in Middlesbrough, having arrived in 1841 to join the Middlesbrough Pottery. It was one of the few manufacturing firms in the town at the time and was owned and run by Richard Otley, a former secretary to the S&DR.[121] Wilson is described by Jeans as a protégé of Joseph Pease and in 1842 Wilson, when still only 20, was already a shareholder in the S&DR and on the management committee. His move to Middlesbrough was encouraged by Pease, as perhaps were his later business ventures.[122] Like Gilkes, he was from a Quaker family, and also related to the Peases: a great aunt (Dorothy Wilson) was married to John Whitwell, an uncle of Joseph Pease, and Whitwell's sister Rachel was Joseph's mother. Wilson was also linked to the S&DR through his sister Mary, who was the second wife of John Harris, an engineer with the S&DR.[123]

The Tees Engine Works (Gilkes, Wilson and Co) appears to have been the second iron and engineering plant in Middlesbrough, after Bolckow Vaughan.[124] In addition to maintaining S&DR rolling stock, the works also manufactured steam engines for a variety of purposes including locomotives, stationary and marine engines, and agricultural engines.[125] After the ironstone discovery in 1850, the firm continued as a specialist engineering business, but also branched out into blowing engines for blast furnaces and other blast furnace equipment as the new iron works were built along the Tees. Later bridges were added to the product line. It remained an independent operation until 1865 when the business amalgamated with an iron firm, Hopkins and Co (see below).

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[120] The other partners were Oswald Gilkes, Gilkes' son, and William Bouch, an employee of the S&DR. Contracting out work to independent firms was an established practice by the S&DR. See Cookson, 'Quaker families', p. 131-3; Kirby, *Origins*, p. 102-10.
[121] Jeans, *Pioneers*, p. 87. There was another partner, Davidson.
[122] According to Kirby, the pottery was in difficulties. Pease also injected more capital and sent Wilson was to inject some fresh blood. Kirby, *Origins,* p. 138; Jeans, *Pioneers,* p. 91; Obituary of Isaac Wilson, *Northern Echo*, 23 Sept. 1899.
[123] Family links cited here and below are taken from: Joseph Foster, *Pease of Darlington. With notices of the families of Robson, Backhouse, Dixon and others, being the descendants of Joseph Pease of Shafton, in the Parish of Felkirk, Yorkshire (1665-1719)*, (England, Private circulation, 1891); Kirby, *Men of Business*, pp. 128-33.
[124] Gilkes, Wilson and Co (Tees Engine Works) should not be confused with Gilkes, Wilson, Pease and Co (Tees Ironworks).
[125] Kirby, *Origins*, p. 134. It is unlikely that at this early stage the firm produced such a wide range of products; blast furnaces and marine engines are likely to have been added later as industry developed.

Gilkes and Wilson moved into pig iron production soon after 1850, setting up another firm to do this. Taking on another partner, Charles Leatham, they formed Gilkes, Wilson, Leatham and Co (1852) and established the Tees Ironworks at Cargo Fleet on the riverside to the east of Middlesbrough. Initially the works had two blast furnaces; this was increased to four by the early 1870s, and later puddling furnaces to produce cast iron railway products such as chairs and sleepers were added.[126] This firm is one example of the tendency noted above for some Cleveland ironmasters to extend their business interests by establishing new firms rather than enlarging their existing one. It is also one in which the close Quaker network connections were evident. Charles Leatham, also a Quaker, was married to Joseph Pease's daughter Rachel. That the marriage (6 March 1851) pre-dates the formation of the partnership might be indicative of another possible reason for the Pease involvement in promoting new iron businesses. It is that of finding a suitably secure, remunerative career, and one with the appropriate status, for close relatives and fellow Quakers, in this case a son-in-law. Later, after Charles Leatham's death in 1859, his place was taken in the partnership by another member of the extended Pease family, Joseph Beaumont Pease, the son of Joseph Pease's cousin John Beaumont Pease, and the firm became Gilkes, Wilson, Pease and Co.

It is not known whether Leatham or J.B. Pease brought any capital into the firm, but it is likely that the venture had Pease backing. In fact the later history of the firm shows just how close it was to the Pease businesses. On J.B. Pease's death in 1873, Joseph Whitwell Pease, who replaced his father as the head of the Pease business interests, inherited the shares. By the end of the 1870s, when the firm was in financial trouble, he supported the business, injecting over £28,000 between 1879 and 1881. Continued failure to improve performance meant that the firm, renamed Wilson, Pease and Co after Gilkes' retirement, had accumulated a bank overdraft of £151,698 by 1901. This was debited to J.W. Pease's own account at the Pease bank (by this time trading as J. and J.W. Pease and Co).[127]

Thomas Snowden and W.R.I. Hopkins

Snowden, Hopkins and Co, also had links with Pease interests, although it was with the railway rather than through the Quaker or family network. Thomas Snowden was an engine driver and engineer who was employed by the S&DR from sometime in the early 1840s.[128] Similarly, William (Randolph Innes) Hopkins was closely associated with the S&DR, though as an investor rather than an employee. His father, John Castell Hopkins, was a shareholder in and a

[126] Burnett and Hood, *Middlesbrough Directory* (Middlesbrough, 1871), pp. 36-37; 'Statistics of the iron and steel trades', *JISI*, 2 (1871), p. iii; *Middlesbrough Directory*, (Middlesbrough, 1885-6), p.20.
[127] Kirby, '*Men of Business'*, pp. 79-80.
[128] Jeans, *Pioneers*, p. 153; Hadfield thesis, p. 390.

member of the Railway's management committee from 1841 or earlier, and along with other Committee members was one of the promoters of the Wear Valley railway in 1845.[129] William Hopkins had joined the management of the S&DR by 1858.

The Hopkins family was one of some means and William Hopkins was at first apprenticed to an architect (John Middleton). After working at the Great Exhibition in London (1851) his interests turned to engineering and he was sent to Middlesbrough to manage the Worlicks Patent Fuel Works in which his father had invested.[130] He was thus well placed and connected to take advantage of the new iron trade as soon as its potential became apparent. He quickly abandoned the unprofitable fuel works and set up as an ironmaster with Snowden as Snowden, Hopkins and Co. His younger brother James Innes Hopkins and Robert Lloyd were the other partners.[131] This business set up the Tees-side Ironworks (1853) with plant that included puddling furnaces and rolling mills for producing bar and angle iron. It was therefore an early instance of diversification in the local economy as the firm initially concentrated on processing pig iron supplied by other firms on Teesside. A few years later the firm integrated backwards into iron smelting, building two blast furnaces between 1857 and 1859. By 1871 there were four blast furnaces in operation and puddling had expanded to 102 furnaces.[132]

The early history of this company is an illustration not only of how the iron firms were linked into a network of interests and the chain production, but also provides another example of how investors kept their businesses interests in separate, but linked, organisations. Thus, in 1865 when Hopkins and Co (the name changed after Snowden's retirement in 1861) merged with Gilkes, Wilson and Co's Tees Engine Works to form Hopkins, Gilkes and Co, no steps were taken to amalgamate the plants, and nor were there any moves to combine the other companies in which the partners were involved. Gilkes, Wilson, Pease and Co remained a separate entity despite Gilkes and Wilson being partners in the new firm and the potential benefits from coordinating production between the different sites.[133] For his part, Hopkins also retained separate interests in another pig iron producer Lloyd and Co (see below) and also had investments in ironstone mining and collieries in south Durham as well as the railways.[134] Isaac Wilson too maintained a wide range of business and interests in the iron industry as a partner in

[129] Kirby, *Origins*, p. 184 and Appendix 2 and 3 for details of the S&DR Management Committee and promoters of S&DR related railways.
[130] Jeans, *Pioneers*, pp. 149-53.
[131] According to Jeans, J.I. Hopkins and Robert Lloyd joined the partnership on Snowden's retirement rather than at the beginning. Ibid., p. 153.
[132] *JISI*, 2 (1871), pp. iii, viii,
[133] Factors working against integration were that the plants were in different parts of Middlesbrough and J.B. Pease was a partner in one but not the other firm. A major restructuring would need unanimity among partners – almost certainly if they were operated under Quaker influence.
[134] Jeans, *Pioneers*, pp. 153-57. In the 1881 Census Hopkins is described as a coal owner.

several other firms including Lloyds and Co (Linthorpe Ironworks, see below) and Stevenson Jacques (Acklam Ironworks). He was also a director of the North Eastern Railway.[135]

William and Thomas Whitwell

Another firm with close Quaker and family associations with the Peases was W. Whitwell and Co, established in South Stockton (Thornaby) in 1859 by William Whitwell and his younger brother Thomas. Like Isaac Wilson, the Whitwell brothers were from a Quaker family from Kendal and the links with the Peases, Darlington and Teesside in general were numerous and close. William and Thomas's father was the cousin of Joseph Pease, and there is a family link at an earlier generation between the Whitwell family and that of Isaac Wilson as well as other family connections through an uncle and an aunt.[136] The Whitwells were also connected to Teesside as both William and Thomas were born in the area at a time when their father was working in the district.[137]

It is not surprising therefore that in the early 1850s the Whitwell brothers were sent to Darlington to acquire a profession in the newly expanding and prosperous area and where they could be looked after by the Peases.[138] William Whitwell was initially employed in the Peases business in Darlington, and Thomas, who became a gifted engineer, also received his training through Quaker connections. First he was apprenticed to Alfred Kitching, an engineer and locomotive builder in Darlington – also a Quaker, and then continued his training as an engineer at Robert Stephenson and Co's Forth Street Works in Newcastle. Both these firms had close connections with the Peases and the S&DR.[139] Thomas returned to the Cleveland area in 1859 to set up the Thornaby Ironworks in partnership with his brother. Thomlinson notes in his biographical sketch that there were others in the partnership; he is not explicit as to who they were but it is possible that some of the initial financial backing came from the Peases or their associates and also from the Whitwell family textile manufacturing business in Kendal. Once again, Pease and Quaker influence was in evidence in the selection and training of potential ironmasters to run a business that was closely tied into existing business interests.

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[135] Wilson was also mayor of Middlesbrough (1854) the town's second MP after Bolckow (1878), and chairman of the river authority, Tees Conservancy Commission. Obituary of Isaac Wilson, *Northern Echo*, 23 Sept. 1899.

[136] William and Thomas's great grandmother was Dorothy Wilson, the younger sister of John Wilson, Isaac's grandfather. There were also family links between the Whitwells, Isaac Wilson's family and the Backhouses.

[137] William was born in Saltburn (1835) and Thomas in Stockton (1837).

[138] This was not only in terms of helping their future careers. Thomas was looked after by Joseph Pease's family at their home in Darlington (Southend) when the young man contracted scarlet fever. Diary of Joseph Pease (3 April, 9 April 1855).

[139] Cookson, 'Quaker families', pp. 124-5; William Thomlinson, *Thomas Whitwell: A Biographical Sketch* (Middlesbrough, 1878), pp. 7-11.

Theodore Fox and Jeremiah Head

The examples so far are all of early entrants to Cleveland. But even though the Quaker connection became less prominent after the first decade, the working of the network continued to encourage new firms into the district. A feature of new firms in the 1860s was the entry of more specialist and downstream producers. One example is Fox, Head and Co, started by Theodore Fox (b. 1831) and Jeremiah Head (1835-99) in partnership with a local landowner, Charles Newcomen of Kirkleatham Hall. Set up in 1863, this firm built and operated the Newport Rolling Mills to produce semi-finished and finished iron products from 40 puddling furnaces, 14 other furnaces and rolling mills. By 1871 the range of products was fairly extensive, including plates for boilers, ships and bridges, wire billets, puddle bars and non-conducting material for boilers and steam pumps.[140]

Both Fox and Head were from Quaker families, and Fox, from Falmouth, was also closely related to the Peases – two of his sisters were married to Peases.[141] It is not certain what enticed Theodore Fox to Middlesbrough, nor what capital he brought to the firm, but it is likely that he was attracted, or encouraged, to move to a district that offered both opportunities in an industry in which he had experience (the south Wales iron industry) and way in through his family connections. A move to Cleveland when an opening arose was a logical step. This was provided by Jeremiah Head in 1862. Head, who already had connections with Teesside and the Peases, approached Joseph Pease with a scheme for a rolling mill to produce boiler and ship plate at Middlesbrough, a plan that he believed would be 'lucrative' as few ship plates were produced in the area at the time.[142] Through Pease, who had by this time had more or less withdrawn from active business life, Head was put in touch with his son J.W. Pease and finally Fox.[143]

Once again, the workings of the Pease-Quaker networks can be seen, and it is useful to trace back Jeremiah Head's career to illustrate how the connections worked to provide openings and to nurture a career. Head was from an Ipswich Quaker family, and after formal education at Friend's schools in the town, he became an engineering apprentice at Robert Stephenson and Co

[140] Burnett and Hood, *Middlesbrough Directory*, 1871. Fox, Head and Co was a 'co-operative' firm, although in practice it applied only to profit sharing rather than management. Jeans, *Pioneers*, p. 268-81; Fox, Head and Co., *The Co-operative Scheme of Fox, Head & Co.*' (Middlesbrough, 1874).

[141] Mary Fox was married Joseph Pease's son Joseph Whitwell Pease and Helen Fox was married John William Pease, younger brother of J.B. Pease. The connection goes back further – Fox's grandmother was a cousin of Isaac Wilson's father.

[142] Jeans, *Pioneers*, p. 278.

[143] See Jeans, *Pioneers*, pp. 275-6; Kirby, *Men of Business*. The other partner's (Newcomen) involvement was also through Joseph Pease, who introduced Head to Joseph Dodds, a Stockton based solicitor and ironmaster, who introduced Head to Newcomen.

in Newcastle.[144] It is through his work with Stephenson that he was first connected with the Peases: he designed a pair of condensing steam engines for the Priestgate Mills (Darlington) of Henry Pease and Co.[145] Also through the Peases, Head met the Leeds agricultural machinery manufacturer John Fowler (Fowler was married to J.W. Pease's sister Elizabeth) and together they worked at Stephenson's Forth Road plant producing steam ploughs.[146] A proposal to establish a separate Newcastle-based company by Head and Fowler to concentrate on manufacturing agricultural machinery was abandoned following Robert Stephenson's death in 1858, but revived when Hewitson from Leeds agreed to put up the funds.[147] Head subsequently moved to Leeds to manage the new firm in 1859, but by 1860 he appears to have suffered something of a physical, or perhaps mental, breakdown. He took time away from the Leeds business, becoming Fowler's sales representative in Swindon. A year later, following his recovery he returned north, this time to form Fox, Head and Co. Head was also connected to the Stockton engineering firm of Head, Ashby and Co, which later became Head, Wrightson. His brother Charles was one of the founding partners, and Jeremiah himself was married to Rebecca Wrightson, sister of the other main partner, Thomas Wrightson.[148]

Lloyd and Co

If Fox, Head and Co represents a step up the value-added ladder from basic iron production towards the processing end of the industry, then the formation of Lloyd and Co in 1864 and the building of their Linthorpe Ironworks was more of a horizontal expansion. This should not necessarily be seen as a retrogressive step, however; although it did not help with the diversification of the local economy, it did add another six blast furnaces to pig iron producing capacity at a time when raw materials were plentiful and iron prices, and hence demand was buoyant. At least it was at the time when the investment decision was made. It also illustrates how differing combinations of investors in existing firms set up a new one. Thus Lloyd and Co's partners included Robert Lloyd, William Hopkins and Isaac Wilson. All had other interests in the industry, and shortly after Lloyd's formation were to acquire interests in Hopkins, Gilkes and Co (see above). Interestingly, although the Linthorpe plant was adjacent to the Tees-side Ironworks of Hopkins, Gilkes and Co, the two were not merged either as one company or as a

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[144] Jeans *Pioneers*, pp. 268-71.
[145] Henry Pease was Joseph's younger brother. He ran the original family worsted business in Darlington at the Priestgate Mills (Henry Pease and Co). Cookson, 'Quaker families', p. 130.
[146] Another sister, Rachel, was married to Fowler's brother William.
[147] Stephenson wanted to concentrate his firm's production on locomotive and marine engines, but agreed with Joseph Pease to back Head and Fowler's project with £30,000 each. Jeans, *Pioneers*, p. 274-7.
[148] Head married Rebecca Wrightson in 1860 before he established Fox, Head and Co.

single works. However, that is not to say that in practice they may have been operated as a joint plant.[149]

Crewdson, Hardy and Co

A business that combined the features of the diversification of ownership and diversification into specialised, higher value products and which also had Quaker family and finance connections was the Yorkshire Tube Works of Crewdson, Hardy and Co. It was established in 1873, rather later than the others already considered, to specialise in pipes and tubes. It was thus another example of a user plant for the output of the smelting and processing firms.

Originally, the firm was set up as a partnership between seven investors, six of whom had existing interests on Teesside, and three of these had Quaker family connections to other ironmasters already in the district.[150] The leading partner was Edward D. Crewdson, a Quaker from a Kendal banking family that set up Crewdson and Co, known as The Kendal Bank, and which became Wakefield, Crewdson and Co.[151] He was already a partner in Jones, Dunning and Co (Normanby Ironworks), and through the bank was, in 1874, to become the mortgagor of the Loftus Iron Co, and later Skinningrove Iron Co.[152] Crewdson had close religious-cum-family connections with Isaac Wilson, the Whitwells and other Quaker businesses based in Kendal and Darlington. Another Quaker partner was J.F. Wilson, a nephew of Isaac Wilson, who was also involved with several other Cleveland iron firms, most notably Gilkes, Wilson Pease and Co where he became the managing partner. The third Quaker was William Jones, a close family friend of the Peases. He had numerous connections with other aspects of Teesside industry as a partner in a Teesside chemical works and as a former employee of the Darlington Gas and Water Company and the Stockton and Middlesbrough Water Company.[153] The other local investors were William and Thomas Gill, ironmasters who owned another Cleveland firm (Jackson, Gill and Co, Imperial Ironworks), John Livingstone, a plumber and owner of a brass and copper works, Edward Crowe, an engineer at Teesside Ironworks and James Taylor, a Middlesbrough ship owner. The only non-Teesside partner was W.H. Hardy, who at the time of moving to Middlesbrough was manager of a tube and pipe works in Wednesbury. Looking at the terms of the partnership offered to Hardy, it is apparent that the Cleveland investors were keen to import specialist skills from outside the area. Hardy was paid a salary (£300, rising to

[149] The Linthorpe works was bought in 1879 by Edward Williams, the former general manager at Bolckow Vaughan.
[150] Partnership deeds, 1 April 1873, 11 Oct. 1877, 1 Mar. 1882, Teesside Archives, U/S/1785. Telephone interview (19 Jan. 2005) and correspondence with Frances MacLennan, a descendent of W.H. Hardy.
[151] J. Orbell and A. Turton, *British Banking: A Guide to Historical Records* (Aldershot, 2001), pp. 177, 522.
[152] See Chapter 4 for Crewdson's role in the formation of Skinningrove.
[153] W. Jones, *Quaker Campaigns in Peace and War*, (London, 1899), pp. 72-4.

£400 after five years) and he was not required to put up any capital; rather, as the firm made profits, his share was retained within the firm and hence his financial interests were gradually built up. By the 1890s Hardy became the principal shareholder, with ownership of the company vested in family members.

It is clear from these brief outlines that all the firms were either initially supported by, or grew out of the Quaker family and business community. For some, the new industry offered employees and others already connected with local business, the opportunity to start up their own ventures, as in the case of Gilkes, Snowden, Lloyd and Hopkins. For Wilson and the Whitwells it is possible to see their introduction to the iron industry as a way of finding a suitable occupation for talented young men who, as members of a non-conformist sect, had few other outlets for their ambitions. But on another level, setting them up, or at least providing them with the means to set up, in the industry was a way of increasing the demand for the goods and services in which the Peases and Backhouses had already invested heavily; it offered the prospect of extending their business interests by furthering the district's industrial development. As well as becoming a leading member of Middlesbrough's business community, Wilson was deeply embedded in the Quaker network and his business activities played an important part in the first stage of the iron industry's development.[154] He also contributed to later phases through his involvement in extending his businesses and helping to establish other iron enterprises, such as Lloyd and Co.'s Linthorpe works. This works was initially set up to increase the supply of pig iron to the neighbouring and related business of Hopkins, Gilkes and Co (Tees-side Ironworks), a firm that specialised in rolling rails and bar and angle iron for shipbuilding. Rather than buy on the open market, the firm wanted secure supplies from a closely allied supplier. The relationship between the firms, however, was more than one of supplier and customer: three of four partners in the new firm were also partners in Hopkins, Gilkes.

The Whitwells' firm was part of the second phase of the expansion of the district in the late 1850s and early 1860s. In contrast to Wilson, William and Thomas Whitwell concentrated on building up their own business and were far less involved in extending their interests by the creation of other firms. But once again the firm's formation is an example of how use was made of the infrastructure and other resources under the control of the Quaker business community. The investment in blast furnaces at the Thornaby works was an addition to the district's existing smelting capacity, and was thus part of the duplication process in the development of an industrial cluster, rather than part of its diversification. The same is the case

[154] For much of his adult life Isaac Wilson was not a practising Quaker. His funeral, however, was at the Quaker Meeting House in Great Ayton, where he is buried. I am grateful to Richard Waldmeyer of Middlesbrough Quaker Meeting for this point. See also *Northern Echo*, 26 Sept. 1899.

with Lloyd's and both firms enhanced Cleveland's advantage as a specialist pig iron producer. As part of this process of specialisation, Thomas Whitwell also made an important contribution to the advances in blast furnace design and practice, most notably with his development of the Whitwell hot blast stove. These stoves were produced at the Thornaby plant and sold to other smelting firms.[155] As with many other firms, Whitwell's facilities later expanded beyond pig iron production to rolling mills, forges and bar iron, thus also adding to the diversification process.

Crewdson, Hardy presents a rather different case. As a producer of pipes it was a much more specialist business and contributed to the downstream expansion and diversification of the cluster, adding capacity to the user end of iron production chain. At the time of its formation there was only one other pipe and tube business in Cleveland (Cochrane, Grove).[156] Crewdson Hardy was also a supplier of components to blast furnace and iron processing firms – a speciality was the production of tuyérè coils for furnaces – and thus added to the development of specialist industry suppliers.[157] The involvement of existing investors and ironmasters in the venture indicates a readiness to exploit the opportunities of a growing market, in this case the expansion of gas and water distribution and sewage systems in Victorian cities and the growing demand inside the cluster for components. It also shows a high degree of willingness among investors from different firms to cooperate in the expansion of the industry. Establishing a new firm would not only make use of existing resources, but would contribute to extending the activities and interests of the industry into new areas. The business network in this final case was rather wider than in the other two, encompassing not just the existing Quaker business community, but also extending to other ironmasters and entrepreneurs in the district, and in the case of the recruitment of William Hardy, into a national network of professional iron works managers and engineers.

While the main focus of these examples has been Quaker-connected firms, there were many others that entered the Cleveland industry that had no direct link to the Pease or Backhouse businesses, at least before setting up on Teesside. Data on entrepreneurs and investors' origins shows that there were three other routes through which firms were drawn to the district. First, there were the existing iron firms in the north east and others connected with the coal industry, mainly from Tyneside or County Durham. Amongst these were Bell Brothers and the Carlton Iron Company. Second, there were those ironmasters, ironworks managers and engineers who

[155] Harrison, 'Production of pig iron', pp. 97-9; Allen, 'Collective invention', p. 6.
[156] Cochrane, Grove (est. 1861) was an offshoot of the much larger pig iron firm Cochrane and Co, an early entrant to Cleveland.
[157] *Kelly's Directory of Middlesbrough 1887*, (Middlesbrough, 1887), p. 2.

were drawn from a greater distance. Among these existing businesses and entrepreneurs, who were already in the same or closely related sector, were Bernhard Samuelson, an engineer who ran an agricultural machinery manufacturers in Banbury and Charles Cochrane, from a well-established iron firm in Dudley. In this category could be included the Swedish engineer John Gjers. At first working for Cochrane's, he later designed blast furnaces for other firms before setting up his own plant, the Ayresome Ironworks (Gjers, Mills and Co) in 1870.[158] Third, as the industry developed, there was a growing business community in Cleveland, the members of which encouraged the entry of new firms. Examples include Ralph Ward Jackson (see below) and Joseph Dodds, a Stockton solicitor and MP, both of whom played leading roles. In the mid-1870s Dodds was connected with at least five businesses.[159]

<u>Bell Brothers</u>

Bell Brothers was one of the earliest entrants to Cleveland, building its first blast three furnaces on Teesside in 1853. As the firm's partners were deeply embedded in the industrial and business community in north-east England and already part of the region's iron and chemical industries, they provide a useful example of the way in which regional connections also played a part in Cleveland's development. The firm is significant for two other reasons. First, it had experience of smelting Cleveland ore in its furnaces prior to 1850 and was thus familiar with the ore's properties. Moreover, the Bells, notably John Bell, a geologist, were instrumental in the search for commercially viable ore deposits in Cleveland.[160] Second, Bell Brothers entry to Cleveland was linked to a local rival to the Pease-Backhouse-S&DR network – Ralph Ward Jackson.

The Bell Brothers firm was formed as a partnership between Isaac Lowthian (1816-1904), Thomas and John Bell in 1844 to take over the management and eventually the ownership of the Walker Ironworks. This works was set up in 1827 by Losh, Wilson and Bell, the main partner of which was William Losh, a notable Newcastle merchant and businessman who also owned a chemical plant (Walker Alkali Company).[161] Losh had taken on one of his employees, Thomas Bell, the father of the Bell brothers, as a partner (1808). Thomas Bell initially managed the works, which rolled bar iron and rails to meet the rising local demand for manufactured iron, especially from collieries for iron rails. It had a capacity of 80 to 100 tons per week, which was

[158] J.K. Harrison, *John Gjers: Ironmaster, Ayresome Works, Middlesbrough* (Aalst-Waalre, 1982).
[159] Jeans, *Pioneers*, pp. 94-116.
[160] Joseph Bewick, who had surveyed Yorkshire coast for Benjamin Thompson (Birtley Ironworks, Tyneside) in the late 1820s had a high regard for John Bell: 'It was no doubt owing to the examination and surveys which…Mr John Bell…caused to make in different localities, that the extent and position of the ironstone beds became known to the public' Jeans, *Pioneers*, p. 169; Marley, 'Cleveland ironstone', pp. 172-4.
[161] Bell, 'Family history', pp. 28-3; Marley, 'Cleveland ironstone', pp. 171-4.

sizeable plant for the time, and drew its supplies from scrap iron and Welsh bars that were cut up and re-rolled. Inputs were supplemented by pig iron from the near-by Lemington blast furnaces.[162]

Lowthian Bell started work at Walker 'sometime before 1840' and soon became the works manager.[163] In was then that Bell began to experiment with Cleveland ore, building a furnace in 1842 to produce forge pig iron from a mix of mill and furnace cinders (high in iron content) and ironstone imported up the coast from the Whitby Stone Company. This is an early example of Bell's ingenuity in finding cost cutting ways of producing iron and may have been a direct response to the limited supplies of local ore and the rising pig iron prices. A second furnace was erected in 1844. The importance of these two furnaces lies not just in their use of Cleveland ironstone, as other firms were doing the same, but also from two other factors. Firstly, they were the first blast furnaces to be specifically designed to smelt the Cleveland ore. Secondly, it indicates that the Bells, and Lowthian Bell in particular, had a good knowledge of the existence and properties of the ironstone well before the 1850 main seam discovery and their entry to Teesside. Their knowledge would have been reinforced by the fact that in 1844 the Bells, on the founding of their firm, also took on the lease of the Wylam Ironworks, where supplies Cleveland ore had been, and continued to be used.

There was, however, considerable concern about the quality of the ironstone supplied from Whitby. Using data from the Birtley Ironworks, Lowthian Bell maintained that with ironstone costs of 30 to 34 shillings per ton of pig, iron was cheaper on the Glasgow market than it cost to produce in five out of the 11 years between 1840 and 1850.[164] Moreover, the average Glasgow price over the whole period was within 6d of the Birtley cost. To remain profitable therefore an ironworks needed a far cheaper source for their iron inputs, either from lower extraction and transport costs or from a much higher iron yield from the ore. The effect on the Tyneside ironmasters at Birtley, Walker, Wylam and Lemington was that they brought in blackband ore from west Scotland and also started to import the iron-rich hematite from Cumberland.[165] Bell Brothers even investigated the possibility of acquiring their own blackband royalties in Scotland. John Bell went to survey Fifeshire in the hope that the East Coast coalfield would

[162] Bell, 'Manufacture of iron', pp. 123-4, 150; Bell, 'Family history', p. 21.
[163] Lowthian Bell was the prime motivator and decision taker behind the firm. Unusually for the time, he had received a scientific education at Edinburgh University and on the Continent, in Denmark, Germany and France – the Sorbonne and in Marseilles. By the 1840s Bell had made a name for himself as an industrialist on Tyneside and metallurgical chemist. Bell, 'Family history', p. 18.
[164] Bell, 'Manufacture of iron', p. 116 ff. In his calculations Bell assumes that the iron firm supplies coal from its own collieries.
[165] The Derwent Iron Company, later the Consett Iron Company, had also resorted to hematite after the exhaustion of the local ores. I.L. Bell 'Manufacture of iron', p. 122; K. Warren, *Consett Iron 1840 to 1980: A Study in Industrial Location* (Oxford, 1990), p. 38.

provide ores similar to those found in the coal measures of the west. Needless to say his trip was unsuccessful.[166]

At this time, the mid-1840s, Cleveland did not provide the solution to the shortage of iron ore in the north east. However, it is clear that Bell Brothers was ready to take advantage of any significant improvement in the supply conditions as soon as they occurred, which they were able to do in 1850 with the discovery of the main seam. Bell Brothers quickly acquired a lease for mining ironstone on the Normanby estate, to the south east of Middlesbrough, from the royalty owner, George Ward Jackson, and more or less simultaneously, as a site for the blast furnace plant, bought 30 acres of waste ground, much of it marsh, from the Hartlepool West Dock and Railway Company on the north bank of the Tees at Port Clarence. This was directly opposite Middlesbrough.[167]

The prime mover behind the railway company was Ralph Ward Jackson, the younger brother of the owner of the Normanby royalty, and Bell Brothers' association with Ralph Ward Jackson was significant.[168] It enabled the firm immediately to plug into an established railway network on the north side of the Tees that linked up Port Clarence with the south Durham coalfield and Weardale limestone quarries. As the main architect of the system Ward Jackson must have seen the potential for a symbiotic relationship between the Bell and Ward Jackson interests both to the north of the Tees – the railway – and the south side – the ironstone mines at Normanby. There is no evidence of direct financial backing by Ward Jackson for the Port Clarence works, but there is a suggestion that he was able to induce the Bells to locate furnaces north of the river, unlike most other new works that were on the south bank, by offering the lease of the Normanby ironstone as a *quid pro quo*. Given the growing interest in, and rising cost of, leases at the time (1851-52), it would have been a good bargaining chip. Of particular benefit to Ward Jackson was the additional coal traffic the ironworks would bring to the Clarence section of his railway system. The line, which had been built in the early 1830s (opened in 1833), ran from collieries at Ferryhill, Coxhoe and Byers Green to Port Clarence. It had originally been promoted by Stockton businessmen to challenge the dominance of the S&DR and Middlesbrough in the area's coal trade, especially after the building of the Middlesbrough extension. Navigation problems on the Tees led to the construction of the Stockton and Hartlepool Railway to link the Clarence Railway with Hartlepool where there were better deep

[166] Obituary of John Bell, *JISI*, 9 (1878).
[167] In conjunction with a chemical manufacturer, Hugh Lee Pattinson, who was Lowthian Bells' partner in the Washington Chemical Company and also father-in-law, new blast furnace works using Cleveland ironstone were also established on the south bank of the Tyne at Felling (Pattinson-Bell partnership) and at Washington (a Washington Chemical Company - Bell Brothers venture). Marley, 'Cleveland ironstone', p. 211
[168] G.A. North, *Economic Heritage*, pp. 44-7; E. Waggott, *Jackson's Town* (Hartlepool, 1980), pp. 2-5.

water harbour facilities. It was promoted initially by Christopher Tennent and after his death in 1839 by Ralph Ward Jackson. Although Hartlepool proved to be a much more satisfactory port than Middlesbrough, by the early 1850s Ward Jackson's West Hartlepool Harbour and Railway Company, formed from the merger of the Clarence and Stockton and Hartlepool Railways, faced intense competition for the coal trade from two rivals. In the south there was the old adversary, the S&DR, with its port facilities at Middlesbrough. To the north there was a newer rival in the form of the Hartlepool Dock and Harbour Company, which also owned and controlled the main harbour facilities (Victoria Dock) at Hartlepool that were used by Ward Jackson's company. Ward Jackson responded by building a new harbour at West Hartlepool. In this intensely competitive environment, the siting of the Bell Brothers' plant on the north bank of the Tees made good use of the increasingly under-utilised section of the railway from Billingham to Port Clarence, generating additional revenues from the carriage of minerals and finished products.

The mutuality of interests between Bell and Ward Jackson continued into the 1860s with the promotion and eventual construction of the Cleveland Railway. This line linked the ironstone mines at Skelton (1861) and ultimately Skinningrove (1865) with a jetty at Normanby on the south bank of the Tees. For Ward Jackson it meant that he was able to break into the increasingly profitable ironstone transport business on the south side of the river that was dominated by the S&DR. For Bell Brothers it enabled the firm to open new ironstone mines in the Cleveland Hills to the south-east of the original mines. As the demand for ore from the Clarence furnaces increased – by 1858 there were four operating – the new mines provided an additional source of ironstone under the control of the company. The railway also offered a cheaper and more efficient transport system as the ironstone was brought to the Normanby Jetty directly opposite the ironworks and sent across the river in barges. Not only did this avoid shipping the ore up the coast ore by the circuitous rail route inland, it also meant that Bells did not have pay dues to the river authority (Tees Conservancy Commission), as these were levied on movements along but not across the river. The line could also help drive down carriage costs since it challenged the S&DR monopoly.[169] For Bell Brothers the outcome was highly satisfactory, even if for Ward Jackson, whose company collapsed in 1865 and was taken over by the NER, the result was less than happy.[170]

[169] The line's construction met with considerable opposition from the S&DR and the Tees Conservancy Commission. Ward Jackson's original proposal for a swing bridge across the Tees to join the two parts of his railway system was thwarted by numerous objections, led by Joseph Pease, who as MP for Darlington, directly opposed Ward Jackson, an MP for Hartlepool. Kirby, *Men of Business*, pp. 40-1; North, *Economic Heritage*, pp. 44-7.

[170] Lowthian Bell later became a director of the North Eastern Railway.

3.4 Networks and Performance

The preponderance of Quaker-linked firms in the early stages of Cleveland's iron industry provides an opportunity to test whether business networks do produce a beneficial effect on an industry's growth. It is not possible, however, to measure the network contribution directly as there is no way of determining the nature or form Cleveland's development would have taken in their absence. The approach used in this study was to assess network contribution indirectly by comparing the business performance of Quaker-connected and non-Quaker-connected firms. The basic hypothesis is that firms connected to the network perform better than those that were not connected, and may be seen as a partial test of the model proposed in Figure 2.3 (p.36).

The underlying logic can be briefly stated: in a world of imperfect information, the selection of business partners or, for a bank or other investors, the choice of business ventures and borrowers to finance poses substantial difficulties. In essence it is an asymmetric information problem; that it is impossible distinguishing between a 'good' and a 'bad' borrower or partner without facing significant, if not insuperable, transactions costs. The selection of members of a network as appropriate business partners reduces these costs and consequently makes the identification of those most likely to be successful entrepreneurs easier. There are several possible reasons for this. One is that there is likely to be a greater degree of trust within a network, greater knowledge of members' attributes, or it may be that there are more effective constraints on members. It is not only easier to monitor, observe and discipline those members who transgress unwritten rules, the effect of the loss of status if expectations are not met acts as a disciplining mechanism. In short there are two potential effects. One is that the quality of entrepreneurship is higher, and the second that resources, especially financial, are more forthcoming, thus providing conditions more conducive to growth and development of an enterprise.

Data limitations meant that the usual measures of performance – profits, turnover, output, employment – were not available. For this reason survival is used as a proxy, with the underlying assumption that the longer a firm survives, the greater the contribution it makes to growth and development. Defining survival as a binary variable, where 1 indicates survival and 0 failure, it is possible to estimate a logistical regression model that relates the log odds of the probability of survival to the characteristics of firms:

$$\text{Ln} \frac{S_i}{1 - S_i} = b_0 + b_1X_{i1} + b_2X_{i2} + \ldots + b_nX_{in} \quad \text{(A1)}$$

S_i is the probability of survival of firm i, the Xs are the independent variables representing the characteristics of the firm, and the coefficients b_1 to b_n which relate a firm's characteristics to the probability of survival.[171]

To test the hypothesis that being a member of the Quaker network contributed to the success of a firm, the independent variables include a measure of each firm's connection with the network (the variable 'Quaker'). Network membership is defined as where at least one owner-investor or partner in the firm was a Quaker, from a Quaker family or closely related to one, either by descent or marriage.

The likelihood of the survival was not solely determined by membership of the Quaker network, however; it was the outcome of many other influences. These are captured in the other variables in the model, and summarised in Table 3.9. Previous experience in the iron industry can be expected to have a significant positive influence on success, perhaps as a result of a knowledge of the market environment or the possession of technical expertise in production for example. This is captured in the variable 'Experience'. Experience is defined as a situation in which one partner in a firm had experience in the same sector as the sector in which the Cleveland firm operated. For example, if an investor in a Cleveland pig iron producing firm had previous experience in iron smelting, this is defined as previous experience, but if the investor had a background in engineering or colliery management, then this is not counted as experience.

The date the firm was established is included to test for any systematic beneficial effects that may arise from being an early entrant into the industry. It may be, for instance, that firms set up in the 1850s and early 1860s benefited from first mover advantages such as developing a reputation in the market, establishing links in the industry or by gaining preferential access to resources – buying land cheaply or acquiring ironstone royalties at lower cost before the inward rush of firms as expansion took off.

[171] D.W. Hosmer and S. Lemeshow, *Applied Logistic Regression* (New York, 2000); M.J. Norusis, *SPSS for Windows Advanced Statistics Release 6.0* (Chicago, 1993), pp. 173-84.

Table 3.9: Model Variables

Variable		**Measure**	**Expected effect**
Dependent variable			
Survival	Firm survival measured as 5, 10 or 15 years or after 1880.	Binary	
Independent variables			
Quaker	At least one partner was a member of the Quaker network.	Binary	+
Experience	Previous experience in the industry sector before establishing a firm in Cleveland.	Binary	+
Date	Date established in Cleveland.	Continuous	-
Other	At least one investor in the firm had interests in another Cleveland firm in the iron and related sector.	Binary	+
Size	Large firms are distinguished from all others according to the number of blast furnaces, puddling furnaces, rolling mills.	Binary	+
Sector dummies		All binary	
Wrought	Specialists in the wrought or malleable iron sector, or in rolling.		-
Engineering	Specialist in the engineering sector, e.g. steam engines, pipes and tubes, blast furnace plant, railway engineering products.		+
Diversified	Firms operating in more than one sector of the iron industry, e.g. pig iron and wrought iron.		+
Miscellaneous			?
Base group – pig iron	Other firms in related sectors, e.g. non-ferrous metal, shipbuilding.		

It might also be expected that a firm whose investors had interests in other firms in the Cleveland area also improved the chances of survival (variable ‘Other’). While this is not necessarily an unambiguous benefit, having interests in and control over other businesses may be a way of linking firms at different stages of the production process, thus reducing (transactions) costs and making supplies or sales more secure and predictable. Spreading risks and the potential for cross subsidising operations is another possible advantage. As indicated above, some investors did establish or have interests in firms at different stages of the production process. There is also the possibility that a single investor with interests in different firms could add to their vulnerability: problems with one firm, which places the investor in financial difficulty, may be transmitted to his other investments.

Firm size (variable 'Size') is expected to reduce the risk of failure. This may be because a large business has more resources on which to draw, either to invest in profitable ventures or to sustain itself though difficult periods, and because it has a stronger market position. The latter may put a firm in a position to negotiate better terms with suppliers, with banks or with customers. Again, however, the effect of size is not unambiguous since these firms may be less adaptable to sudden market shifts. Nevertheless, hypothesis here is that size has a positive impact on the probability of survival. The size variable is measured very simply by distinguishing between large firms and the rest, with a large firm defined in terms of the production plant owned and operated. Thus a firm with six or more blast furnaces, 100 or more puddling furnaces or operating two or more plants is classified as a large firm.[172]

Finally, dummy variables are included in order to pick up sector specific changes within the iron and closely allied industries. One of the most important is the decline in the demand for wrought iron products after 1873, especially iron rails as railway companies switched to steel. The dummy variables distinguish between: wrought (or malleable) iron firms; engineering firms; diversified firms operating in more than one sector; and a miscellaneous category that includes non-ferrous metals and shipbuilding. The expected effects of these sector dummies on survival are measured in relation to specialist pig iron producers (the base). It is anticipated that diversified and engineering firms will have a greater probability of survival because of a reduced vulnerability to market swings over the economic cycle compared to that faced by pig iron producers. Moreover, these sectors, especially engineering, may have had higher long-run growth prospects as the economy developed and the demand for more technical, higher value added products rose. On the other hand, firms in the wrought iron sector are expected to have a reduced chance of survival given their exposure to the major structural shifts in demand. The miscellaneous variable has no anticipated sign.

The full model can be summarised as:

$$\text{Ln}\ \frac{S_i}{1 - S_i} = b_0 + b_1\text{Quaker} + b_2\text{Experience} + b_3\text{Date} + b_4\text{Other} + b_5\text{Size} + b_6\text{Wrought} + b_7\text{Engineering} + b_8\text{Diversified} + b_9\text{Miscellaneous} \quad \text{(A2)}$$

[172] As with other variables, data limitations, especially a lack of reliable data on capital employed, meant that a simple definition of size was used.

<u>Data</u>

The model was estimated using observations on 103 firms.[173] Data problems meant that not all of the 130 Cleveland firms could be included and to increase the sample size ten observations from Darlington-based firms were added. This can be justified by geographical proximity to the Cleveland industry and on the grounds that they were established and grew (or failed) at the same time as the iron industry developed in Cleveland. They were also similar types of firm, depended on the same resources and markets and also connected to the same networks.

Before examining the results it is useful to consider some of the data problems and thus the inaccuracies that may distort the estimates of the model. First there is the difficulty of identifying which firms survived and which did not. Failure is straightforward to identify for firms that closed and were liquidated. For others, however, a name or ownership change, or even the replacement of some owners and investors by others, does not necessarily signify failure. It may be that a new partner was added or ownership transferred, with the business sold as a going concern as the original owners retired. On the other hand ownership and name changes may follow financial difficulties from which the firm was rescued by a new owner, floated as a limited company, or even liquidated, restructured and reopened. In these cases the original firm is defined as a failed business, but because it has not always been possible to trace a firm's precise history, there is the possibility of misclassification.

Inaccuracies are also likely in the some of the other variables, especially in identifying those firms in which there were Quaker-related investors or where the partners were also partners in other Cleveland iron businesses. In many cases the partnership deeds are not available and reliance has been placed on secondary data such as directories, press reports and previously published sources. The 'Quaker' variable is defined as a binary variable indicating the presence or absence of an investor with Quaker links. A scaled variable measuring the strength of linkage to the network would have enabled an assessment of the association between the probability of survival and the degree of connection to the network. The measurement of firm size also presented problems as data limitations prevented the use of the usual measures of turnover, capital employed or numbers employed. These would have provided a continuous scale, enabling a finer distinction to be made between small, medium and large firms. A more fundamental problem with assessing firm size is finding a single measure that was appropriate for the thirty year period of the study. Over that time firms' sizes changed and consequently, the distinction between large and other firms that has been used should be regarded as only a

[173] See Appendix 2.

very crude approximation. Finally, it is likely that there are some influences on the chances of survival that have been excluded from the model. These are discussed in more detail below.

Results

The full model (equation A2 above) performed poorly, with few of the coefficients statistically significant. There was evidence of a high degree of correlation between some of the explanatory variables and for the number of observations, there are too many regressors. Elimination of the least significant and most highly correlated variables and the estimation of a reduced version of the model, however, yielded statistically significant and economically meaningful results. A selection of these is shown in Table 3.10. All the reported results refer to survival for a period of ten years. Results for survival for five years, fifteen years and after 1880 are generally insignificant, and some possible reasons are discussed below.

All specifications show that being a member of the Quaker network had marked and statistically significant effects, increasing the odds of survival; this was also the case for Quaker-financed and for larger firms. Having interests in other firms reduced survival odds. Taking equation 4 as an example, other things equal, the odds of survival were five times higher for Quaker firms, four times higher for Quaker-financed firms, five times higher for large businesses, and 70 per cent greater for firms whose investors did not have interests in other businesses (Table 3.11). The relatively poor statistical performance of the model, however, means that the results should be seen as suggestive rather than as precise measures of the effect of network membership on survival. Nevertheless, on the assumption that longer-lived firms make a greater contribution growth, there is sufficient consistency to conclude that the results are indicative of the importance of the Quaker network.

In drawing these conclusions, however, a number of important provisos have to be borne in mind. One is that firms may survive because they were able to draw on the resources of the network in order to keep afloat rather than because the network gave rise to the selection of better entrepreneurs or encouraged the development of better businesses. In other words network-related businesses, insulated from the demands of the market, were able to survive but would under other circumstances, and without the support of the network, collapse. The model is unable to distinguish between these two possibilities and there is some evidence that unsound firms may have remained in business longer than market pressures would normally allow. Statistically, the failure to find a longer-run relationship (i.e. beyond 10 years) may reflect this. Anecdotally, one example is the repeated support given to Gilkes, Wilson, Pease and Co (see above). Another possible reason for the poor performance of model for survival beyond 10 years, or after 1880, is that by the 1870s there were major changes in the iron sector that affected the viability of all firms in Cleveland. Especially important were the technological advances in steelmaking and the decline in the demand for wrought iron.

Table 3.10: Coefficients for Logistical Regression Models

Dependent variable: 10 year survival. Sample size:103					
Independent variables	(1)	(2)	(3)	(4)	(5)
Quaker	1.816**	1.551**	1.697**	1.619**	2.129***
Quaker Finance	1.839**	1.411*	1.401*	1.430*	
Other interests	-1.313*	-1.157**	-1.287**	-1.25**	-1.011*
Size	2.388**	1.348	1.647*	1.630*	1.44*
Experience	-0.020		0.317		
Time+	-0.004				
Wrought	0.092	-0.600			
Diversified	-1.344				
Engineering	20.709				
Constant	-24.217***	-3.526***	-4.208***	-4.096***	-3.347***
-2 LL	84.905	99.316	100.394	100.683	104.743
R^2 Nagelkerke	0.407	0.249	0.360	0.232	0.183
H-L Chi^2 (df/sig)	8.366 (8/0.399)	3.032 (7/0.882)	5.197 (7/0.636)	1.214 (5/0.944)	2.236 4/0.692

(p values:*** p<0.01; ** p<0.05; * p<0.10. + Time = Date firm established - 1840)

Table 3.11: Survival Odds (Model 4)

	Odds
Quaker	5.050
Quaker Finance	4.179
Other interests	0.286
Size (large firm)	5.105

(Note: odds = e^b, where b is the coefficient from Table 3.10)

As regards the inability of the model to predict survival over the shorter period of five years, one explanation is that the industry was expanding at an increasing rate under buoyant market conditions. The Quaker network may have drawn firms in to the industry, but this did not necessarily increase the chances of survival above that of others. In fact, up to 1874 most firms survived, thus there were too few observations that were failures to derive meaningful results. Similarly, the fact that most firms had at least one investor with experience in the sector (Table 3.8) also meant that there were too few observations for the effects of the 'Experience' variable to be detected.

3.5 Conclusions

The close links between the investors and firms involved in the development of the Cleveland iron and related industries suggest that whether or not the geographical factors made the growth of an iron industry inevitable, the actual process owed much to the network of investors. There were effectively four interconnected business networks relevant to the development of Cleveland.

One was of existing iron firms on the Tyne near Newcastle and in County Durham. They had developed some expertise in blast furnace practice and in the production of puddled and rolled iron and therefore provided a pool of north east based ironmasters on which the new Cleveland industry could draw once its potential had been realised. There was also a well-developed mining industry in the region, based primarily on coal, but also iron ore. As with iron production, mining skills and capital could be quickly transferred into Cleveland and thus bring about the rapid exploitation of the newly discovered ironstone. This network was not just important once the main Cleveland ironstone deposit had been discovered; it was instrumental in bringing about its discovery. Secondly, there appears to have been something of a national network of ironmasters some of whom quickly responded to the 1850 discovery. Businesses were set up in Middlesbrough by ironmasters from Staffordshire (Cochrane) and Oxfordshire (Samuelson), and technical expertise drawn from South Wales and Sweden. For example, Bolckow and Vaughan appointed works managers from Wales, and John Gjers, the Swedish engineer, was first employed by Cochrane's before establishing his own firm. Thirdly, there was a growing business community on Teesside. This was closely linked to the wider business community, and not just the Quaker one, in the already established towns of Stockton and Darlington in the lower Tees valley, and Hartlepool. Ward Jackson and Joseph Dodds are two examples.

Finally, the one on which most emphasis has been placed in this chapter was the Quaker business and banking network centred on Darlington. This included Backhouse's bank and, most importantly, the Pease family, with their interests in the S&DR, the Middlesbrough estate and port, collieries and the coal trade, ironstone mines. The network, based on membership of the same religious denomination and, what often amounted to the same, extended family connections also went wider than Darlington and Cleveland to include financial interests from bankers based elsewhere in England, including London and Kendal. Some evidence was presented to show that being part of this Quaker network improved the chances of survival in the Cleveland iron industry, either as a result of the more efficient selection of owner-investors, or because the network was able to support firms in difficulty for longer. Both interpretations are consistent with the network making a contribution to growth. The results, however, are subject to numerous qualifications and should be regarded as tentative.

Nonetheless, the importance of networks to the development of Cleveland's iron industry should not be underestimated. The networks provided a conduit for information which enabled the marshalling of resources that were essential to the growth of a previously unexploited region. Moreover, they contributed to the clustering process in the district, increasing both the scale and diversity of production. But the process was more than sending out information in a neutral way. The networks acted as routes through which incentives to set up new firms and extend existing ones could be channelled. More precisely there were powerful incentives for the owners of the infrastructure (railways, port, coal and ironstone mines) and the early entrants to the industry to encourage the setting up of iron processing and using firms and other ancillary and supporting business. This development of downstream activities provided a market for the basic iron products, and the supporting activities and upstream industries increased the efficiency and reduced external dependence of the district. From point of view of new investors and the firms, the incentives were not just that this was a new source of an important raw material. Cleveland offered opportunities to develop new activities out of the existing ones; as the cluster of firms expanded and the infrastructure improved, then so too did the profitable opportunities, creating incentives for existing business owners to make further investments in railways, port facilities and improving river navigation. This this was not always done cooperatively; as the case of Ward Jackson and the Cleveland railway demonstrates, there was rivalry between competing networks.

Important as physical assets are to a sector such as iron, the availability of other key inputs such as finance, technical expertise and marketing are crucial. They make up the institutional infrastructure of an industrial district. Although not discussed in this chapter, the institutions that developed in conjunction with the industry added to the business networks, extending their scope, and intensified the ties and interdependencies between the firms. The effect, at least in the early development of the cluster was to improve firms' efficiency, by helping coordination in the industry, the dissemination of technical advances and in some cases by facilitating further entry and thus expansion of the cluster. Particularly relevant to this aspect of the district's growth were, among others, the employer's organisation, the Cleveland Iron Masters Association (1866), the Cleveland Scientific Institution, the Cleveland Institution of Engineers (1864) and the creation of a secondary market in iron.[174] The last is marked by the substantial growth in the number of iron merchants based mainly in Middlesbrough and the building in 1868 of the Middlesbrough Exchange with a weekly iron market. A measure of its importance is shown by the twenty-four iron merchant firms operating in Middlesbrough by 1871 and that between 1869 and 1880 the membership of the Exchange rose from 166 to 591; it included merchants, ironmasters and other representatives of iron firms.[175]

Together these factors created a more profitable and diversified industry that in turn drew in new investors, firms and technical experts, leading to cumulative growth. The evidence therefore lends support to the influence of networks on the process by which of an industrial cluster develops as indicated in Figure 2.3 (p. 36). Cleveland's expansion, however, was development within a fairly narrow, specialist range of iron-based activities. This resulted in considerable vulnerability to shifts in market and technological conditions, and ultimately questions over the district's sustainability by late 1870s.

[174] Yasumoto, *Victorian Ironopolis*, pp. 41-51.
[175] Burdett and Hood, *Middlesbrough Directory 1871*, pp. 57-8; The Middlesbrough Exchange Company Limited, Register of Shareholders, Members and Holdings, Teesside Archives, BS.MEX/2/1/6.

Part 2: Transition

Chapter 4: Iron and Steel in Transition – An Outline of the Issues

4.1 Introduction

In some respects the 1870s can be seen as a watershed for the Cleveland iron and steel industry, or what more accurately at that time was almost exclusively an iron industry. The decade began with the continued expansion of output at an increasing rate and an explosion of new firms in the iron processing sector. By the end, pig iron production was barely above its mid-decade level and a wave of bankruptcies hit the industry as it was caught between a cyclical downturn in the economy and a shift in demand away from iron towards steel. This challenge from steel threatened the very basis of the prosperity of the iron cluster. It could have resulted in a rapid transition from the expansion stage of the life cycle to the decline with barely a pause for the industry or the district to mature. Indeed, some writers have seen the zenith of the industry, if not the district as falling 'in the latter half of the 1860s and 1870s.'[176]

At round the same time, major changes were taking place in the wider business environment and in the Victorian economy and society. Four principal ones are especially relevant to Cleveland's iron and steel industry. Firstly, there were major developments in the nature and ownership of business organisations following the reform of corporate regulations that made joint stock company status with limited liability freely availability. Secondly, there were the related changes in the financial markets, including both the capital markets and the banking sector that affected the ability and the way in which firms could raise finance. Thirdly, there were changes, or at least supposed changes, in attitudes towards business and enterprise as the ownership of established firms passed to the second or later generations. The new wealthy industrial-aristocrats, it is argued, sought other outlets for their energies and developed interests away from the original source of their wealth – in politics, or managing their estates and the like.[177] Fourthly, there was growing international competition, especially from the US and

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[176] Yasumoto, *Victorian Ironopolis,* p. 191.
[177] See M.J. Wiener, *English Culture and the Decline of the Industrial Spirit* (Harmonsworth, 1985); C. Wilson, 'Economy and society in late Victorian Britain', *EcHR*, 8 (1965), pp. 197-8; T. Nicholas, 'Clogs to clogs in three generations? Explaining entrepreneurial performance in Britain since 1850', *JEH*, 52, (1999); T. Nicholas, 'Businessmen and land ownership in the late nineteenth century revisited', *EHR*, 53 (2000), pp. 777-82; T. Nicholas, 'Wealth making in the nineteenth century: the Rubenstein hypothesis revisited', *BH*, 42 (2000), pp. 155-68; T. Nicholas, 'Enterprise and management', in R. Floud and P. Johnson, *The Cambridge Economic History of Modern Britain, Volume II: Economic Maturity, 1860-1939 (Cambridge, 2004),* pp. 227-51.

Germany. Britain's international leadership in a number of sectors, including iron and steel, was challenged and then lost in both technological and market terms as rival producers adopted newer technologies more readily and pursued more strategically orientated approaches to business.

All these affected Cleveland's iron and steel industry. The aim of the second part of this thesis is to examine how firms in the district responded to the changes and the effects on the firms' and the industry's performance. Specifically, three aspects will be covered. Chapter 5 investigates the impact of the changes in corporate legislation on business organisation and finance. This is followed in Chapter 6 by an examination of the response to the shifts in technology, concentrating especially on the development of the basic open hearth steel process. In Chapter 7 several aspects are drawn together in a case study that explores the strategy of Dorman Long. This firm was one of the new entrants into the industry in the 1870s that by 1914 had become one of the largest businesses on Teesside and in Britain.

Together these chapters demonstrate that the adjustment of Cleveland's iron and steel firms brought about a revival in the growth of the industry cluster. After all, iron and steel making, and the Teesside economy as a whole, did not collapse; a number of companies made the transformation to steel production successfully, and with development of other related industries, the district maintained its position as a major centre of heavy manufacturing. It is suggested that life cycles of industries and industrial districts do not necessarily fit the simple model of maturity followed by decline, with decline necessarily built into past conditions. Whether the life cycle is extended and a district renewed depends on how businesses respond to shifts in the external factors, especially the ways in which the opportunities open to them are exploited. In Cleveland, out of the integrated and interrelated network of iron and steel firms, at times interdependent and at others competing, came the development of closely related engineering and shipbuilding industries. Ultimately, the district produced a new growth centre based on chemicals, which, along with the other manufacturing activities in the area, also developed from the iron and steel sector.

Naturally, the external changes noted in the second paragraph above did not just affect Cleveland. The whole of the British iron and steel industry faced similar pressures and challenges beginning in the mid-1870s and running through to the First World War and beyond. There has been widespread and long-standing interest in the industry's difficulties and it was an issue that attracted much contemporary comment. Iron and steel was one of the four industries selected for special investigation by the 1886 *Royal Commission into the Depression of Trade and Industry*; later a Board of Trade Committee in 1916 reviewed the industry's past difficulties and its prospects for the post-war period.[178] And ever since Duncan Burn's damning indictment of the industry originally published in 1940, there has been a steady stream of research and analysis into performance both at the sector level and of individual firms.[179] For many, the failure of the industry to respond effectively contributed to the slippage in Britain's dominance in iron and steel. It is also taken as an indicative of a deeper malaise in the British economy – the loss of entrepreneurial vitality in manufacturing as a whole.[180]

The purpose of the rest of this chapter is to review some the arguments that seek to explain the decline in the industry as they provide not only a useful background to the later discussion of Cleveland's firms, but also because some of the criticisms that have been levelled at the industry are of direct relevance to the district. These are covered in Sections 3 and 4. Before that Section 2 presents an outline of the basic statistics on the comparative size of the British, US and German iron and steel industries and brief assessment of Britain's trade performance. The data suggest that not all of the disparaging comments about the sector are entirely justified.

4.2 Trends in Output and Trade in Iron and Steel

There is little doubt that Britain lost its position as the world's dominant producer of iron and steel in the final decades of the nineteenth century (Tables 4.1 to 4.3). It was a relative decline rather than an absolute one for total output continued to rise, apart from a temporary drop in pig iron output in the early 1890s. By the beginning of World War I iron production was double, and steel had risen to 16 times, the 1870 level. The deterioration in the relative position, however, was rapid as Britain's share of world output was overtaken by the US in the 1880s, 1886 to be precise, and Germany in the 1890s (1893). As a proportion of world production, Britain' share fell from almost half in the early 1870s to 15 per cent for iron; for steel the reduction was from over 40 per cent to 15 per cent in 1913. On the on the eve of war the German steel industry was two and a half times, and the American steel industry four times, the size of that in Britain.[181]

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[178] *Royal Commission on Depression of Trade and Industry, Final Report, Minutes of Evidence and Appendix,* (Parliamentary Papers 1886-7, C. 4893,C.4715, C.4715-I); *Report of Departmental Committee of the Board of Trade to consider the position of the Iron and Steel Trades After the War,* Board of Trade (1918, Cd 9071).
[179] Burn, *Steelmaking*.
[180] M. Dintenfass, *The Decline of Industrial Britain* (London, 1992).
[181] Chapter 6, Section 6.2 offers a fuller analysis of the data on British iron and steel output.

Table 4.1: British Iron and Steel Output (million tons, annual average)

	Pig Iron	% World	Steel	% World
1860-64	4.15	-	0.11*	-
1870-74	6.38	47.6	0.43	43.9
1880-84	8.16	40.8	1.79	32.7
1890-94	7.28	28.5	3.14	24.6
1900-04	8.64	20.2	4.97	15.1
1910-14	9.50	14.9	7.2	10.8

*Data for 1868. Source: S. Pollard, *Britain's Prime and Britain's Decline: The British Economy 1870-1914* (London, 1989), p. 77; Mitchell, *Historical Statistics*, pp. 281-3.

Table 4.2: Pig Iron Output in Britain, Germany and the USA, 1870-1913

	Metric tons, million			Per cent of world output		
	Britain	Germany	US	Britain	Germany	US
1870	6.1	1.4	1.7	49	11	14
1880	7.9	2.7	3.9	43	15	21
1890	8	4.6	9.4	29	17	34
1900	9.1	8.5	14	22	21	34
1910	10.2	14.8	27.7	15	22	42
1913	10.4	19.3	31.5	13	24	39

Source: W.S. Woytinsky and E.S. Woytinsky, *World Population and Production: Trends and Outlook* (New York: The Twentieth Century Fund, 1953), p. 1117.

Table 4.3: Steel Output in Britain, Germany and the USA, 1870-1913

	Tons, million			Per cent of world output		
	Britain	Germany	US	Britain	Germany	US
1870	0.22	0.13	0.04	43	25	8
1880	1.29	0.69	1.25	31	17	30
1890	3.58	2.10	4.28	29	17	28
1900	4.90	6.36	10.19	18	23	37
1910	6.37	12.89	26.09	11	22	44
1913	7.66	17.32	31.30	10	23	42

Source: P.E. Paskoff, 'The growth of the American steel industry, 1865-1914: technological change, capital investment, and trade policy', in E. Abe and Y. Suzuki (eds.), *Changing Patterns of International Rivalry: Some Lessons from the Steel Industry* (Tokyo: 1991), p. 78.

In terms of world trade, the situation was similar, if less dramatic (Table 4.4); and, as with production, the decline was relative rather than absolute. Exports were higher in terms of both value and volume in the 1910 to 1914 period than in the 1870s, but the fall in the share of world exports was striking, declining from over 80 per cent to 32 per cent. Imports rose steeply from a negligible amount in the 1870s to 40 per cent of exports in volume and 26 per cent in value by the end of the period. The extent of this reversal in fortunes can be illustrated by the ratio of exports to imports: this fell from 26:1 to 2.5:1 in volume, and in value from 12:1 to 4:1. As Table 4.5 shows, not only did this represent a major shift in imports and exports, but it also marks a rising degree of import penetration. As a total of pig iron output, imports increased from 2.5 per cent to 21.6 per cent between 1870 and 1913 as overseas producers captured more of the British market.[182]

The trade position can also be illustrated by considering the unit value of exports and imports. There was a downward trend in the value of imports per ton from £12.52 to £6.50, while at the same time the unit value of exports rose from £7.10 to £10.50 (Table 4.3 and Figure 4.1). This may be partly explained by changes in relative prices of imports and exports, as production costs fell faster abroad than in Britain or from lower import prices as a result of dumping of output by foreign producers.[183] But it seems unlikely that prices and costs account for the entire shift in relative unit values; part was due to the change in the composition of trade, with a movement to higher quality-higher value exports compared to imports.[184]

Table 4.4: British Iron and Steel Exports and Imports (annual average)

	Imports		Exports		
	Tons (m)	£m	Tons (m)	£m	Exports % of world exports
1870-74	0.19	2.38	2.95	30.5	80+
1880-84	0.35	4.15	3.90	27.6	70+
1890-94	0.36	4.14	3.01	23.5	60+
1900-04	1.09	7.93	3.31	28.8	44
1910-14	1.79	11.99	4.42	46.5	32

Source: Pollard, *Britain's Prime*, p. 27.

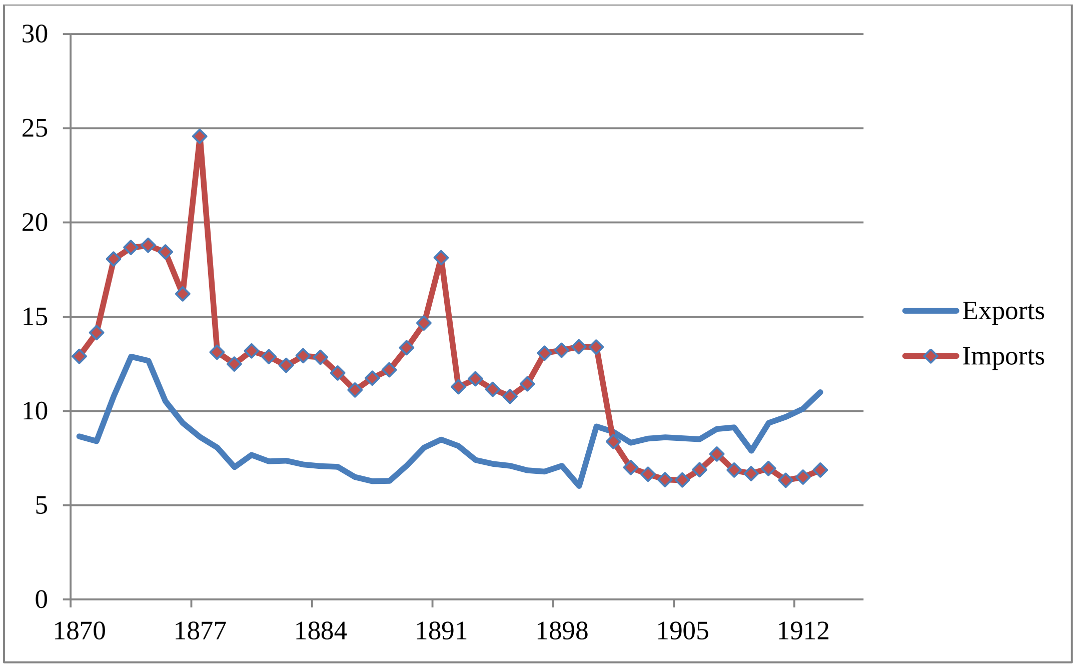
Table 4.5: Iron and Steel Output, Imports and Import Penetration (thousand tons)

	Output				
	Pig iron	Steel ingots and castings	Total	Iron and steel imports	Import % output
1870	5,963	240	6,203	150	2.4
1880	7,749	1,295	9,044	348	3.8
1890	7,904	3,579	11,483	386	3.7
1900	8,960	4,901	13,861	800	5.8
1910	10,012	3,674	16,386	1,367	8.3
1914	10,260	7,664	17,924	2,220	12.4

Source: Mitchell, *Historical Statistics*, Chapter 5, Tables 2, 4, 7, pp. 281-3, 289-90, 294-5.

[182] Import penetration is defined here as simply the ratio of imports to output rather than the usual domestic demand.
[183] See below, pp. 109-14.
[184] Tolliday, 'Competition', pp. 23-26.

Figure 4.1: Unit Value of Exports and Imports (£ per ton), 1870-1913



Source: The data series for this graph are derived from various years of the Board of Trade, *Annual statement of the trade of the United Kingdom with foreign countries and British possessions*, as follows:
1869-73: Board of Trade, 1874, C.1029;
1874-78: Board of Trade, 1878-9, C.2371;
1878-82: Board of Trade, 1883, C.3637;
1883-87: Board of Trade, 1888, C.5451;
1888-91: Board of Trade, 1892, C.6676;
1892-95: Board of Trade, 1896, C.8097;
1896-1900: Board of Trade, 1901, Cd.549, Cd.664;
1901-04: 1905, Board of Trade, Cd.2497, Cd.2626;
1905-07: 1908, Board of Trade, Cd.4100, Cd.4150;
1907-11: 1912-3, Cd.6216, Cd. 6336, Cd.6491;
1911-13: 1914-16, Cd.7968, Cd.8069.

A similar pattern is evident at the level of individual products, or at least for groups of products (Table 4.6). In 1913 the unit value of exports of iron and steel sheets was 28% higher than for imports, and for steel bars and angles the figure for exports was over twice that for imports. Further, a comparison of the balance of trade in these products indicates that the deterioration in trade performance may not have been as serious as has often been suggested. There was indeed a significant increase in imports in tonnage terms and only a slow rise in exports between 1910 and 1913 (Table 4.7). Overall the net exports of these products halved (231,744 tons to 116,804), and there was even net imports of sheets and plates. In value terms, on the other hand, the trade balance held up well despite the rising import volumes; it declined by just £125,000 (1910-13), with much of this accounted for by a collapse in exports to, and a surge in imports from, Germany between 1912 and 1913.[185] Once again, one probable explanation of the better performance in trade values than volumes is that exports were of an increasingly higher quality in comparison to the more basic imports.

Table 4.6: Unit Value of Exports and Imports of Plates and Bars, 1913 (£ per ton)

	Exports	Imports	Ratio
Iron and steel ship, bridge,, boiler and other plates (not under 1/8th inch thick)	9.2	7.2	1.28
Steel bars, angles and shapes	14.2	6.8	2.09

Source: Board of Trade Iron and Steel Industries Committee, *North East Steelmakers Association: Statistics and Documents,* (Board of Trade, 1916), pp. 4-7.

Table 4.7: Exports and Imports of Plates and Bars, 1910-1913

	Volumes (tons)			Values (£)		
1910	Exports	Imports	Trade Balance	Exports	Imports	Trade Balance
Plates and sheets	121,131	57,765	63,366	933,607	438,794	949,813
Bars and angles	227,202	58,794	168,408	2,952,970	401,750	2,551,220
Totals			231,744			3,046,033
1913	Exports	Imports	Trade Balance	Exports	Imports	Trade Balance
Plates and sheets	113,949	134,612	-663	1,232,998	973,086	259,912
Bars and angles	251,059	133,592	117,467	3,571,478	910,540	2,660,938
Totals			116,804			2,920,850

Source: Board of Trade Iron and Steel Industries Committee, *North East Steelmakers Association: Statistics and Documents*, (Board of Trade, 1916), pp. 4-7.

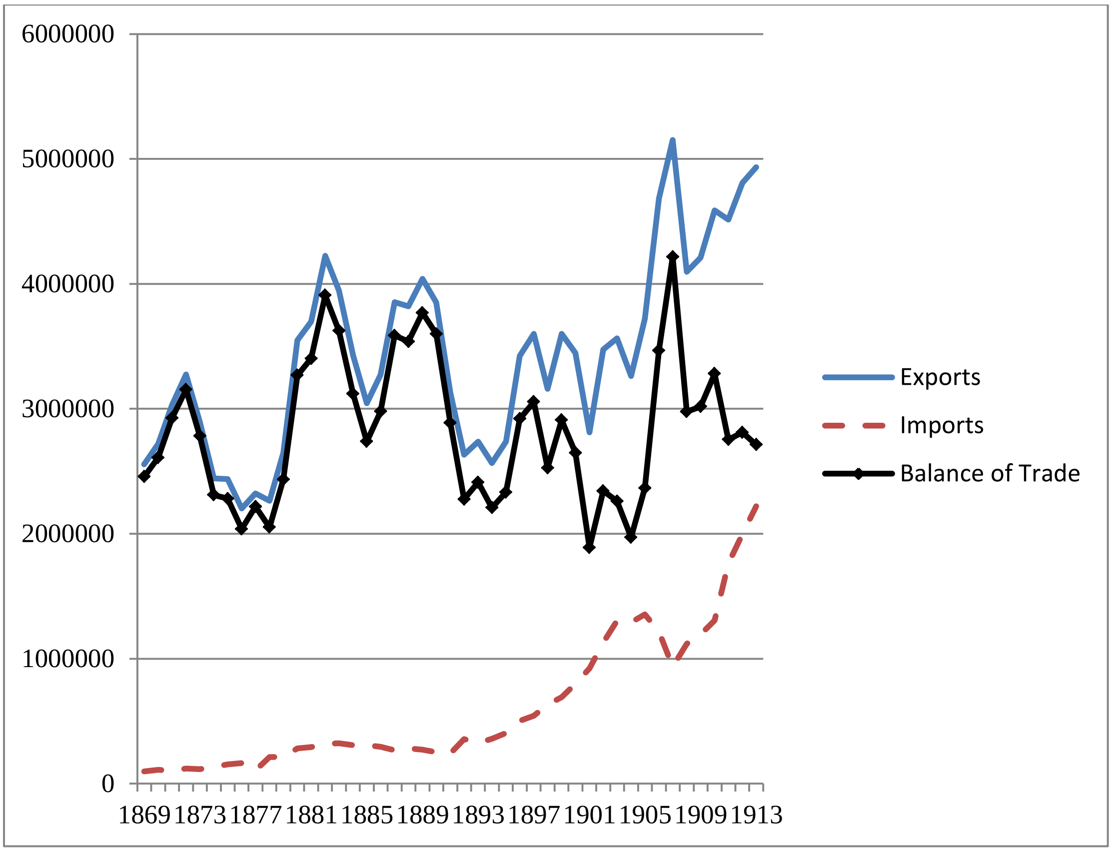
The general picture indicated by this brief assessment of the statistics is one of slowing growth, as might be expected with the maturing of the industry and economy. It was overtaken is size by both the US and Germany by the end of the nineteenth century. There was also a loss of ground in international markets as export growth slowed and imports, especially from Germany, rose. In some products Britain even became a net importer in volume terms by 1913. Nevertheless, the state of the industry was not as bleak, and the rate of relative decline not as rapid, as is often presented. The most startling signs of decline are the result of measuring the size of the sector and its trade performance in volume terms, i.e. as tons of iron and steel. This is partly because it is easier to obtain the data, but also partly because of an obsession with quantities and the sheer physical size of the industry. But because the products are not homogeneous, figures in tons of iron and steel are not necessarily good measures of the *economic* value of output since they ignore the range and quality of products. When this is

[185] Board of Trade Iron and Steel Industries Committee, *North East Steelmakers Association: Statistics and Documents*, (Board of Trade, 1916), pp. 4-7.

taken into account, there is some indication that, at least in trade terms, the decline in the competitive condition of the sector was not as serious as some commentators have suggested.

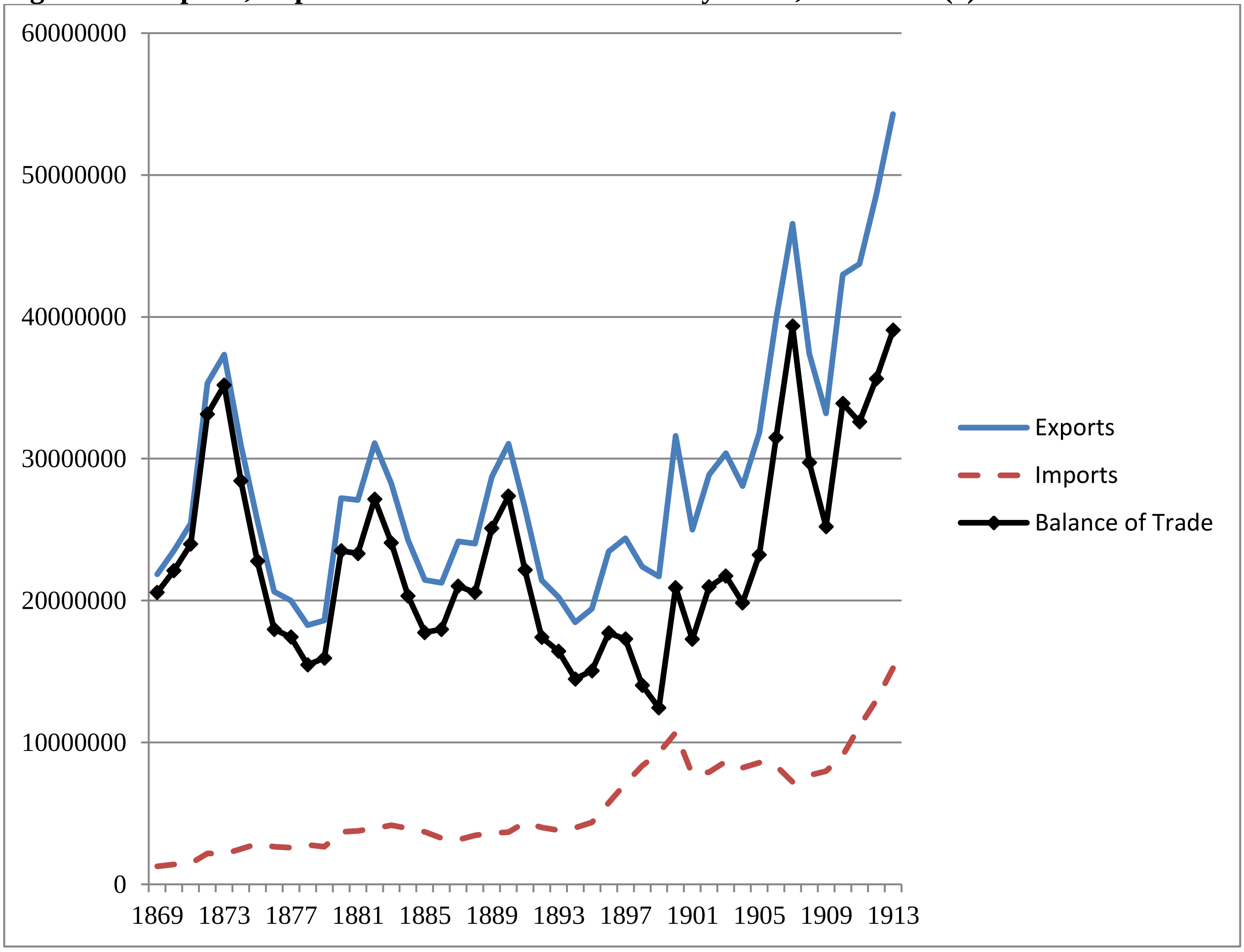
This is most clearly demonstrated by the balance of trade (Figures 4.2 and4. 3). In volume terms, by 1913 the trade balance was barely above the level of 1869 as imports expanded at a rate that far outstripped the growth in exports. From 1887 the compound growth rate of imports was 8.6 per cent per year whilst export tonnage grew at 1.5 per cent. By contrast, although imports grew faster than exports in value, the discrepancy was not so marked, with annual (compound) growth rates for exports and imports over the same period of 3 per cent and 5 per cent respectively. This had the result that by 1913, the trade balance in Britain's favour was £18.5 million wider than it had been in 1869. Taking five year averages, by 1909-13 Britain was importing 129,000 tons more than it had been in 1869-73, but the trade surplus had widened by £6.3 million.

Figure 4.2: Exports, Imports and the Balance of Trade by Volume, 1869-1913 (tons)



Source: Board of Trade, *Annual statement of trade*, 1874-1916 (see Figure 4.1 for full references).

Figure 4.3: Exports, Imports and the Balance of Trade by Value, 1869-1913 (£)



Source: Board of Trade, *Annual statement of trade*, 1874-1916 (see Figure 4.1 for full references).

4.3 Explanations: Entrepreneurial Failures and Institutional Constraints

In many respects it is rather surprising that economic and business historians have spent so much time and energy investigating the relative decline of the British iron and steel industry. The history of industrial development is littered with cases of firms and industries that have suffered as a result of shifts in comparative and competitive advantage. The explanation, of course, lies in the totemic nature of the industry; it is often considered an indicator of a country's economic strength and a symbol of national and regional pride. As the supplier of one of the basic products of an industrial economy, it is an early sector to develop and thus is at forefront of the industrial growth process, viz. the recent rapid rates of industrialisation in China, India and Brazil in the early twenty-first century, with China alone producing 626 million tons of crude steel in 2010, 44 per cent of the world's output.[186] And as an early contributor to industrialisation, it is also likely to be an early casualty of maturity as demand and

[186] World Steel Association, *Steel Statistical Yearbook 2011*, (Brussels, 2011), Table 1, pp. 3-5.

production move away from basic products as real incomes rise and the infrastructure of initial development – railways, bridges and so forth – is completed.[187]

It was probably inevitable that Britain would lose her pre-eminent position as an iron and steel producer. In the face of rapid industrialisation in the larger countries of the US and Germany, the potential for bigger home markets and a later start presented American and German steelmasters with a reasonably straightforward strategy for success: produce high volumes to meet rapidly expanding market demand by increasing capacity, usually in newly built plants using the latest technology. For their British counterparts, with slower growing demand and established sites, the decisions were more complex. Whether they failed to make the appropriate adjustments and investments cannot be judged solely by a comparison of the size of the industries in 1913, but by answering the question of whether Britain's industry grew more slowly and lost more of its export market, and home market to imports, than might reasonably be expected. In some ways, this is an almost impossible question to answer as the standard against which to assess performance is difficult if not impossible to predict. One way of determining the counterfactual is to consider what the output of the UK iron and steel sector would have been had the share of exports to neutral markets, i.e. where the US and Germany did not have the particular advantage of geographical proximity and national preference, and the degree of import penetration been maintained. [188] Temin suggests that steel output would have been approximately 2.4 million tons higher, making the annual average growth rate from 1890 to 1913 4.6 per cent instead of 3.4 per cent. Growth in the German steel industry was 9 per cent per year, and as Table 4.3 shows, an additional 2.4 million tons of British output and 2.4 million tons lower German output would still have left German production 50 per cent higher in 1913. This result offers support for the view that irrespective of other developments in the industry, Britain was unlikely to have been able to keep its leading position. Other researchers, however, have adopted a more critical, and often more indirect, approach. By looking at the characteristics of the industry, they have drawn inferences about the causes of the growth slowdown, and concluded that the loss of markets was avoidable.

In general, a declining market share is the manifestation of deeper problems in two possible areas. The first is a loss of cost competitiveness as a result of a relatively low level of productivity, or a slowing in its rate of growth, compared to producers in other countries. The other is a concentration on the wrong markets, either in terms of products or geographical area.

[187] As an essential capital good, iron and steel is subject to accelerator effects, i.e. output changes tend to be in greater proportion than GDP changes.
[188] P. Temin, 'The relative decline of the British steel industry, 1880-1913', in H. Rosovsky (ed.), *Industrialization in Two Systems* (New York, 1966), pp. 147-9.

Both of these can be regarded as the result of underlying inefficiencies and the outcome of deeper problems and structural weaknesses in the industry that resulted in a failure to adapt to changing circumstances. Explanations of the shortcomings of Britain's iron and steel industry along these lines fall broadly into two groups: the entrepreneurial failure hypothesis and the institutional constraints hypothesis. According to the entrepreneurial failure explanation, the decline was due principally to the inability of the entrepreneurs in the late Victorian and Edwardian period to take the necessary decisions to modernise the industry. It was a want of vision and an unwillingness to take risks that was in stark contrast to the boldness of the early ironmasters. At root, the argument is an indictment of individual business behaviour of the owners and decision takers, who had become more conservative, and possibly complacent in their attitudes. By contrast, the institutional constraints hypothesis suggests that decision making was constrained by the rigidities in, and fragmentation of, the industry's structure. It was the collective impact of these constraints that prevented British iron and steel firms from adopting the latest technologies and modernising their organisations, rather than a failure of leadership. While the structural conditions are seen as the underlying cause of the restrictions, it is possible to view both hypotheses as complementary: it was a lack of vision on the part of the iron- and steelmasters that explains why they were unable to break free from the difficulties they faced.

By contrast, not all commentators have seen the problems of the industry as the result of institutional or behavioural characteristics. The market and resource constraints hypotheses ascribe the difficulties to factors that were rather more fundamental. Specifically, these stemmed from restricted access to growing markets and to the difficulty of obtaining the appropriate raw materials. Moreover, they were binding constraints from which the industry was unable to break free however adventurous or far-sighted its entrepreneurs. These explanations are now examined in more detail.

Entrepreneurial Failure

It is, perhaps, ironic that three of the four major technological advances in steel making in the third quarter of the nineteenth century were developed in Britain, and yet it was the large scale adoption of these processes that undermined Britain's lead in production. The main advances began in 1856 when Henry Bessemer announced the development of his converter (the Bessemer converter) that for the first time enabled steel to be mass produced at low cost.[189] At about the same time, William Siemens and his brother Frederick developed the regenerative

[189] J.C. Carr and W. Taplin, *History of British Steel (Oxford*,1962), pp. 19-30; Geoffrey Tweedale, 'Bessemer, Sir Henry (1813–1898)', *Oxford Dictionary of National Biography* (Oxford University Press, Sept 2004; online edition, May 2006).

furnace that was in the 1860s to be applied to steel production by the French metallurgist Emile Martin as the open hearth furnace or Siemens-Martin process.[190] Apart from the size of furnace, with the open hearth eventually becoming substantially larger, the two methods differ principally in the time taken for the conversion of pig iron into steel. For the Bessemer converter it is 15 to 20 minutes but it takes several hours for the open hearth method. The rapidity of the Bessemer conversion makes the chemical reactions in the converter more difficult to control and thus the quality of the steel less reliable; higher grade steels are more easily produced by the open hearth method.

The spread of both techniques initiated a rapid rise in the demand for, and consequently production of, steel. In the early stages, the demand for rails was strong as the more durable, lighter and ductile product was substituted for iron. The switch from iron to steel, however, took some to complete time; the production techniques needed to be improved before the quality of the products could be assured, and steel prices needed to fall.[191] But ultimately steel would undermine the prosperity of specialist iron producers unless they made the transition to the new material. At first, the application of the new techniques was limited mainly to the production of acid steel using low phosphorus iron ore, hematite. High phosphorus ore was unsuitable because of the large amounts of slag and difficulties in eliminating the impurities made the resulting steel brittle and of poor quality. The problem was eventually solved for the Bessemer process by Sidney Thomas and Percy Gilchrist, who discovered that by using a chemically 'basic' lining such as dolomite (or other limestones) in the converter, pig iron made from ore with high phosphorus and sulphur content could be used to make steel of a useable quality. Known variously as the Thomas or basic Bessemer process, and the product as Thomas or basic steel, this method was mainly employed to produce steel that was suitable for rails. For many years it was not deemed of sufficiently good quality in Britain for widespread use; until 1890 the Admiralty and Lloyds would not permit basic steel in shipbuilding.[192] The basic process was later applied to the open hearth method, but rather than using ore with high phosphorus content (basic Bessemer needed ore with greater than 2 per cent), the basic open hearth process required low phosphorus ore (less than 0.5 per cent). This was a condition that caused particular difficulties for British producers. The problem with high phosphorus (and high sulphur) ores in the basic open hearth process is that a heavy slag is formed during refining,

[190] Carr and Taplin, *History*, pp. 31-35; H. T. Wood, 'Siemens, Sir (Charles) William (1823–1883)', rev. Brian Bowers, *Oxford Dictionary of National Biography* (Oxford University Press, 2004).
[191] For a discussion of the relative merits and costs of iron and (Bessemer) steel rails, see E. Williams, 'On the manufacture of rails', *JISI*, 1 (1869), pp. 156-71; I.L. Bell, Evidence to the Royal Commission on Depression of Trade and Industry, *Minutes of Evidence and Appendix, Part I* (Parliamentary Papers 1886-7, C.4715, C.4715-I), pp. 328-9.
[192] *Iron and Steel Trades After the War*, p. 5. See also Chapter 6.

impeding the oxidisation of the impurities and causing the phosphorus to return to the molten metal. Consequently, the steel is brittle and of poor quality. [193]

The tardiness of the British iron and steel producers in adopting these technical advances in steel making on a large scale, along with a number of other technological improvements, lies at the heart of the entrepreneurial failure hypothesis. Set out originally by Burn and re-iterated and developed by Aldcroft, Landes, Allen and Abé, the failure was one of a lack of vision, poor technical ability and a reluctance to take risks that together led steelmasters to make the wrong investment decisions, or when they did, to make them too late by which time they had ceded ground to US and German producers.[194] Unlike the German producers, who built their expansion on the basic Bessemer method, British firms adopted the acid open hearth process using hematite from Cumberland and imported low phosphorus ores, mainly from northern Spain. Given the problems with the basic process, the availability of suitable ore and the quality demands of the British market, especially from shipbuilders, the decision may initially have been rational; it was certainly profitable. Similarly, German industry's specialisation in basic Bessemer steel made good economic sense as they had access to substantial deposits of high phosphorus iron ore (Minette ores) from Lorraine from the early 1870s. Over time, however, as the low phosphorus ore became scarcer and prices increased, acid steel became increasingly uncompetitive and susceptible to undercutting both in the home and export markets.

Burn and others have argued that these problems could have been anticipated and overcome had British producers adopted the basic process earlier by making use of alternative ore supplies.[195] Cleveland ironstone was found to be unsuitable, being of intermediate phosphorus content (1.5per cent), but there were other sources in Lincolnshire and Northamptonshire which could have been exploited from the 1890s. This view was challenged by McCloskey on the grounds that when transport to Cleveland for smelting and refining was taken into account, the cost advantages of using these East Midlands ores disappeared.[196] More significantly, Tolliday has pointed out that real problem was not transport, since new works could have been built in Northamptonshire, but technical difficulties in the production process, which would not be remedied until 1930s.[197] Abé on the other hand maintains that there were other options and that

[193] Tolliday, 'Competition', p. 40. See Chapter 6 for a more detailed discussion of the problems of steel production.
[194] D. Aldcroft, 'The Entrepreneur and the British Economy, 1870-1914', *EcHR* 17 (1964), pp. 113-34; D. Landes *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750* (Cambridge, 1969); Allen, 'International comparisons', pp. 911-37; Abé, 'Technological strategy', pp. 45-76.
[195] Burn, *Steelmaking*, p.173-84.
[196] D.N. McCloskey, *Economic Maturity*, p. 67.
[197] Tolliday, 'Competition', p. 38. See below, pp. 103-4.

both the basic Bessemer and basic open hearth processes could have been more widely adopted.[198] Producers could have mixed local ores with scrap or with imported ores from Sweden and Spain to reduce the phosphorus content, and dealt with other processing problems such as the high sulphur and silicon content of local ores by using existing techniques, such as mixers. That they did not is seen as evidence of entrepreneurial failure.

In addition to choosing the wrong processes, another line of criticism is that British producers did not utilise the latest technologies and techniques of production.[199] This included a failure to integrate the production process and thus save costs from having to reheat pig iron to produce steel, and maintaining old, small and inefficient production plants that were costly to run. Instead of building large scale plants on new sites with the most advanced equipment, such as mechanical and electrical materials handling and continuous rolling mills, and using advanced techniques like hard-driving, i.e. operating large blast furnaces at high temperatures and pressures, the British firms relied on *ad hoc* improvements to their original plants on the same, often confined sites. This limited the ability to realise scale economies of the sort achieved by Carnegie Steel at the Edgar Thompson Works in Pittsburgh. Completed in 1879, this was a steel rail-mill, fully integrated from blast furnace to rolling mill on one site.[200]

Underlying these errors were deeper problems of management. These included a shortage of trained professional managers with an appropriate technical background who were capable of making the crucial decisions. This reflected a general weakness in Britain's educational system that in contrast to Germany was not geared to producing technical experts in sufficient numbers. It went hand in hand with and was compounded by the continued domination of company boards by family members or descendants of the firms' founders.[201] They often lacked the skills or interest to pursue a more adventurous strategy. And even when the ageing iron or steelmasters remained in control, they were too conservative, cautious or wedded to traditional methods to tackle the challenges posed by new technology and the growing German and American businesses.

The outcome was that British firms specialised in the wrong products – acid rather than basic steel – and productivity growth lagged so that with higher costs their lead in the industry was quickly overhauled. Allen for example suggests that by 1907-8 labour productivity across the

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[198] Abé, 'Technological strategy', pp.66-8.

[199] R. Allen, 'Entrepreneurship and technical progress in the northeast coast pig iron industry:1850-1913', *Research In Economic History,* 6 (1981), pp. 35-71.

[200] A.D. Chandler, *Scale and Scope*, pp. 128-9.

[201] For an early study, see C. Erickson, *British Industrialists: Steel and Hosiery, 1850-1950* (Cambridge, 1959)

steel industry was 50 per cent higher in Germany and 85 per cent higher in the US. For total factor productivity the lead was 15 per cent in both countries.[202]

Institutional Constraints

An obvious objection to the entrepreneurial failure hypothesis is that it does not explain why there was a general deficiency in the quality of entrepreneurship. In competitive market economies it would normally be expected that a new generation of entrepreneurs would replace the old, and that if this did not happen within a firm, then it would occur through the growth of new, more efficient businesses. In the same way that new businesses, industries and districts had overtaken the old ones at an earlier stage of the iron and steel industry, with Cleveland in the mid-nineteenth century being a notable example of a new centre of production, the opportunities for expansion and profits at the expense of inefficient incumbents ought to have occurred in the late Victorian and Edwardian period as well. For Elbaum and Lazonick, the problem with the entrepreneurial failure explanation is that it concentrated on the behaviour of individual entrepreneurs rather than identifying 'systematic sources of variation in enterprise performance'. In their view iron and steel was just one example of an industry in which 'modern technological and organizational innovations (were) impeded by inherited socioeconomic constraints'.[203] The underlying causes were the entrenched and rigid economic and social structures which reinforced conservative business attitudes. The problems stretched right across economic life from the nature of industrial organisation and labour relations to the financial system and trade. For steel it was not just that the broader economic and social institutions were faulty; it was the very structure of the industry that determined the dynamics of development. Specifically, the highly fragmented and competitive nature of the sector produced a dynamic that resulted in relative, and ultimately absolute, decline rather than growth.

The source of the difficulties lay in the highly competitive market, described by Elbaum as the most atomistically competitive of the major iron and steel producing countries, and its implications for investment decisions,.[204] The adoption of the latest technology required heavy investment but yielded considerable cost advantages as a result of economies of scale. The realisation of the benefits, however, was conditional on high levels of capacity utilisation and depended either on increasing market share or a rapidly expanding market. With many small businesses competing vigorously in a slowly growing market that was frequently disrupted by

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[202] Allen, 'International comparisons', p. 932. Broadberry estimates that having risen by 125 per cent from 1861 to 1900, labour productivity in the British steel sector remained static up to 1911 (S.N. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850-1990* (Cambridge, 1997), p. 172.

[203] B. Elbaum and W. Lazonick, 'The decline of the British economy: an institutional perspective', *Journal of Economic History*, 44 (1984), p. 568; B. Elbaum, 'Steel industry', pp. 51-81.

[204] Elbaum, 'Steel industry', p. 62.

cyclical fluctuations, firms faced considerable instability in demand. Scrapping existing plant and replacing it with modern, large scale facilities was a high risk strategy; there was no guaranteed return unless a firm could ensure market dominance. Indeed, in the absence of sustained high levels of output, unit costs would rise and even the most advanced and largest producers could be undercut by firms with lower capacity works and older technology, inflicting heavy losses. As each firm in the industry faced similar conditions, an optimal strategy was to delay large investments in up-to-date technology that required wholesale rebuilding and adopt the lower cost and less risky option of making piecemeal improvements. The problem can be seen as a form of prisoner's dilemma game: the optimal strategy for each firm making its decisions independently was not optimal for the industry as a whole. International competitiveness of the sector would have been maintained had all firms cooperated and invested, but given the likely reaction of others, no individual business was prepared to take the risk.[205]

The problems were exacerbated by two factors. First, there was slow growth in the domestic market. Where markets were expanding rapidly, then the risks of high cost investments in large-scale plant were significantly lower since firms were not reliant on taking market share from their rivals. In the slow growing British market, however, this, apart from exports, was the only way in which a firm could expand. Even where a firm expected eventually to capture a significant share from its competitors, the slow growing demand extended the payback period and left the expanding firm vulnerable to defensive cost-reducing investments by existing firms attempting to shore up their own competitive position. And even though this investment may be in older technology, it could be sufficient to deter large scale expansions.[206] As other have, Elbaum points to the lack of investment in the production of basic Bessemer steel by British firms as a prime example of the failure of the industry to adapt and a major cause of its loss of competitiveness and the dominance of German producers for the product.[207]

The second factor stemmed from the nature of wage setting and work organisation.[208] Wages in the steel sector were set by collective agreements according to a two part formula. There was a base level, negotiated locally, that related wages to plant output (tonnage), plus a variable element under which wages were adjusted to steel prices according to a sliding scale. Although this produced a relatively strike free industry and imparted some wage flexibility in cyclical

[205] Elbaum sees the problem as a zero sum game, but the prisoner's dilemma seems to capture the fact that what may be optimal for the industry is not necessarily optimal for each firm rather better. And, moreover, it is not necessarily a zero-sum game. Elbaum, 'Steel industry', p. 64.
[206] Elbaum, 'Steel industry', pp. 63-4
[207] Ibid., pp. 66-7.
[208] Ibid., pp.69-71; Elbaum and Lazonick, 'Decline', p. 570; Owen, '*Empire to Europe*', pp. 118-9.

downturns, the tonnage rates tended to penalise high-output, high-productivity plants. The effect was to enable older, lower productivity firms to survive through lower labour costs and deterred large scale investment in high capacity facilities since the wage bill would rise. Added to the high dependence on worker control over work organisation and manning levels, an inheritance from the contracting system employed by earlier ironmasters, the overall effect was to raise the cost and reduce the benefits of large scale investment and plant reorganisation.

Much the same argument about the exacerbating effects of a slow growing market is advanced by Chandler.[209] His assessment, however, is that it was more than just investment in large scale plant and the latest technology that determined the success of US and German manufacturers. It was part of a strategic, longer-term approach to business by the owners and senior managers that in parallel with investment new high-capacity plant saw two other major investments. These were in the organisational aspects of business rather than in productive equipment. One was the development of large scale business organisations controlled and administered by professionally trained managers; and the second was establishing large sales organisations dedicated to maintaining high volumes of sales and thus output – or throughput to use Chandler's term. In this way the reduced unit costs of operating large scale plants could be achieved by ensuring high levels of capacity utilisation.

For British industry the relative backwardness stemmed from the failure to build business organisations of sufficient size and professionalism; instead they relied not only on traditional production methods, but also on long-established organisational structures, employment methods and the marketing of products through agents rather than sales departments. It is, however, not always clear which way causality runs. The vast and massively expanding US market needed investment on a huge scale, but that in turn required large administrations to run the huge production units efficiently, as well as committed sales staff to maintain the flow of orders to justify the output levels. Although in retrospect all three elements appear as a strategic plan, the organisational changes may also be regarded as a response to the creation of the great enterprises which, once established, were able to cement their initial competitive advantage by further strategic investments, both in productive and organisational capacity. In Britain the apparent neglect of these three complementary investments – production, management and sales – may not simply reflect an attachment to traditional methods. It may have been partly the result of the greater efficiency of existing arrangements for producers whose output was more specialised and less standardised. Ultimately it was the result of a slower expansion in market demand that deterred the British iron and steel masters from following the American example.

[209] Chandler, *Scale and Scope*, pp. 284-5.

As Chandler comments: ‘Only a courageous and somewhat irrational set of British steelmakers and financiers would have made the investment required to build and integrate works in Britain large enough to compete with those of Pittsburgh and the Ruhr in order to regain those distant markets. By not doing so, however, the British lost markets forever.’ [210]

Slow home market growth and the institutional constraints of a fragmented sector, however, do not necessarily absolve British industry from the charge of entrepreneurial failure. Abé maintains that while there were some difficulties that the industry’s leaders could not have overcome, there were others they could reasonably have been expected to confront.[211] In particular, the limitations of the British market might have been surmounted by consolidating and reorganising the industry through mergers and takeovers followed by investment in new large scale, technologically advanced plant. To some extent restructuring did occur but the practice in Britain is often criticised on the grounds that whilst ownership was consolidated, it rarely resulted in the necessary rationalisation and integration of business operations or production units, of the stripping out of the old plant and its replacement with the new.[212] Too often a merger or acquisition left the acquired company as a semi-independent, wholly owned subsidiary, still run by the original owners, or more likely their second or third generation descendants. In other cases, the reorganisation was too slow and mismanaged that even when the most advanced plant was built, the benefits that could have resulted were incapable of being realised. Boyce’s study of the linked South Durham Steel and Cargo Fleet Iron Company reorganisation by Furness is a case in point.[213] In short, it may be argued that while the way the industrial structure had evolved may have placed constraints on the main decision makers, it was not beyond the ability of a visionary and risk-taking entrepreneur to break free of the constraints in order to challenge other British firms and the growing US and German industrial leadership. That they did not may signify that there were deeper social and institutional constraints that were manifest in business attitudes and practices and these ultimately placed limitations on both aspirations and business decisions.[214] At this point the institutional constraints and entrepreneurial failure explanations begin to merge, or at least complement each other.

[210] Chandler, *Scale and Scope*, p. 284.
[211] Abé, ‘Technological strategy’, p. 48.
[212] See the discussion of Dorman Long in Chapter 7.
[213] Boyce, ‘Cargo Fleet Iron’, pp. 839-75; G. Boyce, ‘Corporate strategy and accounting systems: a comparison of developments at two British steel firms, 1898-1914’, *BH* 34 (1992), pp. 42-65.
[214] For example ,Wiener, *English Culture*.

4.4 Market and Resource Constraints

Britain's fall in the rankings of iron and steel producers has not been seen by all as an indication of weakness of enterprise. Famously, McCloskey argued that Britain's firms faced binding constraints on their decisions and made the best possible choices in the circumstances.[215] Three constraint stand out: the nature of the market; the availability of suitable iron ore resources; and access to export markets.

Apart from the overall size and rate of growth of the market, a number of other features of the nature of demand for iron and steel in Britain may explain the apparent backwardness of home producers in adapting to the technological and other changes. They mark out the British market as distinct from those in the US and Germany at the end of the nineteenth and early twentieth centuries. One prominent aspect is that the major source of early expansion, the demand for relatively simple products such as rails, had come to an end as the railway system neared completion. Added to this was the slowdown in replacement demand as longer-lasting steel rails were substituted for iron and thus needed replacing less frequently.[216] The flattening in rail demand was replaced by rising demand for higher quality steels for engineering and shipbuilding as well as for more specialist products such as tinplate and galvanised sheets. Many of Britain's producers also specialised in orders for products with non-standardised specifications that had short production runs both for the home and export markets. This specialisation meant that there was less scope for new technology or for achieving economies of scale, which by definition requires standardisation. It enabled smaller firms to meet the demand competitively and profitably with less modern technology and production methods, often by relying on a highly skilled workforce.[217]

While these developments are particularly relevant to small scale, specialist iron and steel producers, they can also be seen as applicable to bulk steel production. The decline in the rail market and the rise in shipbuilding shifted the demand towards a higher grade of steel that could not be produced using the Bessemer process. It needed the slower, more controllable open hearth method that gave a more reliably high-quality product. Resource availability partly dictated that it was in acid open hearth steel that Britain's producers specialised, using low phosphorus hematite ores from Cumberland or imported from northern Spain where a number of British firms had mining interests. For some this was a highly successful strategy, as is shown by the performance of the Consett Iron Company, a highly profitable acid steel producer

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[215] McCloskey, *Economic Maturity*, pp. 126-7.
[216] Bell, 'Evidence', pp. 328-9.
[217] Tolliday, 'Competition', p. 60; Pollard, *Britain's* Prime, p.31

that specialised in ship plate.[218] The alternative was to produce basic open hearth steel, which was later to become the dominant process in the industry. As we have seen, Britain's producers have been accused of being slow to adopt the process (Burn, and Burnham and Hoskins), but until the 1890s basic open hearth steel was not really an option for British producers, at least using local ores. The problem, as Tolliday and Wengenroth have discussed in detail, arose from the requirement of the basic open hearth process for relatively low phosphorous ores, less than 0.5 per cent.[219] One option was to use the East Midlands ores of Northamptonshire and Lincolnshire. However, due to the high silica content a heavy slag was produced in the smelting process and therefore the blast furnaces had to be operated at higher than normal temperatures. As a result the production of basic pig iron suitable for the open hearth furnace was prohibitively costly. Another option was to mix the ore with other imported ores, but again this raised costs. In either case, not only would the steel have been uncompetitive, it was also of questionable quality because of the silica. Indeed, it was not until proper scientific research work was undertaken in the 1920s that the difficulties of using the East Midlands ore for steel production were overcome. Pig iron quality and blast furnace efficiency were found to be highly sensitive to temperature and it was only through careful control of the smelting process that iron of an acceptable quality could be produced. Even then its use was for basic Bessemer steel rather than in the open hearth, and suspicion about quality persisted because of the its sulphur content.

A further possibility was to use the extensive Cleveland ore deposits. The problem with this ore was that with an intermediate phosphorus content of 1.5 per cent, it was suitable neither for the basic open hearth steel nor for basic Bessemer production. There were early attempts to adapt the smelting of Cleveland pig to both basic processes. By adding puddler's tap to the blast furnace, a waste product from the wrought iron industry, the phosphorus content could be raised in smelting and the resulting pig iron used in the basic Bessemer converter. It was a method adopted by the North Eastern Steel Company in Middlesbrough. Alternatively, the phosphorus could be reduced by adding hematite ores to the blast to produce pig iron that was suitable for the basic open hearth furnace. However, both were costly compared to the production of acid steel and the quality uncertain, not least because pig from the Cleveland ore also produced a heavy slag in the steel making furnace, compromising the conversion process. Solutions to the difficulties came in the 1890s through advances in the steel making process rather than changing the phosphorus in the pig iron. At first mixers were used as an intermediate process between the blast furnace and the open hearth furnace to improve the quality of the iron. From

[218] See Chapter 6; H.W. Richardson J.M. Bass, 'The profitability of Consett Iron Company before 1914', *BH*, 7 (1965), pp. 71-93; Warren, *Consett Iron*.
[219] Tolliday, 'Competition', pp. 34-40; Wengenroth, *Enterprise*, p. 255.

1906 they were replaced by the tilting furnace devised by Benjamin Talbot of the Cargo Fleet Iron Company. It involved the periodic tilting of the open hearth furnace to remove the excess slag and regular partial emptying and recharging to maintain the phosphorus at the appropriate levels.[220]

Once a solution had been found there was major investment in basic open hearth capacity and a rapid expansion in output. Production rose to almost 3 million tons by 1914, 37 per cent of the total output of steel, from an almost negligible amount 25 years earlier (Table 4.8). This hardly suggests a sluggish response either in terms of technology or entrepreneurship.

Table 4.8: Steel Output by Process, 1889-1914 (selected years)

	Percentage of total output				
	Open hearth basic	Open hearth acid	Bessemer basic	Bessemer acid	Total output (tons)
1889	2.0	38.0	11.8	48.2	3,570,669
1894	3.3	47.3	12.7	36.7	3,107,682
1899	6.1	56.3	10.7	26.9	4,853,325
1904	16.4	64.2	16.2	3.2	5,026,879
1909	23.5	47.0	10.6	18.9	5,884,628
1914	36.7	47.0	6.2	10.2	7,835,113

Source: *ICTR* 17 May, 1912, p. 799 and NFISM *Statistical Report 1918* (July 1919), p. 5.

Whatever the delays there may have been in developing basic open hearth technology or the constraints on iron ore availability in Britain, these factors do not explain why British manufacturers did not expand their basic Bessemer capacity. Using cheaper imported high phosphorus ores they might have challenged US and especially German producers in their home or neutral export markets. Leaving aside the question of ore availability, there was, however, a further hurdle facing British firms: it was the protection of home markets by both the US and Germany.[221] The effects of protection are uncertain and often disputed since on the one hand it permits the expansion of output behind the protective wall, but on the other can reduce the level of productivity and slow its growth by reducing competition and thus the incentive for efficiency raising investment.[222] There are also differential effects on the protected sector depending on the nature industry and the structure of the tariff. In the case of the iron and steel industry, however, it does appear that trade policy had beneficial effects for the industries in the protecting countries and a deleterious one on Britain's.

[220] See Chapter 6 for further discussion. For a description, see C. Hood, *Iron and Steel: Their Production and Manufacture* (London, 1911). There were alternatives to Talbot's furnace, notably that of Monell, which was adopted by Bolckow, Vaughan in 1908, but proved to be technologically inferior (Abé, 'Technological strategy', pp. 57-61).
[221] For a discussion of ore availability see Tolliday, 'Competition', pp. 43-6.
[222] See Abe's comments on Paskoff, 'American steel', p. 111.

For the US the protective barriers were raised to significant levels after 1873, with *ad valorem* rates in the 1883-90 period of 40-48 per cent for pig iron, 61-79 per cent for steel rails and 89-98 per cent for shapes.[223] This high degree of protection did decline progressively up to 1914 with successive Tariff Acts easing the duty, but the tariffs remained a major barrier to imports from Britain when added to the geographical protection provided by transport costs. The impact on cost competitiveness can be gauged by comparing the dollar prices of British and US pig iron and steel rails in 1883 after adding the duty and freight charges (Table 4.9).

Table 4.9: British and US Prices after Duty and Freight Charges (per ton), 1883

	Pig iron	Steel rails
British price (£ s d)	£1 19s 5d	£5 7s 5d
British price in £	1.9708	5.6042
x $4.8665 ($ per £)	9.5909	27.2728
Duty in $	6.72	20.16
Transatlantic freight ($)	0.9733	0.9733
Rail freight in US ($)	2.50	2.50
British price in $	19.78	50.9
US price ($)	22.67	37.75
UK:US %	87.3%	135%

Source: Author's calculations using data from I.L. Bell, 'Evidence', p. 352; Paskoff, 'American steel', p. 90.

The data reveal that the tariffs provided a significant advantage for American producers in steel rails and reduced the cost benefits of British pig to only the narrowest of margins, and these were highly susceptible to relatively small fluctuations in British prices. Thus a 12 shilling (30 per cent) rise in Cleveland pig, well within the price fluctuations of the previous 10 years, would have rendered it uncompetitive, and for higher priced hematite pig the British cost advantage was even more vulnerable. Added to a preference for home produced goods, the tariffs could effectively shut out the British exports, and this indeed is what seemed to happen. The effect on imports into the US market was very marked (Table 4.10). Imports of iron and steel rails, which came almost exclusively from Britain, fell from two-thirds of US output in the early 1870s to virtually nothing by the end of the decade and into the 1880s. That this occurred at the same time US rail production doubled not only indicates the benefits to the American producers, who were able to take advantage of the expansion of demand as the railway system

[223] Paskoff, 'American steel', p. 90.

grew, but also of the adverse effect on British exports and output. And if Paskoff's assessment is correct that the American industry needed protection before 1880 and perhaps as late as 1890, it gave US firms the not only the opportunity to expand output, but also to invest in efficiency-raising plant. The effect was that by the lasts decade of the century cost reductions from the scale and technological advance of US firms rendered the tariff unnecessary, although protection continued.[224]

Table 4.10: US Output and Imports of Rails, 1870-1884 (thousand tons)

	US Output	US Imports	Imports % of output
1870	554	356	64.3
1871	693	505	72.9
1872	893	474	53.1
1873	795	231	29.1
1874	651	96	14.7
1875	708	16	2.3
1876	785	0	0.0
1877	683	0	0.0
1878	788	0	0.0
1879	994	39	3.9
1880	1,305	259	19.8
1881	1,647	346	21.0
1882	1,508	200	13.3
1883	1,215	35	2.9
1884	1,021	28	2.7

Source: Bell, 'Evidence', p. 142, Table LXVII.

For Germany it has been suggested that the benefits of protection were rather more complex, involving an interaction between tariffs, cartelised domestic production, especially strong among the bulk iron and steel firms, and pricing strategy in export markets. From the introduction of tariffs in 1879 the level of protection was considerable, ranging from about 25 per cent for pig iron to several hundred per cent for bar iron (Table 4.11). The level of duty remained the same for the period up to the First War, although the *ad valorem* rate varied with prices. For steel, it remained in the 15-25 per cent range.[225]

[224] Paskoff also argued that protection in the US enabled weaker firms to remain in business and thus reduced the pressure for anti-trust action, Paskoff, 'American steel', p. 105.
[225] S. Webb, 'Tariffs, cartels, technology, and growth in the German steel industry, 1879-1914', *Journal of Economic History*, 40 (1980), p. 310.

Table 4.11: German Tariffs on Iron and Steel, 1879 (per ton)

	Duty in shillings	British price (shillings)	Rate %
Pig iron: Cleveland	10s	37.33	28.6
Pig iron: hematite	10s	59.33	16.9
Bar iron: Cleveland	25s	5.6	446
Bar iron: Staffs	25s	7.8	321
Ingot steel	15s	--	--
Iron rails	25s	111.6	22.4
Steel rails	25s	88	28.4
Iron and steel plates	30s	--	--

Source: Bell, 'Evidence', p. 29, Table VIII; p. 115, Table XLVI.

Webb's study of the effective rate of protection in German iron and steel shows that the degree of protection varied across the industry. This resulted partly from the structure of the tariffs, but also from the industry's composition, in particular whether a firm produced final or intermediate products and whether or not it was vertically integrated. For some non-integrated firms producing end products (e.g. cast iron) protection was effectively negative because the impact of duties raised the prices of intermediate inputs. The most protected were the heavily cartelised, vertically integrated mass producers of iron and steel. Effective protection on all steel goods averaged about 12 per cent between 1883 and 1913, peaking at 37 per cent in 1900-02. For pig iron and heavy rolled steel this was significantly higher, averaging 51 and 23 per cent respectively, and again peaking in 1900-02 at 70 and 42 per cent for each product group.[226] These figures demonstrate just how heavily protected the large German steel producers were, and is significant both in that it was greatest at the time the industry grew rapidly and for the products in which it specialised. This helped the development of large scale, technically advanced production methods that ultimately gave it a competitive advantage over Britain.

The effect was more than simply expanding behind a protective tariff wall, however. The tariff gave rise to an incentive to integrate production vertically to avoid paying duties on inputs and this in turn increased the scope for adopting and further developing the latest technology in bulk steel production. The relevance of vertical integration is that many of the advances in production techniques came from vertically linked processes and, given the heavy capital expenditure needed, this required high levels of output if it was to be economical. Cartelisation in a secure home market meant that high domestic prices could be maintained, thus profitability could be ensured even during periods of low demand. It also enabled heavy discounting in export markets, with firms able to sell at or below cost. The effect was to stabilise the combined demand from home and export markets at high levels this enabled firms to achieve low unit costs by operating plant close to capacity, with overseas losses subsidised by the high

[226] S. Webb, 'Tariffs', p. 317.

margins on home sales. Overall, this reduced the risks of investing in large scale production facilities and it was the resulting increased investment rate in a more stable environment that ultimately raised German productivity and eventually led to output levels overtaking those in Britain.[227] According to Webb's estimates the effect raised German productivity in steel by 10 per cent above British levels by 1912-13 and this accounts for one-third to one-half of the output differential, somewhere in the region of 3.6 to 5.5 million tons or 46 per cent to 71 per cent of British output of steel. [228]

Wengenroth has similarly argued that German expansion was 'at the expense of the British' and points to 'the industry's collective behaviour and to national economic policy, especially customs policies, as dominant factors.'[229] Interestingly, this analysis of Germany's industry was at least partially recognised at the time, notably by Lowthian Bell, although, understandably, he did not foresee the implications it would have for the relative strengths of the British and German industries. Thus in Bell's evidence in 1885 to the Royal Commission on Depression of Trade and Industry, when asked about steel imports and the relative costs in Britain and Germany, he replied:

> I do not think it is possible that the German makers can deliver steel at a cheaper rate than it can be produced at home. That a certain quantity is sent into this country I do not dispute and, as is well known, Germany competes with us in neutral markets, but this they have done at times when the cost must, I think, have been more than the price they received. The explanation of this I take to be as follows: Some years ago the home demand in Germany was so great that large importations, chiefly from the United Kingdom, were made to meet it. During several of these years the iron trade must have been a very profitable one to the iron makers on or near to the Rhine, because, in addition to their natural advantages, they enjoyed protection against British iron masters in the form of transport and protective duties. Stimulated by profits thus artificially raised, the German works were extended to a point which, when home demand fell off, left about one third of the entire make of the empire in the hands of the manufacturers. The choice now lay between stopping the works to this extent and seeking an export trade equal to the surplus power of their furnaces and mills, even when no profit or even a loss attended the latter policy. By its adoption the works are kept fully employed, which is more economical than when only at partial work, and men are kept together

[227] Webb, 'Tariffs', p. 323; Wengenroth, *Enterprise*, pp. 266-73, 272-73.
[228] Webb, 'Tariffs', p. 323; output figures are from: Board of Trade, *Iron and Steel Trades after the War*, p. 23.
[229] Wengenroth, *Enterprise*, p. 272.

> ready for any improvement in the trade when the time arrives. The freight and duty on steel imported into Germany are such that the manufacturers by getting rid of the excess of their produce in the way described are able to obtain about 40s per ton more for articles required at home than they can for what is exported. Suppose, then, that upon the latter no profit or say a loss of even 10s per ton was realised, the effect would be that instead of receiving 40s on the whole output they are content with something between 23s 4d and 26s 8d per ton with the advantage, whatever it may be worth, of having their establishments fully employed.[230]

4.5 Conclusion

The purpose of this chapter has been to provide some background to the later analysis of Cleveland's iron and steel sector by identifying the main trends in the industry in Britain and the various explanations that have been put forward to explain its performance. It is well established that iron and steel output grew more slowly than in the US, Germany, and a number of other European countries. As technology spread and other economies industrialised, the demand for, and the production of, this most fundamental of industrial products grew rapidly. Britain's relative decline therefore was inevitable; but this was not an absolute decline. In 1913 pig iron output was 14 per cent above the turn of the century level and steel 57 per cent higher. In terms of world output in the same year, Britain produced 13 per cent of the world's pig iron and 10 per cent of the steel.[231] Trade was marked by sharply rising imports, but the quantity measure (i.e. tons) tends to overstate the problems as Britain shifted to higher quality exports and lower value imports. As a result the balance of trade in value terms improved, especially after the trough in 1891-4 when exports fell by 13 per cent in two years. These statistics and the analysis in this chapter show it is not altogether clear that entrepreneurial failure and institutional constraints were evident or entirely to blame for the relative decline. The industry was beset by other difficulties, not least among which were the protectionist policies of the largest potential markets, the US and Germany.[232] Coupled with the slower growth and the highly cyclical nature of the industry, expansion was more difficult in Britain than elsewhere. In Cleveland, the technical limitations on the use of the local ore, which had been so important in the early growth of the industry, held back some of the adjustment to steel. But as Chapter 6 will demonstrate, British firms were not dilatory first in finding ways around and later in

[230] Bell, 'Evidence', p. 44.
[231] W.S. Woytinsky and E.S. Woytinsky, *World Population and Production*, p. 1119.
[232] For the effect of US tariffs in tinplate, see W.E. Minchinton, *The British Tinplate Industry: A History* (Oxford, 1957); Broadberry, *Productivity*, pp. 172-4.

solving this problem. Moreover, as will be explored in Chapter 7 there were still entrepreneurs in the industry with the drive to create large organisations. First, however, the effect of the mid-nineteenth century changes in corporate legislation, often thought to be a crucial factor that enabled the growth of large companies, will be examined in the next chapter.

Chapter 5: The Effects of Changes in Corporate Legislation on the Iron and Steel Industry in Cleveland

5.1 Introduction

It is well documented that the Joint Stock Company Acts of 1855 and 1856, and consolidated in 1862, led to a sharp rise in the promotion of joint stock companies, and that iron and steel was one of the first sectors to take advantage of the benefits of incorporation and limited liability.[233] As Watson has shown, by 1881 there were 46 iron and steel companies quoted in *Burdett's Official Intelligence*, with a market capitalisation of £23.5 million, and this had risen to 106 (market capitalisation of £86.5 million) by 1910.[234] Between 1881 and 1900 the proportion of blast furnaces operated by publicly quoted companies had increased from 23.5 to 65 per cent.[235] These changes had a marked impact on firms in the Cleveland iron and steel and related engineering industries and it is the aim of this chapter is to investigate the effects. In particular, it will look at the way in which firms made use of the changes in corporate legislation of the 1850s and 1860s, the effects on financing business and the ownership structure of firms.

The traditional view on the significance of the new corporate legislation, exemplified by Shannon, Todd, Jefferys and Hunt, is that the free availability of incorporation and limited liability was not only inevitable, but also a natural and logical concomitant of economic development.[236] The growth of large scale enterprises with substantial capital requirements meant that businesses needed access to a wider source of funds. This could be achieved only though incorporation, the protection of investors by limited liability and meeting investors' preferences for liquidity by the free transfer of ownership rights, i.e. a secondary market in shares. Indeed, in some interpretations the failure of the legal developments to keep pace with the business ones held back economic development. Consequently, the corporate reforms were

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233 P.L. Cottrell, *Industrial Finance, 1830-1914* (Aldershot, 1980), p. 154.
234 Katherine Watson, 'The new issue market as a source of finance for the UK brewing and iron and steel industries, 1870-1913', in Y. Cassis, G. Feldman, and U. Olsson (eds.), *The Evolution of Financial Institutions and Markets in Twentieth Century Europe* (Aldershot, 1995), p. 225.
235 Ibid., p. 225.
236 H.A. Shannon, 'The coming of general limited liability', *Economic History*, ii (1931), pp. 267-91; H.A. Shannon, 'The first five thousand companies', *Economic History*, iii (1932), pp. 396-424; Geoffrey Todd, 'Some Aspects of Joint Stock Companies, 1844-1900', *EcHR*, 4 (1932), pp. 46-71; James B. Jefferys, *Business Organisation in Great Britain 1856-1914 (*University of London Ph.D. thesis, 1938, reprinted by Arno Press, New York, 1977); B.C. Hunt, *The Development of the Business Corporation in England, 1800-1867* (Harvard, 1936). See also Taylor's interpretation of R. Harris, *Industrializing English Law* (Cambridge, 2000): James Taylor, *Creating Capitalism: Joint-Stock Enterprise in British Politics and Culture, 1800-1870* (Suffolk, 2006), p. 11.

a necessary legal catching up with the economic imperatives.[237] For brevity, this will be called the 'growth view'.

There is some indication that following the legislative changes, iron and steel companies did seek finance from the equity market. Watson notes that although many firms did not rely on market funds, there was a tendency for companies to approach the market for additional capital when the industry was in the 'upper half' of the cycle.[238] Newton's paper on Sheffield capital networks examines the activities of three company promoters floating iron and steel companies in the district.[239] Their promotions primarily tapped into local sources of funds but also brought in some extra-regional capital. This not only financed the expansion of the Sheffield iron and steel industry but also helped to develop a domestic industrial capital market '...educating a solid core of investors into the act of investment'.[240] This had the effect of spreading limited liability, raising funds, encouraging the adoption of new technology, increasing the scale of enterprises and helping firms survive the cyclical downturns.[241]

Similarly supportive views of the benefits of the joint stock form of organisation in the iron and steel sector are expressed by Allen.[242] He suggests that it was the larger, public limited companies with broadly-based shareholding that were likely to be the most advanced, productive and willing to invest in the latest technology. Those that remained partnerships or were private companies whose shareholders were confined to family members, often descendants of the original founders, were likely to be more conservative They stuck with out-dated technology, obsolete plant and old fashioned production and management methods. Widespread share ownership and directors with more varied backgrounds aided the professionalisation of company management, resulting in a greater emphasis on corporate growth and a more realistic attitude to risk taking. Furthermore, the public holding of shares provided a stronger incentive for directors to monitor company behaviour, and although there was no market for corporate control in the modern sense, shareholder pressure, including that from non-family directors, for profits and a steady flow of dividends may have been enough to improve performance.

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[237] Note that Cottrell, *Industrial Finance*, p. 10 and Taylor, *Creating Capitalism*, p. 10, maintain that the legal restrictions on company formation before the 1850s did not impede the raising of finance by industry.
[238] Watson, 'New issues', Table 10.5, pp. 225-7; Table 10.6, pp. 229-30.
[239] Lucy Newton, 'Capital networks in the Sheffield region, 1850-85', in Wilson and Popp, *Industrial Clusters* pp. 130-54.
[240] Ibid., p. 152.
[241] Ibid., p. 154.
[242] Allen, 'Entrepreneurship', pp. 56-7.

Not all researchers have seen incorporation as a logical and necessarily beneficial development in business organisation, or at least have been so sanguine about the way it was fashioned in the mid-nineteenth century. Armstrong for example presents evidence of the often questionable, and frequently fraudulent, practices of company promoters. He maintains that such activities, especially notable in the 1850s to 1860s, restricted the benefits of incorporation: investors were 'turned off home industrials' and some sound firms shied away from going public because of the adverse publicity that surrounded the promotion of new companies. The effect was that British firms remained small, family ownership dominated, and the resulting lack of capital meant that they were unable to compete with the large-scale, professionally managed firms that were developing abroad, especially in the US and Germany.[243] This is a position that is particularly relevant to the iron and steel industry.

There is also an alternative explanation of the roots of the 1850s relaxation of company law that directly contradicts the 'inevitable and logical' interpretation. This will be termed the 'socio-political view'. Taylor has shown, convincingly, than an important source of the political pressure behind the 1855 and 1856 Joint Stock Company Acts was a desire by the authorities to eradicate the anomalies and discretionary decision making in the process of granting of corporate status.[244] Described by Taylor as a 'troublesome responsibility', it was a system that was open to abuse and the justified criticism that it was opaque and seemingly arbitrary. Of wider significance, perhaps, is Taylor's contention that the apparent shift in policy was in many respects a continuation of the government's ultimate objective of maintaining financial stability, but by the almost counter-intuitive method of liberalising regulations rather than tightening them.

Specifically, by granting firms free access to the protection of limited liability, creditors would be discouraged from the reckless lending to companies that occurred after the 1844 Act as shareholders' liability for the debts would be limited and thus so too would be creditors' claims. And for investors, because lifting the restrictions made incorporation and limited liability virtually automatic, subject only to minimal requirements, as shareholders they would have would have to exercise greater responsibility in their choice of investments. They would no longer feel they had the protection of a business that had been regulated by the state, and in the same way that creditors were forced to become more prudent, it was the duty of investors to

[243] John Armstrong, 'The rise and fall of the company promoter and the financing of British industry', in J.J. Van Helten and Y. Cassis (eds.), *Capitalism in a mature economy: financial institutions, capital exports and British industry, 1870-1939*, (Aldershot, 1990), pp. 133-134.
[244] Taylor, *Creating Capitalism*. See also Cottrell, *Industrial Finance*, pp. 42-5, on the Board of Trade's discretionary powers to confer corporate status before 1855 and the details of the Joint Stock Companies Registration and Regulation Act, 1844 1837.

ensure that companies in which they invested were sound. Thus it was a way of shifting the burden of responsibility for regulation of incorporated businesses from the state to investors and creditors.[245]

According to this view, the legislative relaxation was motivated by a desire to protect investors and the financial system from the speculative excesses of the late 1840s. It was a means of reducing the moral hazard effects of state regulation: less regulation meant more self-regulation and therefore greater stability. Investors and creditors were forced to become more circumspect and behave with greater responsibility. That the legislation resulted in limited liability companies becoming the dominant form of business enterprise was an unintended consequence of the change rather than a reflection of a wholesale conversion to 'the ideology of growth'. As Taylor emphasises, at the time of the 1850s legislation there was no evidence that companies had finally managed to shake off the 'prejudices' and 'misconceptions' that had dogged their earlier existence.[246]

The main purpose chapter is to investigate the impact of incorporation on business behaviour, and how firms in Cleveland made use of limited liability status. As part of this, it is possible to make an assessment of the relative merits of 'growth view' and the 'socio-political view' of the emergence of joint stock companies. In particular, some of the evidence can be used to test indirectly the first hypothesis, i.e. the joint stock form was an economic necessity in a growing economy. Whatever the motivations of the legislators might appear to be, the underlying forces that drive change may often be hidden and become apparent only later. Thus if limited liability is associated with higher investment, growth and expansion, then it could be that the legislative changes of the mid-nineteenth century were responding to the needs of the business community as capital requirements increased and the expanding size of firms demanded different organisational forms. In part, this is a test of a view that institutions and organisations adapt to requirements and to solve problems in an optimal way. The alternative hypothesis is that organisational development proceeds by a series of adaptations to immediate problems and is guided, or influenced, by the balance of social, political and economic forces. This latter approach fits most closely with Taylor's interpretation. A look at the practical implications of the joint stock legislation therefore offers an indirect, if partial, way of assessing the two hypotheses.

The following sections investigate these issues first by considering the trends in, and the overall pattern of, company registration as the Cleveland iron and steel industry developed from the

[245] Taylor, *Creating Capitalism*, p. 17 and p. 176.
[246] Ibid., pp. 210-1.

1850s. Second, the extent to which conversion to joint stock status was linked to the demand for external funds to finance capital investment is examined by considering in detail the flotation of Bolckow Vaughan in 1864-5 (Section 3) and then the post-flotation capital structure and sources of long-term funds of Bolckow Vaughan and Dorman Long (Section 4). Section 5 offers some conclusions.

5.2 Trends in Company Registration in Cleveland

It was perhaps because of the relative newness of the Cleveland iron industry, which made it unattractive to investors, that following the 1850s reform of corporate legislation there was no headlong rush in the district towards the formation of joint stock companies. Nationally, between mid-1856 and mid-1864 Todd estimates that over 3,500 companies had been registered, which after adjustments for failures and abortive flotations, left 2,000 in existence in June 1864.[247] In Cleveland at that time just seven had been registered. Nevertheless, from 1860 onwards there was a steady flow of registrations; measured decade by decade, this increased from 14 in the 1860s to a peak of 22 in the 1890s (Table 5.1).[248] There was, however, a considerable degree of variation from year to year, with peaks in 1864-65, 1872-74, the late 1880s, the mid-1890s and in 1900, and troughs particularly in the late 1860s and mid-1870s (Figure 5.1). In the early days of the industry these fluctuations were associated with the usual cyclical measures of activity (i.e. prices and output) in the sector, which was also the case for variations at the national level. For public flotations at least, this can be easily explained: profits in the immediate past were taken as an indicator of the prospect of future profits and dividends, making the shares in newly floated companies an attractive proposition for investors and company promoters. After the mid-1880s, as the industry matured, the year to year variation in Cleveland was less closely correlated with changes in the economic cycle.[249] New entry, which tended to be pro-cyclical, declined and in any event most existing larger business had already converted.[250]

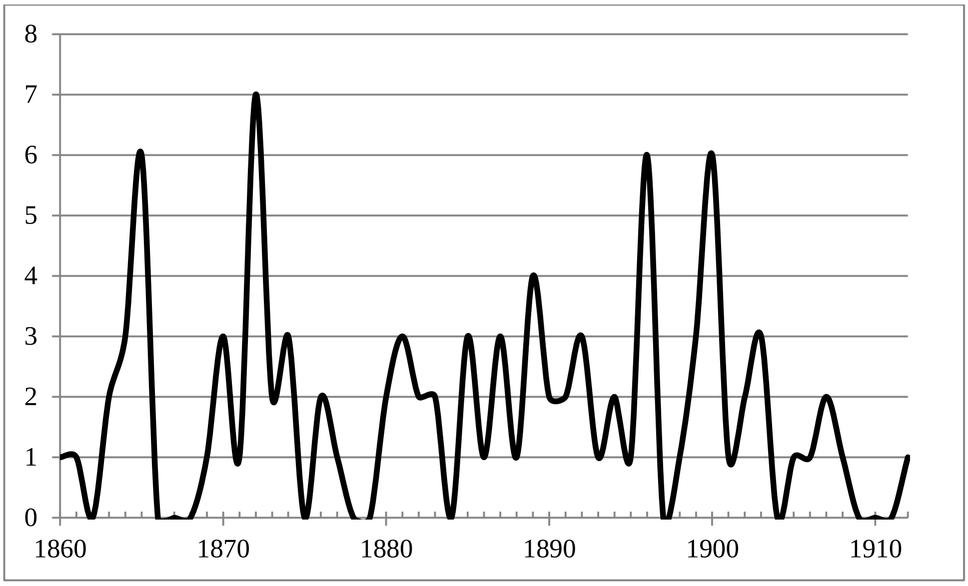
[247] Todd, 'Some aspects', pp. 56-7.
[248] The data for this section is drawn from the sample of businesses in Appendix 1.
[249] In Cleveland the correlation was weak compared with that at the national level. For 1865 to 1884 the correlation coefficients for incorporation with respect to pig iron prices (Cleveland No. 3) and changes in output are 0.33 and 0.26 respectively. For 1865-1912, there is virtually no correlation. For the national data see Watson, 'New issue market', pp. 228-9.
[250] Cottrell, *Industrial Finance*, p. 141 and p. 154.

Table 5.1: Joint Stock Company Registration in the Cleveland Iron and Steel Industry, 1860-1900

	Total	New businesses[a]	New businesses reconstructed from existing firms[b]	Conversions[c]	Not Known
1860-69	14	9	-	5	-
1870-79	17	12	-	5	-
1880-89	21	10	5	5	-
1890-99	22	9	4	8	1
1900-09	17	7	3	5	2
Total	91	47	11	29	3

Notes:
a: new businesses established as joint stock companies.
b: new joint-stock companies formed from failed partnerships or liquidated joint stock companies.
c: conversion unincorporated firms, usually partnerships, into joint stock companies.
Source: Appendix 1.

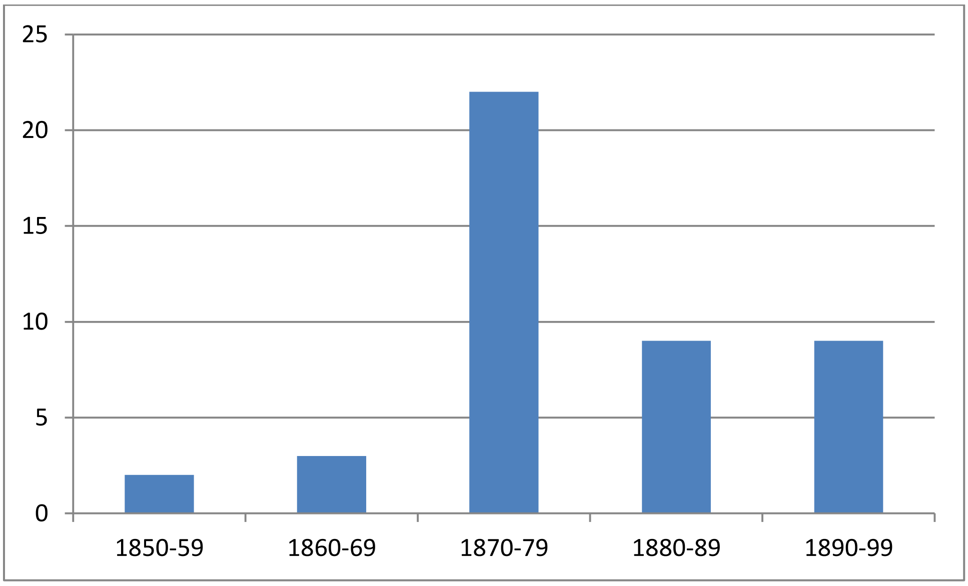
Figure 5.1: Incorporation of Cleveland Iron, Steel and Related Engineering Companies, 1860-1912



Note: the data refer to the total annual registrations of iron, steel and engineering companies as new businesses, reconstructions of failed businesses or conversions to from partnerships to joint stock companies.
Source: Appendix 1

The data reveals some interesting features of company formation. Throughout the period the establishment of new businesses formed a significant proportion of the total number of joint stock companies registered, approximately two-thirds of all companies for the whole period (1860-1909). As might be expected, proportionately this was at its highest during the rapid expansion of the industry in the 1860s and early 1870s, although as a proportion of all new businesses, including partnerships, joint stock firms were still in a minority. By the 1880s and 1890s the proportion of joint stock companies that were new businesses had fallen, despite the overall total rising, partly reflecting a slowing in the growth of the district and a restructuring in the ownership of existing firms. The other principal category of company registration is the conversion of existing businesses into limited companies. By the end of the nineteenth century the joint stock company had become the accepted form of business organisation and many of the established firms that were still partnerships took advantage of the protection of limited liability. Indeed, by the turn of the century all of the big names of the Cleveland iron industry and many of the smaller ones had become incorporated, with long-lived partnerships converting to limited companies, e.g. Weardale Iron and Steel (1863), Bolckow Vaughan (1864-65), Bell Brothers (1873), Samuelson (1887), Dorman, Long (1889), and Head, Wrightson (1890). Smaller firms that survived also converted, such as Pickerings Lifts (1887), Cochrane and Grove (1889) and Crewdson, Hardy (1899). By the early twentieth century virtually all sizeable business in the industry had become incorporated, although most were 'private' companies.[251]

Figure 5.2: Business Failures in Cleveland Iron and Steel, 1850-99



Note: failed firms include failed sole proprietors, partnerships and liquidated joint stock companies.
Source: Appendix 1.

In many respects the picture is much more complicated than a simple division of companies into new entrants and the conversion of survivors. There was a considerable degree of business failure (Figure 5.2), resulting in part from the highly cyclical nature of the industry in conjunction with a tendency for excessive optimism in the upswing that produced periodic over-investment and over-production. This is most notable in the 1870s, the first half of which produced an enormous expansion in iron producing and processing capacity, the employment of which could not be sustained following the downturn in 1874. North Yorkshire pig iron

[251] Private companies were not formally recognised until 1900, and not distinguished in legislation until 1906. However, many firms were nominally private as their shares were usually held by the original partners and family members and not available for public subscription

production was virtually static between 1873 and 1874 at 1.16 million tons, and nationally output fell by 9 per cent.[252] The succession of failures that followed the recessions often left not only collapsed firms and bankrupt ironmasters (e.g. Thomas Vaughan, Richard Jaques, George Swan and many others), but also valuable plant and equipment, and even a pig iron brand name, idle. And even when the closed iron and engineering works were obsolete, the site could prove attractive to new investors in the industry. There was therefore considerable scope for business reconstruction, and in many, if not most, of the cases this was achieved through the flotation of a new company.

Broadly speaking, reconstructions took three main forms.

1. The reconstruction of an existing partnership as a limited company, under the same or a new name, and usually with some or all of the existing partners.
2. The revival and reconstruction of a limited company that had been dissolved. Again this was often under the same name with the existing directors
3. The formation of a completely new company. This was often with help from the main creditors or other interested parties of investors, some of whom were already involved in the iron industry, who had bought up the site and equipment in order to float a new business.

As far as Table 5.1 is concerned, the first two are classified under the 'New Businesses reconstructed from existing firms' category, while a firm in the third is regarded as a completely new business.[253]

A classic case of a partnership that failed and was revived by the same partners as a limited company is Cargo Fleet Iron. The original firm was established as Swan, Coates and Co in 1864 and by 1866 was smelting pig iron in four blast furnaces. In 1876-77 the firm failed in iron recession, leaving debts of £280,000 and the partners – J.G. Swan, George Newcomen and John Legal – were declared bankrupt.[254] Following their discharge from bankruptcy, the ironworks at Cargo Fleet was reopened as a limited company, now named Cargo Fleet Iron Co Ltd, with Swan as managing director. The business prospered for a number of years, expanding to five blast furnaces and acquiring ironstone mines at Liverton, Normanby and Ormesby until it went out of business in the 1890s. Despite its obsolete plant, the firm was then bought up by Sir Christopher Furness for its large riverside site.[255]

[252] Brian Mitchell, *Historical Statistics*, p. 28.
[253] Given that in some cases the details of business failures and flotations are sparse, the allocation of a firm to a specific category is not always clear-cut.
[254] *Northern Echo*, 2 Aug. 1877 and 22 Jan. 1879.
[255] *White's Directory of Yorkshire* 1885-6; see also pp. 194-5 below and Boyce, 'Cargo Fleet Iron', *BHR*, 63 (1989), pp. 847-8.

Moor Steel and Iron Company provides another example of a collapsed partnership that was re-floated as a limited company. Established in Stockton, originally by Shaw, Johnson and Reay in 1872, the firm specialised in iron puddling and rolling, particularly ship plate. It also had coal mining interests. The business collapsed in May 1882 with debts of around £164,000 and the assets were seized by creditors. The two principal mortgage holders took the main property: Lambton's, a Newcastle bank, gained control of the collieries at Whitworth and Castle Eden, in County Durham; and Backhouse's, the Darlington bank, took possession of the ironworks. By 1885 the creditors and two of the partners had re-launched the iron business as a limited company, and with new investment in open hearth acid steel furnaces, switched to producing steel plate. It remained an independent company until 1896 when it was taken over by Weardale Steel and Coal, again as part of the expansion of Furness's business interests.[256]

In the same way that failed partnerships were rebuilt as limited companies, so too were liquidated joint stock companies. The formation of Skinningrove Iron Company in 1880 presents a relatively typical case. The ironworks were first set up by the Loftus Iron Co, a new limited company formed specifically to take advantage of the early 1870s iron boom. It owned and operated ironstone mines at Carlin How and blast furnaces at Loftus. Like numerous others in this industry, the firm ran into difficulties during the mid-1870s, probably in late 1876 or early 1877. The furnaces were blown out by mid-1877 and the managing director, John Westray, faced bankruptcy proceedings. Following the firm's winding-up its assets were offered for auction in Middlesbrough (at the Royal Exchange) and bought up by W.D. (William Dillworth) Crewdson for £50,000 on behalf of the 'first mortgagees'. The plant was then sold to a newly formed company, Skinningrove, also for £50,000.[257]

There are a number of interesting features of the Loftus-Skinningrove case. One is that the chairman of the new company, T.C. Hutchinson was also one of the liquidators of the Loftus Iron Co, and of the other shareholders at least two out of the six were already connected with the Cleveland iron trade. John Rogerson was general manager at the Weardale Iron and Steel Company and ran his own iron merchant business from the Middlesbrough Exchange. Edwin K. Fox was also an iron merchant at the Middlesbrough Exchange and related to one of the partners (Theodore Fox) in another Middlesbrough iron firm – Fox, Head and Co. Secondly, the new company was partially financed by a mortgage with W. D. Crewdson, a partner in the private Kendal-based bank of Wakefield, Crewdson and Co and previously a creditor of the Loftus Iron Co. Although neither Crewdson nor the other partners of the bank took shares in

[256] *Northern Echo*, 17 May 1882; 16 June 1882.
[257] W.G. Willis, *Skinningrove Iron Company Limited 1880-1968: A History* (Middlesbrough, 1969); *Newcastle Courant*, 15 Nov. 1878.

the new firm, Wakefield, Crewdson continued to provide finance for Skinningrove, even after the bank was taken over by the Bank of Liverpool (1893). For example, a £34,000 mortgage was arranged in June 1894.[258]

A more involved example is that of Teesside Iron and Engineering Works Co, a business that had a rather chequered, and at times troubled, history. This firm went through a number of reorganisations between 1879 and 1896, during which it demonstrated at least two of the three ways in which the joint stock company form was used to revive a business in difficulties. The original company (Hopkins, Gilkes and Co) was an early instance of a public joint stock company in the Cleveland iron industry, formed from the merger of two existing partnerships when the engineering business of Gilkes, Wilson and Co (Tees Engine Works) amalgamated with the iron smelting firm of Hopkins and Co (Teesside Ironworks) in 1865. The resulting firm produced a wide range of iron products from pig iron to steam engines and bridge design and construction. As with Bolckow, Vaughan (see below), it was promoted in, and attracted a significant number of investors from, Manchester.[259] Following the downturn in the demand for iron in the second half of the 1870s the company experienced financial difficulties and its fate was sealed after the Tay bridge disaster, for which the firm had been a major contractor.[260] After the disaster, Edgar Gilkes resigned and the company was liquidated in 1880.

When iron prices revived in the early 1880s, the firm's idle and potentially profitable plant, however, provided the principal remaining shareholders, among them Isaac Wilson and members of the Pease family, sufficient incentive to reopen the business. Wilson, Pease and Co, a partnership that ran the Tees Ironworks and which had included Gilkes before his departure, bought the business and re-floated the firm as Teesside Iron and Engineering Works Co in early in 1880, with a total nominal share capital of £324,000, £99,000 in £3 preference shares (probably held by Wilson and the Pease family) and £225,000 in £5 ordinary shares.[261] Even with new management, a tarnished reputation and a highly competitive market meant that the company experienced great difficulty in obtaining orders and struggled to survive, let alone to make profit. By 1889 the firm had once again collapsed and been liquidated, but it was soon revived with a further injection of Pease money. The new company, registered in 1890, struggled on for a few years with limited success, this time dogged by poor management and obsolete equipment. Both the firm's plants were eventually shut in 1894 and remained

[258] Teesside Archives Steel Collection (TA/SC/23-3, box 17226).
[259] Prospectus, *Manchester Times*, 21 Jan 1865.
[260] The company was reported to have "stopped payment" in May 1879. *Northern Echo*, 15 May 1879. After the disaster Edgar Gilkes resigned and retired and the company was liquidated.
[261] *Northern Echo*, 25 Feb. 1880; T.R. Tighe, *Teesside Bridge: The Rise, Fortune and Dissolution of a Private Company* (Teesside, 1980), pp. 7-9.

redundant until the liquidation the following year. The works were then were bought up by Sir Christopher Furness in 1896 as another part of his expansion plans.[262]

Furness' purchase of Teesside Iron and Engineering appears to have been something of a new pattern of business reconstruction in Cleveland that started in the 1890s: that of buying up firms that were either in difficulties or closed and then reorganising their assets into a number of different companies. These were then floated as public companies or retained as wholly owned subsidiaries as private companies. Furness tended to follow the former path. In the case of Teesside Iron and Engineering, the engineering side of the business was re-floated as Teesside Bridge and Engineering Co, which as its name indicates, specialised in bridge construction. After a poor start, the company eventually built a sound business. The blast furnace plant was rather less successful. This part of the business was re-launched as Tees Furnace Co in 1896, but lasted only a few years before being closed. The out of date furnaces were pulled down and the site sold to the expanding marine engineering company, Richardson, Westgarth, another of Furness' companies and a product of his amalgamations and reconstructions.[263]

A similar pattern of reinvigorating defunct businesses is shown in the case of Bowesfield Steel Company, and though the pattern is similar to Tees Bridge and Engineering, there are some interesting variations in the details. The Bowesfield works was principally a rolling mill specialising mainly in iron and also steel plate for shipbuilding. The original firm, Bowesfield Iron Co, shut down operations in September 1890, another victim of the shift away from iron and the periodic recessions in the industry. Liquidation proceedings to wind-up the company were quickly instituted at the behest of the creditors, with C.A. Head of Head, Wrightson among the principal ones, and W.B. Peat, an accountant and a well-known figure in the Middlesbrough iron trade, appointed as liquidator.[264] Initial attempts to re-float the business were abortive, and the works lay idle for some years.[265] Improving prospects in the industry by the mid-1890s, however, encouraged a number of local investors to form a group, the Bowesfield Syndicate, to buy up the deserted works and sell them to a new company (for £18,000) set up to re-equip and modernise the firm. The new Bowesfield Steel Company was floated in July 1896 with shares allotted to the syndicate members in payment for the works, inclusive of a £10,000 mortgage,

[262] Tighe, *Teesside Bridge*, pp. 11-6.
[263] *Northern Echo*, 25 July 1896; Tighe, *Teesside Bridge*, p. 26.
[264] *Northern Echo*, 7 Sept 1890, 16 Sept 1890. William Barclay Peat was an accountant with considerable experience of Cleveland's iron and steel industry. He acted as an advisor to several firms in the industry and his London-based firm, which had a Middlesbrough office, audited the accounts of numerous companies in Cleveland.
[265] *Newcastle Courant*, 3 Jan. 1891.

and 30,000 £1 shares (10 shillings paid) offered to the public to raise capital for new equipment and to inject working capital.[266]

This flotation illustrates a well-established way in which promoters and directors were able to minimise their exposure to risk. The shares issued to the vendors were fully paid-up, in contrast to the subscribers whose investment was only 50 per cent paid, and consequently exposed to significant financial losses in the event of a company failure. The flotation was also a way in which the creditors were able to obtain some reimbursement for the losses incurred resulting from the failure of the earlier version of the company. In Bowesfield's case the syndicate members numbered at least two creditors, Charles Head and Thomas Wrightson, and there may have been others.[267] Such promotions are not necessarily entirely cynical, however; the promoters were after all establishing a new company, which, with good management and some luck, would become profitable and produce dividends. Bowesfield did seem to be a genuine attempt to renew the business and break into new markets. The directors planned to branch out from iron, to rolling thin steel sheets for galvanising and corrugating. At that time these products were mostly produced in the West Midlands and South Wales, and not at all on Teesside. Alfred Baldwin, whose companies had steel works in Wales and the Midlands and which were already producing for this market, was brought in as a director, with a nominal investment, presumably to provide expertise and contacts in the sector.[268]

These examples show a varying use and experience of joint stock status by companies in Cleveland. The practice was rather more complex than establishing a completely new business or converting a well-established partnership. Past research has tended to overlook the role of incorporation in facilitating the reconstruction of businesses; it helped produce a more rapid response to changing economic circumstances and enabled firms to take advantage of potentially profitable opportunities. The explanations are relatively straightforward. First, limited liability meant that the failure of a business did not necessarily result in drawn-out and involved bankruptcy proceedings that could leave productive and profitable property unemployed. Second, new investors were not deterred by the possibility of future claims on a business that could arise many years later and which left the ownership of the property in dispute or tied up the business in long-lasting law suits.[269] By emphasising the financing and speculative aspects of company promotion, historians have neglected an important result of the

[266] Bowesfield Steel Company Directors' Minutes (BSDM) vol. 1, 12 June 1896 and *Prospectus,* included in the minute book.
[267] These included local ironmasters such as John Gjers, Joseph Richardson, and others with interests in the industry – W.H. Cowper, J.G. Clapham and A. Bainbridge.
[268] BSDM vol. 1, 12 June 1896. The invitation letter to Baldwin is included in the minutes.
[269] An example of this is the experience in the Newcastle glass industry of the 1830s of Charles Attwood, the early Cleveland ironmaster who set up Weardale Iron Company. See Jeans, *Pioneers,* pp. 4-12.

legal changes. That is, by codifying and standardising the procedures for winding-up a company and determining the claims of its creditors, the reform of corporate legislation made it easier and therefore more likely that the assets of defunct companies would be re-employed. In short, by making it easier to exit, the legislation made entry more likely, and therefore encouraged greater entrepreneurial activity. As to whether joint stock company formation resulted in greater capital investment, one way to assess this from the data on company registration is to compare the proportion of new firms that were set up with the conversion of existing firms. That there were a significant number of new firm registrations, about half according to Table 5.1, could be interpreted as confirming the 'growth view'. That is, the advent of free access to incorporation encouraged the influx of funds to finance capital formation. However, there are two qualifications to this interpretation. First, it is not surprising that in a rapidly growing industry in which new business formation was fairly high as was the case in Cleveland in the 1860s and 1870s, some entrepreneurs took advantage of the protection offered by incorporation. Second, by the end of the nineteenth century, as noted above, the joint stock company had become the principal form of business organisation, at least for larger firms in established industries. While it is difficult to predict the counter-factual, i.e. what business formation would have been in the absence of the reform of company legislation, it is likely that in Cleveland this would have been high and therefore the joint stock form may have had little net effect on overall investment or even business formation.

Company conversions pose similar problems of interpretation. Generally, it might be expected that turning a partnership into a limited company would not necessarily increase investment, but this depends on the nature and the details of the conversion. For private companies, any increase in funds would be unlikely since ownership of the business would usually be distributed between the partners and family members. Bringing in a new investor, however, was always a possibility, and there were a number of instances where this occurred in Cleveland; for example in the formation of Ashmore,, Benson and Pease and Co, which had previously been the partnership Ashmore, White.[270] For public flotations, on the other hand, in which shares were offered for sale to a widespread investing public, it might be expected that the new funds drawn in to the business would be used at least in part for expansion and modernisation. This is the justification for the joint stock reforms that underlies the 'growth view'. But here again the picture is complicated. There is no logical reason why funds generated from the public flotation of an existing partnership or private company should necessarily raise investment. In many instances it is just as likely that funds raised were used to

[270] *Northern Echo*, 31 Mar. 1885; *Liverpool Mercury*, 27 April 1885.

pay the vendors and promoters of the company, as in the example of Bolckow Vaughan investigated in Section 5.3.

The other form of incorporation identified in Table 5.1, that of company or business reconstruction, also presents problems when trying to draw inferences about the contribution of incorporation to financing investment. In general it might be expected that a reconstruction is associated both with modernisation and greater investment as in the examples of Bowesfield, Skinningrove and Cargo Fleet (the 1906 reconstruction). An alternative is that the directors' plans were simply to return the plant to production with minimal extra capital expenditure on the firm beyond the injection of basic working capital to finance operations.

One final complication is worth mentioning. It is that public flotations provided entrepreneurs not only with a means of exploiting unwary and ill-informed investors, but also with a method of securing rapid returns on their investments. Thus it may be that entrepreneurs' willingness to invest privately in businesses was increased by the knowledge that a quick return could be obtained from a future public flotation. One possible example of this is the Britannia Iron Works Company. This was a sizeable puddling and rolling mill business established by Bernhard Samuelson in 1870 on a site close to his large smelting plant at Newport, Middlesbrough. The business was floated as a public company in 1872, with the prospectus stating that Samuelson was selling the business because of his decision 'to retire ... from all business engagements requiring his personal attention'. It is an explanation that was at odds with his continued involvement in the Newport ironworks and his agricultural engineering business in Banbury. Whatever the real reason behind Samuelson's decision to float the Britannia works as a limited company, the point here is that his original decision to build the rolling mills and to take on a £82,500 mortgage at 6 per cent may well have been influenced by the knowledge that the business could be sold by establishing a limited company. Samuelson could thus earn a quick return on the investment. The details of Samuelson's earnings from the flotation are not known, but they are likely to have been considerable as the company was launched at the height of the early 1870s expansion and the works were sold with the mortgage. Unusually, Samuelson did not become a director of the company, as was normally the case in the conversion of privately owned businesses.[271] In this way the joint stock company provided an indirect incentive to investment and thus a stimulus to growth, and the effect applies equally to new ventures as it does to the reconstruction of defunct or failing companies. In a sense, it is akin to the practice adopted by some of today's private equity funds and venture capitalists. But as with modern experience, without detailed case by case analysis it is often difficult to

[271] Prospectus, *Birmingham Daily Post*, 7 Dec. 1872.

determine whether the potential returns from a future flotation acts as an incentive to invest and improve the management of the assets or whether it is simply a matter of asset stripping.

Overall, the data show the importance of the joint stock company form to the Cleveland iron and steel industry. Unsurprisingly, it grew to become the dominant form of business organisation in the district, just as it did elsewhere in the country. The discussion has shown how diverse in nature and circumstance the formation of joint stock companies was and thus how difficult it is to draw inferences about the contribution of the liberalisation of corporate legislation to the growth of industry. The fact that most surviving firms of any size had become incorporated by 1900 suggests that at the very least the protection offered by limited liability was an important consideration, especially in an industry that was notorious for the volatility of its market conditions and the risk of business failure. Nevertheless, joint stock status was adopted for many different reasons and had a variety of effects depending on the position of the business and the objectives of the owners. This is examined in more detail in the following sections by looking in depth at how two large firms made use of the opportunities offered by the changes in corporate legislation and especially the extent to which they were able to draw on capital markets for long term funds.

5.3 Bolckow Vaughan: the first five years of incorporation

In the 1860s Bolckow, Vaughan was the largest of the publicly floated iron companies in Cleveland and also one of the most widely known. By the end of the decade its shares were quoted on the stock markets of London, Manchester and Newcastle. Its conversion from a partnership makes an interesting study as it was sizeable, with the company valued at just less under £1 million, and, through its promoter, David Chadwick, brought in substantial investment funds to Cleveland from outside the district. As Table 5.2 shows, and as noted by a number of historians, a majority of the investors were Manchester or north west businessmen, many involved in the cotton trade, and also associated with David Chadwick from the Manchester-based accounting and auditing firm of Chadwick, Adamson.[272] Some of these north west associates of Chadwick were major shareholders and became directors of the company, including H.D. Pochin and Benjamin Whitworth. A number of the shareholders were also directors or shareholders in other iron and steel companies promoted by Chadwick; for example Henry Pochin and Charles Cammell both had interests in Sheffield iron and steel businesses.[273]

[272] Birch, *The Economic History of the British Iron and Steel Industry 1784-1879* (London, 1967), pp. 206-7; Cottrell, *Industrial Finance*, pp. 118-22.
[273] GeoffreyTweedale, *Steel City*.

Table 5.2: Regional Distribution of Bolckow Vaughan Shareholders

Region	No of shares	No of shareholders	Per cent of shares	Per cent of shareholders	Average shareholding
North West	11,603	288	68.3	60.6	40
London	1,100	23	6.5	4.8	48
North East	1,038	35	6.1	7.4	30
Yorkshire	805	38	4.7	8.0	21
Cleveland	611	37	3.6	7.8	17
East Midlands	535	9	3.1	1.9	59
Ireland	448	27	2.6	5.7	17
West Midlands	340	8	2.0	1.7	43
South	160	5	0.9	1.1	32
Scotland	135	4	0.8	0.8	34
South West	75	1	0.4	0.2	75
Others	150	8	0.9	1.7	19
Total	17000	475	100	100	36

Note: BVDM records the address or town of residence of each shareholder. Allocation of shareholders to a region uses standard UK regions.
Source: BVDM Vol. 1, 3 Dec 1864, pp. 45-59.

The public issue produced a substantial inflow of funds to the firm, totalling £510,000 between 1865 and 1869. This was raised from an initial share price of £17 10s, with two later calls taking the paid up value to £30 per share out of a nominal value of £100. To some writers this was a clear case of raising finance to increase investment. Birch for example suggests that Bolckow Vaughan illustrates one of the three 'legitimate' reasons identified by Jefferys for forming a joint stock company, namely the 'desire to extend the sources of capital'.[274] And despite the involvement of Chadwick as a promoter, who was connected with both failed and a fraudulent flotations, Birch suggests that the partners, Henry Bolckow and John Vaughan, had no 'fraudulent intentions'.[275]

As evidence of the honourable motives behind the flotation, both Birch and Cottrell have cited a self-denying ordinance in the terms of sale agreement and the articles of association of the new company. This stated that Bolckow and Vaughan would forego dividends on their vendors' shares until an average dividend of 10 per cent had been paid on ordinary shares for the first five

[274] Birch, *Iron and Steel*, p. 206.
[275] For Chadwick's career see Cottrell, *Industrial* Finance, pp. 113-41; and Newton, 'Capital networks', p.139. Cottrell disputes Birch's view of Chadwick: 'In terms of standards, Chadwick represents the best of the company promoters', p.131.

years of the company.[276] A closer examination of the flotation, however, suggests that the guarantee was little more than cosmetic, and that the raising of funds had little to do with financing extra capital investment. Jefferys' and Birch's 'desire for external sources of capital' was the way in which Bolckow and Vaughan could liquidate part of their investment in the business by selling it to external buyers at the best possible price.

In addition to presenting a case that sheds light on the question of whether the move towards incorporation was motivated by the need to raise funds for capital investment externally, or for other reasons, Bolckow Vaughan is also an interesting example of the way in which the interests of different groups of shareholders might clash, especially in the early years of incorporation. Specifically, this conflict was between the vendors on the one side and the new directors defending their own and the other external shareholders' interests on the other. The original partners, particularly Henry Bolckow, were not only able to maintain their control over the business, or at least its finances, but also to maximise their personal return from the sale. And this, of course, provides pointers to the real reason for the flotation of the company.

To demonstrate this it is useful to consider the detail of the sale and financing of the firm in some depth. Table 5.3 sets out the specifics of the sale agreement and Bolckow and Vaughan's receipts.

At flotation the business was valued at £955,000 (but see below), with Bolckow and Vaughan receiving £400,000 in shares and the remainder in cash – initially £250,000 and the rest in instalments over five years with 5 per cent interest paid on the outstanding balance. It is difficult to estimate the total cash paid to Bolckow and Vaughan as a dispute over the precise valuation of the company meant that not all the instalments were paid on time. Moreover, the actual interest payments to the two partners were published in only the first two annual reports.[277] Making the assumption that the instalments were paid on time, and using the average annual interest rate (APR) approximation, the interest payments can be estimated to have been a minimum of £41,935 10s. In total therefore, Bolckow and Vaughan received around £1 million for the business, £600,000 in cash and £400,000 in shares. This probably rather underestimates the full amount because of the additional interest that had to be paid as a result of delayed payments.[278]

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[276]BVDM vol. 1; Birch, *Iron and Steel*, p. 207; Cottrell, *Industrial Finance*, p. 118.
[277] BVAR 1865, 1866, vol.1.
[278] The annual reports give the actual interest paid as £27,813 5s 3d in 1865 and £26,857 9s 5d in 1866 (BVAR 1865 and 1866).

Table 5.3: Flotation of Bolckow Vaughan in 1864-5

Nominal capital	£2.5 million	25,000 £100 shares
Authorised capital	£400,000	£8,000 vendors' shares, £50 paid
	£297,000	17,000 ordinary shares, £17 10s paid
Total Authorised	£69,750	
Payments to Bolckow and Vaughan, January 1865		
Shares	£400,000	8,000 vendors' shares, £50 paid
Cash	£20,000	Deposit, 31 Dec. 1864
Cash	£230,000	First payment, 2 Jan. 1865
Balance to be paid	£305,000	Equal instalments to be paid six monthly over five years
Company valuation	£955,000	
Bolckow and Vaughan's cash receipts over five years		
Cash deposit	£20,000	
First instalment	£230,000	
Balance	£305,000	
Estimated interest paid on the outstanding balance	£41,935 10s	
Total	£596, 93510s	

Source: BVDM vol. 1; BVAR 1865-1869, vol. 1.

The delays in the instalment payments were the result of a dispute between Bolckow and Vaughan and the other directors over the valuation of the company. When the valuation, conducted by William Armstrong, a notable and pioneering accountant in the north east, and John Mackenzie (from Glasgow), was reported to the directors' meeting in April 1865, Bolckow and Vaughan expressed their disappointment.[279] The minutes of the meeting state that '… in their opinion the valuation had been conducted on a principle different to that specified in the (sale) agreement...and they declined to accept it'.[280] The value of the firm was put at £808,146, lower than originally agreed with the vendors. There followed what appears to be a rather

[279] William Armstrong pioneered accounting techniques in the coal and iron and steel industries, and was involved with the valuation of a number of Cleveland companies, including Bolckow Vaughan and Bell Brothers. See M.V. Pitts, 'In praise of the "other" William Armstrong: a nineteenth century British engineer and early management consultant' *Accounting History*, 6 (2001), pp. 33-58.
[280] BVDM vol. 1, p. 128.

acrimonious dispute with both sides seeking outside legal opinion. Joseph Dodds, a Stockton solicitor and also ironmaster and later MP, acted for the partners and sought advice from the Attorney General and 'other eminent counsel' in London. This supported Bolckow and Vaughan's objections, and on presentation of the advice at the next directors' meeting (20th May), the board agreed to hold a special meeting to resolve the matter. The directors' meeting the following month (21st June), however, was unable to make any progress as the company solicitor, Shipman, had also sought legal advice, this time in Manchester. Even though other matters were dealt with, the atmosphere at the meeting must have been difficult. First, Bolckow and Vaughan were offered a cheque for the purchase money due on 1st July (£22,314 12s plus interest of £3,913 13s). They declined the offer, and when it was put to a vote, the board split. The external directors (George Wood, James Holden and Henry Pochin) all voted in favour of the offer, while Bolckow and Vaughan, supported by Carl Bolckow and Thomas Vaughan, newly appointed to the board, voted against.[281] Second, the board also agreed to send the company secretary, James Jennings, to visit the Ashby Iron Company in Manchester 'to see the way in which (the company) lay their form of business before their board.'[282]

The conflict finally came to a head at a 'special meeting' at the Station Hotel in York on 29th June where it was finally resolved. The meeting lasted for over four hours, and although there is no direct evidence in the minutes of animosity, they do suggest that it was a confrontational and possibly ill-tempered meeting. The Manchester-based directors Whitworth, Holden and Pochin had accompanied the company's solicitor, Shipman, to the Manchester lawyers, and the advice they received was in line with that obtained by Dodds in London: the valuation was not in accordance with the original sale agreement and that 'the duty of the valuers remained to be performed'. The Manchester directors then renewed their offer of an interim payment to Bolckow and Vaughan, this time for £25,000 'without prejudice to the substance to the conduct or any other questions between the parties', but also tied this payment to a resolution that accepted the valuation was not in line with the sale agreement. This attempt to link the payment with a statement on the valuation caused havoc. On the advice of Dodds, Bolckow and Vaughan rejected the payment, presumably because by accepting money they were in some (legal) way signifying agreement with the Armstrong-Mackenzie valuation. Dodds pressed the board to pass a separate resolution accepting that the valuation was inaccurate. The minutes note that there followed 'a lengthy discussion on the point' with the Manchester contingent continuing to press for their original resolution and Bolckow wanting it to be withdrawn. Eventually, it seems, the meeting must have come to a stalemate. Bolckow and Vaughan

[281] Thomas Vaughan was John Vaughan's son and Carl Bolckow, Henry Bolckow's nephew.
[282] BVDM vol. 1, p. 137.

threatened to cancel the sale; Bolckow 'then vacated the chair and left the meeting', accompanied by John and Thomas Vaughan and Carl Bolckow.

This action seriously undermined the future of the company. But while Bolckow's brinksmanship, had it not worked, would have meant the partners foregoing an enormous rise in their wealth, they were already exceedingly wealthy men with substantial property and would still have been left with a highly profitable business had the flotation collapsed. The Manchester directors were in a much weaker position. The collapse of the company would have been hugely costly for them, both financially and in terms of the loss in reputation. They also had legal advice from two different sources against them. Interestingly, Chadwick's name does not appear in the minutes, but his reputation would also have suffered as a promoter and as an accountant and auditor of many of the newly floated companies. It seems likely that he would have pressed for a compromise. With the partners out of the room, Cheetham took the chair and the remaining board members capitulated to Bolckow and Vaughan's demands. Armstrong and Mackenzie were to revalue the business, but with professional legal guidance, and by a separate resolution, Bolckow and Vaughan were offered the £25,000 'on account and without prejudice.'[283]

Whether it was the result of deft legal and financial preparation, or tough bargaining by Bolckow and Dodds, the valuation disagreement demonstrates the difficulties the directors faced in protecting the interests of shareholders. That skilful vendors could outmanoeuvre or manipulate the company into paying an excessive price for the business is also shown by the minimum dividend guarantee referred to above. Simply stated, it ostensibly protected investors by preventing dividend payments to holders of vendor shares until the ordinary shareholders had received a minimum return of 10 per cent a year on average over the first five years of the company. In addition, the vendors would have to repay the company an amount equal to the difference between the actual dividend and 10 per cent if the 10 per cent minimum was not met. A closer examination of the conditions of this guarantee, however, shows that there were numerous exceptions and qualifications. The terms of the guarantee and the imprecise definition of the way in which the minimum average return was to be calculated, therefore, not only failed to protect the shareholders, it also proved to be another lucrative source of company, and thus shareholder, funds for the vendors.[284]

The vagueness of the guarantee can be seen in the terms of the vendors' shares. These were discussed at a directors' meeting on 3rd December 1864, where it was agreed to issue two

[283] BVDM vol. 1, pp. 144-7.
[284] BVDM vol. 1, p. 5.

classes of these shares. Both were deemed to be £50 paid up, but only Class 2 shares had the minimum dividend condition attached. There were, however, a number of qualifications to the dividend restriction. First, if it was possible to declare a 10 per cent dividend on the whole of the shares of the company within the first five years, then the holders of the vendors' shares were entitled to a dividend of the same amount 'without waiting five years to ascertain such average'. Second, any dividend repayments to the company in the event of the average falling below a threshold would apply only if the average fell below 5 per cent and not 10 per cent. Third, the vendors were to be paid interest on the difference between the amount paid up on the vendors' shares (£50) and that called-up on the ordinary shares, initially £17 10s, later rising to £30.[285]

A number of comments are warranted here. Firstly, as there are no details available on the proportion of Class 1 and Class 2 shares issued, it is difficult to judge how much of a protection the clause offered to shareholders. Secondly, the risk of Bolckow and Vaughan having to compensate shareholders was minimised as the average return on ordinary shares that triggered a repayment was set at half the level of the guaranteed minimum. Thirdly, Bolckow and Vaughan had effectively devised something of a sophisticated hedge, or at least a scheme which, by combining the dividend guarantee with the interest payments on the difference in the amount paid on the different types of shares, gave at an insurance against a downside loss but maximised the upside gain, to use modern financial parlance. In the event of dividends being low, the interest payments could be used to make compensation payments, and if profits and dividends were high, these would augment the interest. Finally, as it turned out, the dividend payments in each year were deemed to be above the 10 per cent level, leaving Bolckow and Vaughan with substantial additional earnings from their share ownership. However, as indicated in Table 5.4, it is not certain exactly how the dividends were calculated to be 10 per cent without some rather arbitrary accounting practice. For example, in 1866 the dividend as a percentage of the paid up capital is only 5.7 per cent, but the announced rate was 10 per cent. One way of raising the percentage would have been to value all the shares at £17 10s, the amount paid up on the ordinary shares, giving a 10.4 per cent return; another would have been to exclude the vendor's shares from the definition of capital (11.9 per cent return). As Table 5.4 shows, not only did the company not meet the 10 per cent condition for paying dividends to the vendors in three out of the first five years, but the average for the period fell short of the guaranteed minimum, though not short of the 5 per cent threshold for compensation.

[285] BVDM vol. 1, pp. 11-5

Table 5.4: Bolckow, Vaughan Dividend Payments, 1865-69

Year	Total dividend (£)	Announced dividend	Percentage dividend announced	Actual dividend % on paid-up capital*
1865	75,000	£3 per share on 25,000 shares	10.75	10.75
1866	45,394	Not stated	10.00	5.70
1867	70,625	£2 16s 6d	A little in excess of 10%	7.70
1868	75,000	10%	10.00	8.24
1869	100,000	£3 per share plus a bonus of £1 per share on 25,000 shares	Not stated	11.00
1865-9	366,019			Average: 8.68%

*Author's calculations based on total dividends paid and paid-up capital recorded in the published annual reports and accounts .
Source: BVAR, 1865-69; BVDM, 1865-70.

In brief, the apparently reassuring self-limitation offered by the vendors to the investors that they would not pay themselves dividends at the expense of the ordinary shareholders was not only totally ineffective, but can be seen as little more than a marketing strategy to ensure demand for the shares at flotation. In part it reflects the naiveté of the investors, and this possibly extends to earlier researchers, on the one side, and the financial dexterity, or perhaps duplicity of the company promoters on the other that would almost certainly include Bolckow and perhaps Chadwick too. As Cottrell notes, 'this form of vendors' guarantee on dividend distributions was used again by Chadwick in the 1870s'.[286] It was a successful and lucrative ruse.

Taking the dividend payments and the interest on difference between the paid-up capital on the vendors' and ordinary shares into account, Bolckow and Vaughan benefitted financially to an even greater extent than the estimates above. Table 5.5 sets out these payments and compares them to the dividends paid to other shareholders. For the division of the total dividends, it has been assumed that the vendors and the ordinary shareholders were paid in proportion to the number of shares held, 32 per cent and 68 per cent respectively. Adding these payments to the cash and shares paid for the business suggests that in the first five years of the company Bolckow and Vaughan received over £1.2 million, with £800,000 of that in cash. These enormous sums indicate that far from being motivated to find 'external sources of finance' to expand their business, the primary incentive behind the flotation was to liquidate some of their

[286] Cottrell, *Industrial Finance*, p. 118.

assets tied up in the firm in a way that maximised their yield and at the same time protected their remaining interest in, and control over, a highly profitable enterprise. Having floated the company, however, the firm did, in subsequent years, make use of the capital market that incorporation had facilitated in order to raise funds for capital investment. This is considered in the next section in which comparisons are drawn with another large public flotation, that of Dorman Long, that took place almost twenty five years later.

Table 5.5: Dividends to Shareholders and Interest Payments to Vendors (£)*

Year	Total dividend	Dividends to ordinary shareholders	Dividends on vendors' shares	Interest payments at 5%	Total payments to vendors
1865	75,000	51,000	24,000	27,625	51,625
1866	45,394	30,868	14,526	27,625	42,151
1867	70,625	48,025	22,600	23,375	45,975
1868	75,000	51,000	24,000	17,000	41,000
1869	100,000	68,000	32,000	17,000	49,000
Total	366,019	248,893	117,126	112,625	229,751

*It has been assumed that total dividends were paid to ordinary shareholders and vendors in the same ratio as the number of shares held, i.e. 68:32 (see Table 5.3). Total payments to vendors comprise dividends and interest payments.
Source: BVAR, 1865-69; BVDM vol.1, 1864-70.

5.4 Long-term Finance and Capital Expenditure: A comparison between Bolckow Vaughan and Dorman Long

Bolckow Vaughan

Bolckow Vaughan's 1865 flotation and two cash calls (1866 and 1867) did not and were not intended to raise sufficient funds to cover the cash payment to the two partners for the business. This fact alone indicates that the initial incorporation of the business was not primarily concerned with financing capital expenditure in any direct way. Nevertheless, the phasing of payments to Bolckow and Vaughan meant that there were some funds in the business to support investment in fixed assets, although it was not enough for the whole of the first five years. The accounts show that between 1865 and 1869 capital expenditure amounted to more than £240,000 and as a result the firm had to find alternative sources of funds.[287] This was done

[287] Complete data for fixed investment spending for 1865-69 are not available. The 1868 Annual Report gives the 1865-8 figure as £240,000. For 1869, expenditure was on two main projects – the Skelton ironstone mine and the Middlesbrough salt pits, and was not as heavy. A realistic estimate is about

partly by paying for the Byers Green Colliery, bought in 1865 for £50,000, in instalments over ten years and by an increase in short-term credits – the amount owing on Bills and to short-term creditors more than doubled from £101,474 in 1865 to £230,486 in 1868.[288] Interest payments and dividend policy also ensured that retained profits played little role in generating funds; over the first five years cumulative retained profits (£59,167) amounted to barely one quarter of capital spending, although some caution should be exercised in interpreting the profit figures given the common habit of charging some expenditure on fixed assets to the revenue account.[289] By 1868 the firm was in need of additional long-term funds and a two-year loan for £100,000 from Bolckow and Vaughan had to be arranged.[290]

But while the original flotation of the company may have had little to do with financing capital investment, it would be wrong to conclude that the capital market was not important to, or used by, the company. The prospect of heavy investment in (Bessemer) steel production, the associated development of hematite mining interests in Spain in the early 1870s and the generous dividend payments, which averaged 90 per cent and ranged from 78 to 105 per cent of net profits (1865-70), meant that further funds were needed to maintain the firm's expansion. Table 5.6 shows that for the first half of the 1870s retained profits covered just fifteen per cent of capital spending and the firm went to the capital market for the bulk of its long-term finance. From 1870 to 1876 it raised over £450,000 from ordinary shareholders and £½ million in debentures, thirty-three and fifty-five per cent of gross funds respectively. Over the longer period, up to 1887, shareholders contributed £1¼ million, forty-four per cent of gross funds, with most of this coming in the form of cash calls on the partially-paid, high denomination (£100) shares that were issued at incorporation.[291] It was a method of raising finance that gave considerable flexibility to the company as they were able to rely on shareholders for additional funds at short notice and without the inconvenience of calling an Extraordinary General Meeting (EGM), although it added to shareholder risks.

£10,000 to £20,000, making the five-year spending in the region of £250,000 to £260,000. BVAR 1868, p. 7; BVAR 1869, p. 7.

[288] BVAR 1865 and 1868.

[289] For example, in the 1871 accounts £49,355 of capital spending was charged to the revenue account (BVDM vol. 3, p. 98). More generally, given the problems of early company accounts, the figures from the annual reports and accounts in this and subsequent chapters should be considered indicative rather than entirely accurate. For a discussion of some of the issues see A.J. Arnold, 'Should historians trust late nineteenth century company financial statements', *BH*, 38 (1995), pp. 40-54, and references therein.

[290] BVDM, vol. 2, 21 Oct. 1868, pp. 99-102; BVAR 1868, p. 7.

[291] The company made seven calls between 1866 and 1879, amounting to over £1.2 million.

Table 5.6: Sources of Funds – Bolckow Vaughan, 1870-1914 (Totals)[a]

	1870-6		1870-87		1888-1914	
	£	% gross funds	£	% gross funds	£	% gross funds
Ordinary shares:		--	--	-	--	--
New issues	--	--	240,660	8.6	--	--
Cash calls	375,000	33.1	1,005,640	35.8	--	--
Preference shares	80,440	7.1	312,080	11.1	--	--
Debentures	499,181	44.0	698,267	24.9	934,920	29.0
Retained profits	179,904	15.9	545,952	19.7	2,263,297	71.0
Gross funds raised	1,134,525		2,802,599		3,198,217	
less Loan/debenture repayments	111,000		352,175		684,775	
Net funds	998,362		2,450,424		2,513,442	
Capital expenditure	1,211,400		-		3,548,017	
Retained profits % capital expenditure	15.0				63.8[b]	

Notes;
a: the figures refer to the totals, i.e. cumulative amounts, for the period shown.
b: 1896-1914.
Sources: BVAR 1870-1914 and BVDM, 1870-1914.

More attractive for the risk averse were the preference shares that the company offered to general investors from 1876. In addition to the guaranteed dividend of 5 per cent, these shares were of a lower denomination (£20) and fully paid. They were originally introduced as part of the capital restructuring on the expiration of the vendors' shares issued to Bolckow and Vaughan.[292] At two EGMs in February and April the nominal preference share capital was raised by £240,000 to £400,000, after which circulars were sent to existing shareholders inviting applications. The directors' minutes and annual accounts show a steady flow of applicants until the limit was reached in 1880. Later, in 1882, the limit was raised by an additional £100,000, although this was not fully taken up until 1887. Overall, these preference share issues raised over £300,000 between 1870 and 1887, making a small but significant contribution to the inflow of funds to the firm (11%). After 1887 there were no further issues, and although there are no indications as to why, one possibility is that alternative forms of finance became cheaper. By the 1890s debentures offering an interest rate of 4 to 4 ½ per cent were less costly, and with fixed terms, the potential to refinance at market interest rates, which may fall, and the

[292] The vendors' shares, valued at £400,000, were exchanged for 8,000 5% preference shares of £20 (fully paid) and 8,000 Ordinary Shares of £100 (£30 paid), BVDM vol. 2 (notice of EGM between pp. 357-8).

opportunity for early redemption, they offered firms greater control over their liabilities and interest payments.[293]

Debentures were considered by Bolckow Vaughan's directors as early as 1868, but blocked by Henry Bolckow, who argued that as he was attempting to raise a mortgage at the time, thought it would be 'injurious to his interests'.[294] The first issue was in 1871 following a board discussion on how to finance a substantial increase in planned capital spending of £261,000 for the second half of 1871 and 1872.[295] It proved a highly successful source of funds. The initial agreement was to raise was £100,000 at five per cent (or less) for terms of three, five and seven years and this was soon increased to a maximum of £200,000. The funds were raised by the end of 1873, but heavy expenditure on Bessemer steel plant and increasing blast furnace capacity at this time meant that there was a steady need for funds and in March 1874 the firm sought and obtained permission from existing debenture holders to increase the total issue to £500,000. The additional £300,000 was raised through five, seven and some ten year bonds paying 5 per cent, though this had fallen to 4½-¾ per cent in 1876. At first the issues were offered to existing shareholders, and applications, which were directly to the firm, came from individual investors. There were, however, early indications of institutional investment, with an application in June 1871 for £50,000 of five year bonds from the United Kingdom Temperance and General Provident Institution.[296]

From the last two decades of the nineteenth century companies relied increasingly on loan capital. For a sample of brewing companies Watson found that the proportion of subscribed capital in the form of debentures had risen from nine per cent in 1885 to 38 per cent in 1895 and to 43 per cent by 1910. In her sample of iron and steel companies the dependence on debentures was less marked but still rising: the equivalent figures are 13 per cent in 1885 and 19 per cent in 1910.[297] Bolckow Vaughan's debenture issues were part of this trend and broadly in line with the industry average. Their issues can be divided into two main phases. The first phase, from the first issues in 1871, saw debt rise to peak at 22 per cent in 1875 and subsequently decline for the next 25 years as redemptions exceeded renewals. Over the three decades from 1871-99 the average debt level was 12 per cent. By 1900 all the debentures had been repaid and the firm relied on retained profits and short-term bank borrowing for funds.

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[293] BVDM vol. 4, 27 March 1876, p. 255; 27 Oct 1876, p. 299; BVDM vol. 9, 21 Oct 1891.
[294] BVDM vol. 2, 21 Oct. 1868, p. 99; 27 Nov. 1868, pp. 107-8.
[295] BVDM vol. 2, 24 Feb. 1871, p. 397; vol.3, 22 Aug 1872, p. 190; *Circular to Shareholders*, vol. 4, p. 25; vol. 4, 15 June and 19 Dec. 1876.
[296] BVDM vol. 3, 21 June 1871, p. 34.
[297] Watson, 'New issues', p. 233. For German corporations as a whole, bonds as a proportion of total liabilities was similar to that for British iron and steel companies: 15-18 per cent between 1895 and 1912, C. Fohlin, *Finance Capitalism and Germany's Rise to Industrial Power* (Cambridge, 2007) pp. 172-5.

However, falling profits and unchanged dividend payments meant that by 1905 the firm's financial position had become precarious, with bank overdrafts reaching £ ½ million by the end of 1904. At the February board meeting the company secretary (W.W. Storr) reported a total overdraft of almost £600,000 with three banks (National Provincial, London, City and Midland, and Williams Deacons). To ease the pressure on the company he had already negotiated with the Middlesbrough manager of the National Provincial a deal that would allow the company to increase its overdraft above the arranged level 'without for the moment specifying a limit.' Clearly this would not have been an open commitment from the bank; the condition may well have been that the company should seek longer-term finance through another debenture issue as the minutes of the same board meeting record that the company secretary was 'authorized to inform all the Company's Bankers of the intention of the Board to issue Mortgage Debentures'. The proposal was to issue up to £1 million 4% Debentures and to offer these to current shareholders and 'the clients of Brokers dealing in the Company's shares'. By April a circular had been sent out to shareholders inviting applications and explaining that the funds were needed to repay the firm's bankers and to finance capital spending.[298]

This second phase of debenture issues was highly successful and crucial in helping the firm through a difficult period. In the six years up to 1911 over £850,000 was raised, but most importantly it brought an immediate easing of the short-term cash problem. By December 1905 the overdraft had fallen from its March peak of £709,000 to £403,000, and less than £200,000 in August the following year. The combination of the inflow of long-term borrowing (£587,500 by mid-1907) and a significant recovery in profits meant the firm was able simultaneously to reduce the overdraft (under £100,000 by February 1907), maintain capital expenditure and increase dividend payments. In 1912 repayment of long-term debt had started, and as a proportion of total shareholder capital it began to fall from twenty-one per cent to seventeen per cent in 1914. The firm therefore entered the War without an excessive debt problem unlike the one it would have to face in the 1920s, and which would bring about its eventual demise in 1929. However, it was the firm's good fortune that profits were buoyant. As Tolliday has pointed out, and contrary to Pitts's view, this pattern of reliance on short-term bank finance that was corrected from time to time by the issue of longer-term debt was established well before 1914.[299] Indeed from the early days of incorporation Bolckow Vaughan repeatedly renewed its bank borrowing, as the few examples in Table 5.7 show. It was a risky policy, but one that

[298] BVDM vol. 13, 23 Feb. 1905, pp. 89-91; 30 Mar. 1905, p. 98.
[299] Steven Tolliday, *Business Banking, and Politics: The Case of British Steel, 1918 – 1939,* (Cambridge, MA, 1987), pp. 67-68; Marianne Pitts, 'How are the mighty fallen: Bolckow Vaughan Co. Ltd. 1864-1929', (Warwick Business School: 2007), pp. 13-17. Pitts suggested there was no evidence that the company relied on banks for working capital before 1914.

could be managed when there was confidence that cyclical reductions in profits would recover, as they did in the pre-War years; however, it was one that could not be sustained when the industry remained depressed over prolonged periods.

Table 5.7: Examples of Bolckow Vaughan Bank Borrowing

	Details	**Source (All BVDM)**
1873	£75,000 from National Provincial Bank. 5%, repayable in three monthly instalments. £50,000 from Glyn Mills. Bank rate plus ½%, repayable in three monthly instalments.	vol. 3, 26 Sept. 1873, p. 318
1877	Renewal of £100,000 loan from Glyn Mills for a further two months at the Bank Rate plus ½% (with a minimum of 3½%).	vol. 5, 19 Jul. 1977p. 35
1883	£50,000 from Glyn Mills. Four months at 4%, with 5% preference shares as security.	vol. 6, 3 April 1883, p. 274
1894	Renewal of £50,000 loan from National Provincial for a further six months at Bank Rate plus ½% (minimum 4%).	vol. 9, 7 Jul. 1894, p.317

Dorman Long

The details of the conversion of Dorman Long into a limited company in 1889 are similar to Bolckow Vaughan and many other firms whose ordinary shares were offered to the general investor. That is, it was primarily a means of liquidating the owners' capital, but in a way that control over the business was retained by the original partners. There are, however, a number of differences from the Bolckow Vaughan experience that indicate some of the developments in the capital market and the practice of floating and financing companies that had taken place in the intervening twenty-five years.

At Dorman Long's flotation, £520,000 was raised through the issue of £350,000 ordinary shares and £170,000 debentures. As payment for the business, which was valued at £467,000, the partners Arthur Dorman and Albert Long received one-third of the share capital and took £90,900 in debentures, taking the balance of £261,000 in cash. This left just £53,000 injected into the firm as a result of its incorporation (Table 5.8). While modest, these additional funds are in contrast to Bolckow Vaughan where there was a net outflow over the five years after incorporation.[300] There are also a number of other noteworthy contrasts between the firms. First, the shares were issued at a lower denomination of £5 rather than £100 of the earlier flotation, and were fully paid-up (by instalments within weeks of issue) rather than being left

[300] Without a loan from Henry Bolckow in 1869, the deficit on long-term funds and retained profits would have been £22,368.

with a substantial unpaid portion that exposed investors to future calls. These two details are significant as both increased the attractiveness of the shares to investors: they facilitated secondary market trading and reduced the risk of future of claims against shareholders. For the firm, however, it meant that additional funds could not be called on automatically. Second, debentures were issued at the formation of the company, and these were for a longer term of ten years rather than the three, to seven years for Bolckow Vaughan's first issue. Moreover, paying the vendors in part by debentures meant that the company was not burdened with a special debt to the former owners that had to be paid before other creditors. Dorman Long also made no use of other types of shares with special privileges, e.g. preference shares, although one of its subsidiaries, Bell Brothers, did (see below).

Table 5.8: Sources of Funds – Dorman Long, 1889-1914 (Totals)[a]

	1889-98 £	1889-98 % gross funds	1899-1914 £	1899-1914 % gross funds
New share issues	235,000[b]	51.5	425,000	17.9
Calls	--	--	--	--
Debentures (gross)	79,100[c]	17.3	1,150,000	48.5
Retained profits	142,499	31.2	796,997	33.6
Gross funds raised	456,599	100	2,371,997	100
less Repayments/debenture redemptions	261,000[+]		428,500	
Net funds	195,599		1,943,497	
Capital expenditure	162,521		643,143	
Acquisitions (cash payments)			457,709	
Retained profits % capital expenditure	73%		123.9%	

a: the figures refer to the totals, i.e. cumulative amounts, for the period shown.
b: Share and debentures in 1889 are net of the allocations to Arthur Dorman and Albert Long at incorporation.
c: 1889 repayments comprise the cash payments to Dorman and Long for the business.
Sources: DLAR 1889-1914 and DLDM, 1889-1914.

Unlike Bolckow Vaughan, Dorman Long therefore needed to make no further use of the capital market for the first ten years of incorporation. Capital expenditure, at 73 per cent of retained profits, was more than adequately financed from internal sources (and short-term borrowings). It was a position helped by adopting a far less generous distribution policy than its larger rival. Total dividend payments between 1890 and 1898 were 54 per cent of net profits; the equivalent figure for Bolckow Vaughan in its first five years was 91%. A marked change, however, came in 1899-1900 at the time Dorman Long embarked on a major expansion through heavy investment in the basic open hearth steel process, extension of facilities at its Britannia plant and a series of acquisition (see Table 5.9 and Chapter 7 below). Financing this scale of growth for a relatively small company whose profit after interest payments averaged around £40,000 per year was feasible only through additional long-term funds, and these were raised in the conventional ways from the capital market by two new share issues and a series of debenture issues.

Table 5.9: Dorman Long Expenditure on Acquisitions, 1898-1914 (£)

		Form of Payment		
		DL shares issued	Cash	Total
Ayrton Sheet Works	1898	--	75,000	75,000
Cleveland Wire Works	1900	--	75,000	75,000
Bell Brothers	1899-1902*	225,000	195,000	420,000
NESCo	1903	259,640	19,909	259,604
Wade and Dorman Co Ltd	1911	--	25,000	25,000
Bowesfield Steel	1912	--	20,300	20,300
Channel Collieries	1913-4	--	47,500	47,500
Total		484,604	457,709	942,313

*This figure includes calls made on Bell Brothers shares in 1902, 1905, 1905 and 1913.
Sources: DLAR 1889-1914 and DLDM, 1889-1914.

The first increase in share capital came at the time the company bought up a sheet works, a wire works and first took a financial interest in Bell Brothers. Arthur Dorman's (the chairman's) explanation to shareholders was that new capital was needed to pay for, extend and improve the sheet works; but there was clearly a more general financial strategy being planned for the firm's expansion. And this included not just taking a stake in Bell Brothers, but also making a bid for Bolckow Vaughan (see Chapter 7). At the 1898 September board meeting that involved the firm's auditor W.B. Peat, there was an important discussion on the company's financial position and how to raise the necessary funds. It was decided that the ordinary share capital should be increased by £210,000 (sixty per cent), though this was scaled back to £175,000 at a later board meeting, and the final plan was agreed by shareholders at the EGM in December. The shares were offered to existing shareholders in the ratio of one new for two existing shares, effectively a rights issue, with Arthur Dorman underwriting the issue by taking up the unallocated shares.[301] This was soon followed by a second share issue in 1902. It was made at the time of the full takeover of Bell Brothers when Dorman Long acquired the second half of the share capital

[301] DLDM vol. 1, 18 Oct 1898, pp. 240-2; 8 Nov 1898, pp. 243-6; 1 Dec 1898, pp. 250-2.

(£300,000 nominal, £210,000 paid up) from the Bell family. The EGM of September 1902 authorised an increase in the firm's nominal ordinary share capital by £475,000 to £1 million, £225,000 of which was to be used to exchange for the remaining Bell Brothers shares. The rest raised cash of £250,000, with half of the shares allocated to existing shareholders (one new share for three existing shares) and the remainder taken by Arthur Dorman (90,000 shares) and Hugh Bell (35,000).[302] There were no further share issues in this period except on the takeover of NESCo the following year when additional Dorman Long shares were created to exchange for those in NESCo. The terms of the deal were that following an increase in authorised capital to £1.5 million, Dorman Long offered three of their own shares for each one of NESCo's (with cash paid for fractions of shares), and by the time the acquisition had been completed 258,541 £1 Dorman Long shares had been exchanged for 78,554 shares (£3 paid up) in NESCo plus cash payments of £19,909.[303]

Of over £900,000 of new shares issued after flotation, just under half generated additional cash for the firm, and the rest were used to pay for acquisitions. The additional cash amounted to only eighteen per cent of the gross long-term funds raised between 1898 and 1914. As Table 5.8 indicates, the principal source of funds was not from the share issues but from retained profits and, most significantly, from the capital market in the form of debentures. Up to 1914 there were three debenture issues raising over £1 million (net £722,500), in 1900, 1904-5 and 1914, that is nearly half the long-term finance for the business. In this increasing dependence on debentures Dorman Long was much like other companies of the period, including Bolckow Vaughan, as was indicated above. What marks out Dorman Long is its far greater reliance on debentures, with the effect the company operated with a much higher level of gearing. At an average 32% (1890-1914) this was considerably above the industry averages of the time estimated by Watson, although it is not excessive by modern standards. Perhaps even more striking is that when the Dorman Long group of companies is examined, the dependence on debt finance is shown to have been even greater (Table 5.10). There were no group accounts presented at the time, but combining the separate accounts of the two major wholly owned subsidiaries, Bell Brothers and NESCo, it is possible to provide an indication of the group's gearing. As Table 5.10 shows, both subsidiaries were highly geared, and this contributed to an overall group gearing of 50 to 60 per cent, depending on the way in which Bell Brothers' preference shares are classified.

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302 DLDM vol. 2, 22 Oct 1902, pp. 142-3.

303 DLDM vol. 2, 10 June 1903, pp. 178-80; 22 June 1903, pp. 183-3.

Table 5.10: Dorman Long Companies' Gearing (%)

	Dorman Long	Bell Brothers A*	Bell Brothers B*	NESCo	Dorman Long Group A*	Dorman Long Group B*
1904	32.8	39.1	78.2	49.9	54.4	61.3
1909	32.8	34.2	73.9	46.2	50.3	57.5
1914	37.9	28.2	66.0	43.7	49.1	55.7

*Gearing is defined as: Long term debt/ (Long term debt + Shareholders' funds).
Bell Brothers and DL Group gearing is calculated in two ways. 'A' does not include preference shares as debt; 'B' includes preference shares as debt.
Sources: calculations from DLAR, BBAR, NESAR, 1904, 1909, 1914.

These high and, from 1900, rising rates of corporate borrowing suggest that there was a receptive market for the debt of industrial companies. But, as would be expected, the cost and ease of raising funds varied with both general economic conditions and company performance. Dorman Long's 1900 debenture issue, despite being offered at an interest rate lower than the retiring debt (four as opposed to five per cent) was oversubscribed by almost 70 per cent and had to be scaled back so that only about half of the applications from the public were accepted. Of the other applicants, that is, the existing debenture holders and the shareholders, only the latters' allocation was reduced.[304] A year earlier the Bell Brothers debenture and preference share issue was even more oversubscribed. For the £333,600 of debentures offered for public subscription, applications (£2,466,542) exceeded the amount available by a factor of 6.7. And for the 33,340 preference shares (£10) the oversubscription was even more dramatic, with demand greater than availability by a factor of 15.5. As Hugh Bell reported to the board, the subscription list was closed by noon of the day of opening (26th January 1899) and had been advertised only on the two preceding days.[305] Dorman Long's issue in 1914 was not so spectacular, but was again sufficiently well subscribed that the list had to be closed on the opening day at 11.30 a.m.[306]

Debenture issues did not always run so smoothly, however. In 1904 Dorman Long found it rather more difficult to raise £250,000 from investors. It was at a time when the company was barely profitable, had paid no dividends for two years and it also followed shortly after a £250,000 share issue in 1902. Despite an interest rate of 6 per cent, applications from the public were just £36,650 and the firm had to rely on the underwriters (Edinger and Asch) to place £111, 350 of the £150,000 that they had agreed to underwrite with the 16 sub-underwriters. The

[304] Total application amounted to £675, 810, most of which came from the public (£518,115). The remainder came from debenture holders wanting to convert (£67,200) and shareholders (£91,895). DLDM vol. 2, 1 May 1900, pp. 2-3.
[305] BBDM vol. 1, 22 Feb. 1899, p. 10; 1 Mar. 1899, pp. 12-13.
[306] *Times*, 28 May 1914, p. 19; DLDM vol. 3, 9 June 1914, pp.227-9.

balance, £100,000, was taken up by Hugh and Charles Bell (£50,000) and other directors or their relatives and friends.[307]

The fact that the directors acted as underwriters – and Dorman Long's were not alone in this – means that the total amount of debt issued by companies tends to overstate firms' reliance on, and the importance of, the wider securities market. But companies resorted to this form of underwriting only in difficult periods and there was always the likelihood that the debentures could be sold on to other investors in the secondary market as conditions improved. A more important reason for caution in using the total debenture issues as a measure of dependence on external debt, and as a way of assessing the size of the debt securities market, is that debentures and preference shares were often used to pay for the business at incorporation. This was the case with Dorman Long (see above) and also Bell Brothers in 1899. For Bell Brothers, of the £900,000 price paid to the Bell family for the original (private) company, one third was paid in debentures or preference shares, £133,400 and £166,600 respectively. Thus out of the £1 million apparently raised from the creation of these two types of security (£500,000 of each), the total debt issue overstates the funds from the market by approximately 40 per cent.[308] The Stockton iron and engineering company Head Wrightson provides another example. On its incorporation in 1890, £150,000 debentures were created, of which £120,000 were allocated to the former partners, Charles Head and Thomas Wrightson, as partial payment for the firm. In this case therefore only one-fifth of the debentures were sold directly to the public, and this generated just £30,000 in cash.[309] A related practice that was used by some nominally private limited companies was to issue debentures to the directors in return for loans to the company. In 1874 Bell Brothers borrowed £150,000 by issuing debentures to the three principal shareholders – £75,000 to Lowthian Bell, £35,000 to Thomas Bell, and £40,000 to John Bell.[310] Another iron firm, Samuelson's, also borrowed from its principal shareholder (and also chairman and managing director) Bernhard Samuelson in the same way.[311]

In each of these cases, using the total value of debentures issued has the same effect of overstating the significance of these securities as a means of obtaining finance from the open capital market. But even with this qualification in mind, it is clear that debentures grew in importance from the end of the nineteenth century, and from the evidence of two large

[307] DLDM vol. 2, 20 May 1904, pp. 236-9.
[308] Bell Brothers *Prospectus*, 1899, in BBDM vol. 1, pp. 1-15.
[309] Head Wrightson *Prospectus*, 1890, in HWDM vol. 1; see also HWDM vol. 1, 23 Sept. 1890, pp. 9-15, Teesside Archives U/HW/1/1.
[310] BBDM vol. 1 (old series), 20-22 June 1874, paragraph 81; 3 Aug. 1874, paragraph 96. This is just one of several examples of debentures that were issued when the Bell family made loans to their company.
[311] The balance sheet for 30 June 1888 shows £60,000 debentures held by Samuelson (SBSDM vol. 1, 28 Aug 1888).

Cleveland iron and steel companies looked at in this section, they became the principal source of long-term external finance. This is not surprising as debentures gave firms access to funds without the problem of diluting control over the company, and for investors, they offered a safer asset than equities with a more assured return. For the companies they also proved to be a highly flexible financial tool. As Capie and Collins have demonstrated, banks were increasingly willing to hold debentures as security for loans and overdrafts. Their study found that between 1880-4 and 1910-4 the proportion of loans secured in this way rose from just 1.1 per cent to 15 per cent.[312] Debentures also provided firms with a method of converting short-term bank debt into longer-term securities, as Bolckow Vaughan was able to do in 1905. Dorman Long's issue in 1904 was probably made under similar, if less dramatic, circumstances: shortly before the decision to issue the debentures (May), Arthur Dorman had agreed a six month overdraft of up to £100,000 with Barclays.[313] A more direct process of securitisation occurred when debentures were issued to creditors, as Bell Brothers did in 1877 by issuing debentures to a Mr Lightfoot 'for the amount standing to his credit'.[314] And finally, in some cases where a firm's directors were required to provide personal guarantees for bank borrowing, the guarantors would be indemnified by the firm through the issue of debentures. NESCo for example offered its bankers, Backhouse's, a guarantee of £8,500 on the bank account from five of its directors and set aside £7,500 of its debentures to be issued to the guarantors in the event that any claims were made.[315]

5.5 Conclusions

This chapter has shown that in Cleveland's iron and steel industry there was a variety of reasons why firms sought joint-stock status. These ranged from the formation of brand new enterprises or the straightforward conversion of profitable partnerships on the one hand, to the re-floating of failed firms or the formation of new ones to buy up the idle plant of defunct businesses on the other. Amongst the examples, it is possible to find cases that cover all of Jefferys' four reasons, viz. financing investment in new capital, extending the sources of capital, the retirement of the owners, and the disreputable and 'semi-fraudulent' avoidance of bankruptcy.[316] However, a detailed examination of the industry does not support the 'growth view', i.e. that the changes needed to happen to accommodate the growing scale of capital investment, or at least not in a direct way. The fairly high proportion of private companies suggest that the protection of

312 Forrest Capie and Michael Collins, 'Banks, industry and finance, 1880-1914', *BH*, 41 (1999), pp. 44-7.
313 DLDM vol. 2, 9 Mar. 1904, pp. 227-9.
314 BBDM vol. 1, 11 Nov. 1877, paragraph 277.
315 NESDM vol. 1, 28 Mar. 1884, pp. 141-2.
316 Jefferys, *Business Organisation*, pp. 58-9, 109-10; Birch, *Iron and Steel*, pp. 206-7.

limited liability was an important motive, contrary to Jefferys' assertion, as does the detailed investigation of the flotation of two large Teesside firms, Bolckow Vaughan and Dorman Long. For these, especially the former, the principal motivation, or at least the immediate concern, of the partners appears to be the liquidation of the partners' capital and not the generation of funds for capital investment. Together, these two points show that it is necessary to separate the implications of the changes in corporate legislation, that is, the decision to incorporate from the public flotation of a company. Whilst incorporation is necessary for flotation, it is not sufficient; and the decision to float publicly depended on numerous factors, not least was the access it gave to the means by which vendors could capitalise their past entrepreneurial efforts.[317]

Although the intentions behind the mid-century changes in corporate legislation were not specifically to help industry raise funds, but to find a more effective form of regulating the financial market – the 'socio-political view' – it does not mean that in practice the Joint Stock Acts did not have this effect, amongst others. What the experience of some of the Cleveland iron and steel firms has shown is that the companies used the legislation flexibly and in different ways. It opened up opportunities for the exploitation of the capital markets and gave access to investors' wealth which firms could tap according to their objectives or requirements. At times this was indeed to raise capital for a new company or for the development of a new process, as in the case of NESCo and the development of basic Bessemer steel in the early 1880s. After being floated, companies were able to go to the market for additional funds. In the early years this was through cash calls on the high denomination shares that had been issued at incorporation. Once this avenue had been exhausted or was foregone because it risked upsetting shareholders, there were opportunities for new issues of ordinary shares, or even preference shares – more costly but safer for investors. Later, there was increasing reliance on the debt securities market as debentures became the favoured instrument.[318] Debentures, along with retained profits, provided most of the funds for capital investment, and where excessive short term debts, usually in the form of bank overdrafts, had been built up, they gave a means of converting the debt into longer term, more manageable liabilities. The growth of the securities

[317] Other instances, e.g., the flotation of Arthur Guinness & Co. Ltd in 1886, can be found in Janette Rutterford, 'Valuing equities in the UK and US: fashions and trends', in G. Poitras (ed.), *Handbook of Research on Stock Market Globalization, Volume 1* (Cheltenham, 2012), p. 119.

[318] In Germany there was a similar reduction in equity finance and an increasing reliance on debt (Fohlin, *Finance Capitalism*. p. 219). The appeal of debentures can be easily understood in financial markets with significant information asymmetries and where investors had, in the past, suffered losses from fraudulent share issues. They offered more stable returns and greater security for the investment. For companies also they had an advantage: the dividend was distributing amongst fewer shareholders. For a discussion of some of the issues see J.J. Baskin, 'The development of corporate financial markets in Britain and the United States, 1600-1914: overcoming asymmetric information', *Business History Review*, 62 (1988), pp.212-22.

market, especially for debt, also meant that even in difficult times funds could be raised by issuing debentures (and sometimes additional ordinary shares) to the directors and their families in the knowledge that as market conditions improved the securities could be sold on to other investors.[319] The banks too were willing to lend, at least temporarily, on the security of debentures. And to make the debentures more attractive, there is even an instance of a Cleveland company that attached an 'equity kicker', i.e. a right to buy shares on maturity.[320]

Another important feature facilitated by incorporation and the expansion of the securities markets was the development of the takeover process. This is shown by Dorman Long's acquisition of Bell Brothers and NESCo, and its attempted takeover of Bolckow Vaughan. Similar developments were evident in the formation of two other inter-related iron and steel companies on Teesside – South Durham Steel and Cargo Fleet Iron.[321] Exchanging shares enabled the reorganisation and change in ownership of businesses without the need to make substantial cash payments. It made possible improvements in the efficiency in the use of real assets, although there is some dispute over whether, in these early days of takeovers and amalgamations, the required restructuring and new investment were forthcoming.[322]

All in all, it is too simplistic to consider the advent of widespread incorporation and the parallel developments in financial markets as solely geared towards the financing of larger scale enterprises In reality there was a complex interaction between business and financial markets, and raising funds for capital investment was important, but not exclusively so. There were other reasons why firms sought finance from the investing public and institutions, and other ways in which the legal institution of corporate status and the ownership rights embodied in shares were used. A further effect was that for some firms the relationship with the financial markets became an increasingly important part of their business operations. They were keen that their shares and debentures were registered to be traded on the country's stock exchanges and there is evidence that there was a growing interest in the market performance of their securities. From 1902 Dorman Long monitored the volume and price of shares and debentures traded on stock exchanges and the data was reported at the monthly directors' meetings.[323] Whether this marks an early instance of the British form of short-termism in which the financial aspects of running a business began to dominate the productive side is not clear. Nor is it certain whether the financial sector denied funds for capital investment. The experience of the two large companies

[319] Arthur Dorman and another director in Dorman Long, W.H. Panton, were criticised at the 1904 AGM for selling a part of their shareholding in the company. DLAR 1904, pp. 17-8.
[320] NESDM vol. 1, 27 May 1887, pp. 244-6 and p. 249.
[321] Boyce, 'Cargo Fleet Iron Company', pp. 847-8. See also Chapter 7 below.
[322] Chapter 7 below examines Dorman Long's experience.
[323] For the first entry see DLDM vol. 2, 8 Oct. 1902, p. 138.

investigated in this chapter suggests that there does not seem to have been a shortage of funds available – finance could be readily raised by issuing shares and debentures when industry prospects looked bright. Nevertheless, there was still criticism from the industry, as when Arthur Dorman complained to shareholders that attempts to invest in improvements were ‘fettered by the difficulty of getting capital’.[324] He went on:

> British Capital...is largely being invested abroad. Our home industries are not attracting it, yet I cannot help thinking there is an excellent prospect for its profitable employment in our own country. If capitalists should be persuaded of this, and give their aid to the development of British industries so as to enable us to reduce the cost of manufacture by the judicious extension and improvement of existing plant, I think they would not have cause to regret it.

In this study there is not sufficient evidence to make a conclusive judgement on whether British firms’ investment decisions were constrained by the capital markets. What is clear, however, is that on incorporation the vendors were often paid, or paid themselves, too high a price for the business and in subsequent years there was a tendency in some firms, exemplified by Bolckow Vaughan, to distribute excessive dividends, leaving the firm short of funds or dependent on external sources.

[324] DLAR 1911, p. 15.

Chapter 6: Technology and Products

6.1 Introduction

> I am very glad to find the important question of the basic process, as carried on in the open-hearth furnace, taken up by the Cleveland Engineers… To Cleveland it is a question of the utmost, indeed of vital importance. We first lost our rail trade, then the plate trade, and other branches of our manufacturing may also disappear by steel taking the place of ordinary malleable iron.[325]

This statement by Lowthian Bell, the é*minence grise* of British iron and steel, captures succinctly the repeated adaptations Cleveland's iron and steel industry had to make to maintain its prosperity through the last quarter of the nineteenth and first decade of the twentieth centuries. It was an industry built on iron, but after demand peaked first in the 1870s and then in the early 1880s, and was afterwards undermined by the shift to steel, the Cleveland ironmasters felt that their very existence was threatened. This chapter considers the process of adjustment to the new material – steel – examining in particular how Cleveland firms took steps to meet the technological challenges.

It is possible to identify a number phases in the way in which the district adapted and sought to re-establish itself as Britain's principal producing centre, though this time for steel rather than iron. The first phase was the adoption of Bessemer steel converters in the 1870s, notably by Bolckow Vaughan. This firm employed the acid process using imported hematite ore mainly from Spain, substituting it for the unsuitable, high phosphorus, Cleveland iron that was smelted from local ironstone. The second followed Thomas and Gilchrist's development of the basic process in 1878-9. This seemed to unlock the potential for using the lower quality local iron and gave rise to an expansion in basic Bessemer production, again involving Bolckow Vaughan, along with a newly established firm, North Eastern Steel. Problems with the acceptability of basic Bessemer, or Thomas, steel, especially concerns about its quality among plate and girder makers and users, resulted in the third phase, the investment in acid open-hearth (Siemens-Martin) furnaces from the mid-1880s. Finally, and most successfully, there was the eventual adoption of the basic open-hearth process, which after a long gestation period, dominated steel production from the early 1900s on Teesside, and later worldwide.

The emphasis of the chapter is on the development of basic-open-hearth production and its application on Teesside; the advent of the process seemed to settle thirty years of turbulence and

[325] Delivered to the Cleveland Institution of Engineers on 19 Jan. 1891, *CIE* (1890-3), p. 143.

uncertainty in the district's industry, during which time attempts to meet the technological challenges were never entirely satisfactory. Its importance to Cleveland is that it ensured the survival of mass steel production and a return to prosperity for the area's firms in the years before the First World War. This aspect of the area's industrial history appears to be understated in other histories.

The chapter is divided into four main sections. The first outlines principal trends in iron and steel production between the late 1870s and 1914, drawing particularly on data from the British Iron Trade Association and the *Iron and Coal Trades Review*. The second section reviews the principal shifts in production and technology from the 1870s to the early 1890s, covering early Bessemer production, the introduction of basic Bessemer steel and the acid open-hearth process. The third section discusses the development of the basic open-hearth process and its eventual adoption by Cleveland's steel firms. It is demonstrated that far from being backward, insular and not open to the adoption of new production methods and ideas, they responded to technical advances outside the district and were active in applying those techniques in Cleveland. It took time, however, as the steel producers faced severe technical difficulties. The changeover, when it came, was also a response to economic signals both from the supply and the demand side. On the supply side there was pressure to react to changing input costs, notably the relative costs of overseas and local ore, and on the demand side there was the eventual acceptance of basic open-hearth steel as a product of equal, if not superior, quality to acid steel. The chapter also suggests that throughout the period of the development of the open-hearth process, there was considerable interest in the technical developments. These were shared through the networks of steelworks managers, engineers, scientists and metallurgists, often at meetings of the industry and professional associations. There was also a movement of staff between firms. Moreover, information that was exchanged in these ways occurred both within Britain and between Britain, the US and Continental Europe. Incorporation and maturity in the industry may have reduced the extent of "collective invention" so characteristic of the earlier phases of the Cleveland industry, but it still remained to some extent at the national level.[326]

6.2: Trends from 1880

The early 1880s marked the peak for the iron industry in Cleveland. The growth in pig iron production had paused during the 1870s recession before resuming its upward path, but it was the specialisation in manufactured, or malleable, iron that left the district vulnerable to

[326] Allen, 'Collective Invention', pp.1-2.

technological change and shifts in market demand towards steel. At the beginning of the 1870s production reached over 750,000 tons per year, driven largely by the demand for rails. Rails made up over half of the total output of manufactured iron, with plates accounting for the next largest source of demand at thirty per cent (Table 6.1). The demand for iron, and iron rails in particular, collapsed as the industry was caught between the slowing of railway expansion in Britain, the increasing difficulties in penetrating protected overseas markets, and the switch to Bessemer steel rails. In 1884, at 3,500 tons, rail production was barely one hundredth of the level in 1872-3, and accounted for less than one per cent of total manufactured iron output. This might have spelt the end of much iron processing on the Tees, and did result in the collapse of numerous firms (see Chapter 5). From the end of the 1870s, however, the slack was taken up by the production of ship plate for the growing iron shipbuilding industry. As Lowthian Bell's report for the *Royal Commission on the Depression of Trade and Industry* shows, the gross tonnage of British built shipping doubled between 1878 and 1883 from 522,160 tons to 1.1 million, with the vast majority (85 per cent) being of iron.[327] Responding to this shift, Cleveland's iron manufacturers rapidly adapted their mills and changed over to plates, with manufactured iron production rising sharply from a trough in 1878 to peak at over 850,000 tons in 1882. Plates accounted for over two-thirds of output.[328]

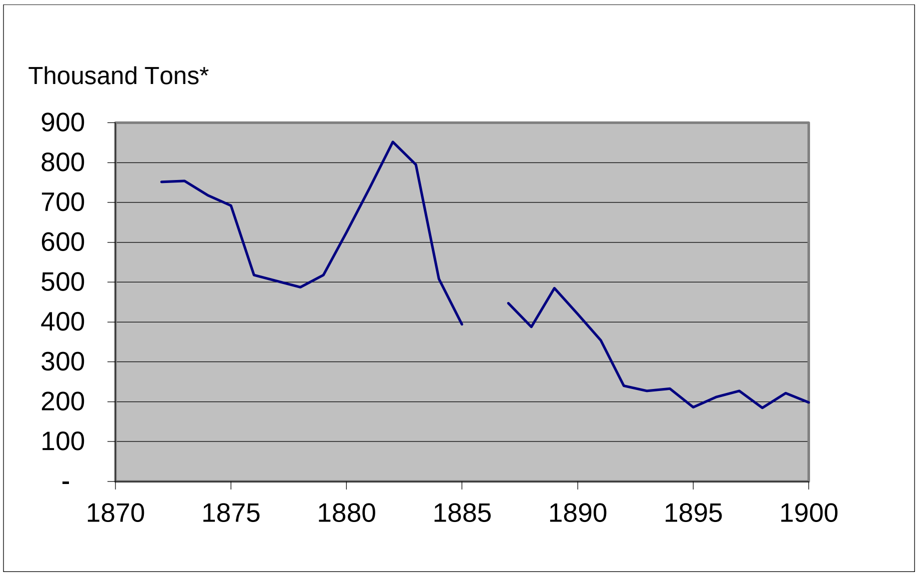
Table 6.1: Manufactured Iron in Cleveland, 1872-1884 (per cent of output)

	Rails	Bars	Plates	Angles
1872	49.0	12.3	29.2	9.5
1873	52.9	12.9	27.1	7.2
1874	45.4	15.6	30.5	8.6
1875	43.9	18.0	30.8	7.3
1876	25.7	20.9	40.9	12.6
1878	9.4	19.5	54.2	17.0
1879	5.2	18.5	55.5	20.9
1880	2.4	21.0	59.8	16.8
1881	5.3	14.0	62.4	18.3
1882	2.7	11.7	65.4	20.2
1883	0.9	10.0	68.5	20.6
1884	0.5	12.3	66.9	20.4

Source: Bell, 'Evidence', p. 323.

[327] Bell, 'Evidence', p. 330.
[328] The peak occurred in either 1882 or 1883, depending on the data used.

Figure 6.1: Manufactured Iron Output in Cleveland, 1872-1900



* Source: Source*: ICTR*, 21 June, 1901; 1872-1881 calculated from Bell, 'Evidence', p. 323.

This was, however, to be the highpoint of Cleveland's manufactured iron industry, both in terms of total production and as a share of total UK output (30 per cent). As Figure 6.1 indicates, the subsequent decline was precipitous. Production collapsed by half in three years, and by half again in the early 1890s. At the turn of the century, production had stabilised at 23 per cent of the level in 1882 and at a 17 per cent national share. It was a decline that mirrored the national trend in manufactured iron, although as Table 6.2 shows, it was both faster and settled at a lower level sooner. On the surface, the contraction appears indicate a disastrous period for Teesside's iron producers, and indeed there were firms that faced severe difficulties, as had occurred ten years earlier with the collapse of the iron rail trade. What the raw data conceals, however, is that just as iron rail makers moved into plates, and some to steel rails, the iron plate makers also switched over, this time to steel plates. The decline does not therefore suggest a failure of the iron industry so much as demonstrate the success of Cleveland producers in adjusting to new production processes and market demand, i.e. for steel.

Table 6.2: Finished Iron (puddled/bar iron), 1881-1900 (thousand tons)

	South Staffs	North Staffs	Cleve-land	Scotland	Lanca-shire	South &West Yorks.	Other*	UK Total
1881	--	--	--	--	--	--	--	2,681
1882	660	195	852	210	277	265	381	2,841
1883	606	185	795	244	236	252	413	2,731
1884	656	185	508	197	239	166	287	2,238
1885	585	171	394	182	208	129	241	1,911
1886	--	--	--	--	--	--	--	1,617
1887	486	157	447	181	204	151	76	1,701
1888	646	181	388	239	197	197	183	2,031
1889	699	186	485	258	219	232	174	2,254
1890	534	170	420	251	217	162	169	1,923
1891	503	170	354	217	213	143	134	1,734
1892	478	159	240	217	214	131	122	1,561
1893	438	124	227	202	174	106	593	1,864
1894	389	187	233	196	145	122	66	1,339
1895	240	116	186	236	147	120	102	1,148
1896	258	126	212	258	172	120	69	1,214
1897	270	148	227	247	162	134	100	1,288
1898	239	131	185	228	186	110	37	1,116
1899	247	125	222	228	154	139	87	1,202
1900	265	114	198	206	149	137	93	1,163

* 'Other' includes Derbyshire, Wales, Shropshire and Cumberland. The accompanying notes to the table in the *ICTR* indicate that puddled bar output in Wales fell from 213,179 tons in 1882 to virtually nothing in 1900. North Staffordshire output for 1896 includes an estimate of 30,000 tons for one firm that did not submit returns
Source*: ICTR*, 21 June, 1901.

Although it was rapid when it came, the changeover to steel in Cleveland did to some extent lag behind other districts, especially South Wales and Scotland. This arose partly because Teesside firms had particular advantages in iron manufacturing, resulting from heavy investment in plant and the availability of skilled labour. The reasons are examined in more detail in the next section; for the present it is useful to identify the main trends in the data on steel production. Even in 1880 when total steel output in Britain exceeded 1 million tons, Cleveland's was just short of 11 per cent of the total (150,000 tons), and virtually all (98 per cent) was Bessemer steel. By contrast, production expanded much more rapidly in South Wales, which accounted for one third of Britain's steel output at that time using both Bessemer and open-hearth processes, and Sheffield (22 per cent) which produced mainly Bessemer steel. In Scotland, like Cleveland, steel production had barely taken hold in 1880, but soon switched over almost exclusively to the acid open-hearth method.

The national picture in 1880 therefore was one of an expanding steel industry dominated by the Bessemer process, but still with a large, if no longer unchallenged, iron manufacturing sector. In 1881 out of a total production of manufactured (puddled) iron and steel ingots of 4.45 million tons, 60 per cent was accounted for by iron, 32 per cent Bessemer steel and only 8 per cent open-hearth steel. In Cleveland, the bias was still heavily towards iron, with the respective figures being 73 per cent iron, 26 per cent Bessemer and 0.5 per cent open-hearth. The growth in steel, however, posed significant problems for the district as the iron from Cleveland ore, and on which the industry had been built, was unsuitable for the steel processes available at the time. It was for this reason that the initial steel production on Teesside was based on imported hematite ore from Cumberland, but principally from northern Spain, and the converters installed by Bolckow Vaughan in the 1870s, the main steel producer in the area, were for the acid process. It was only with the development of the basic process by Thomas and Gilchrist in the late 1870s that pig iron from locally mined ironstone could be used for steel and steel production up to the mid-1880s was dominated by these two variants of Bessemer's method. In 1883, the peak of Cleveland's Bessemer steel production, output reached 485,000 tons, approximately 23 per cent of total Bessemer output in Britain (2 million tons) and 15 per cent of the total in Britain. In fact at this time over sixty-six per cent of British steel was produced by the basic Bessemer method.

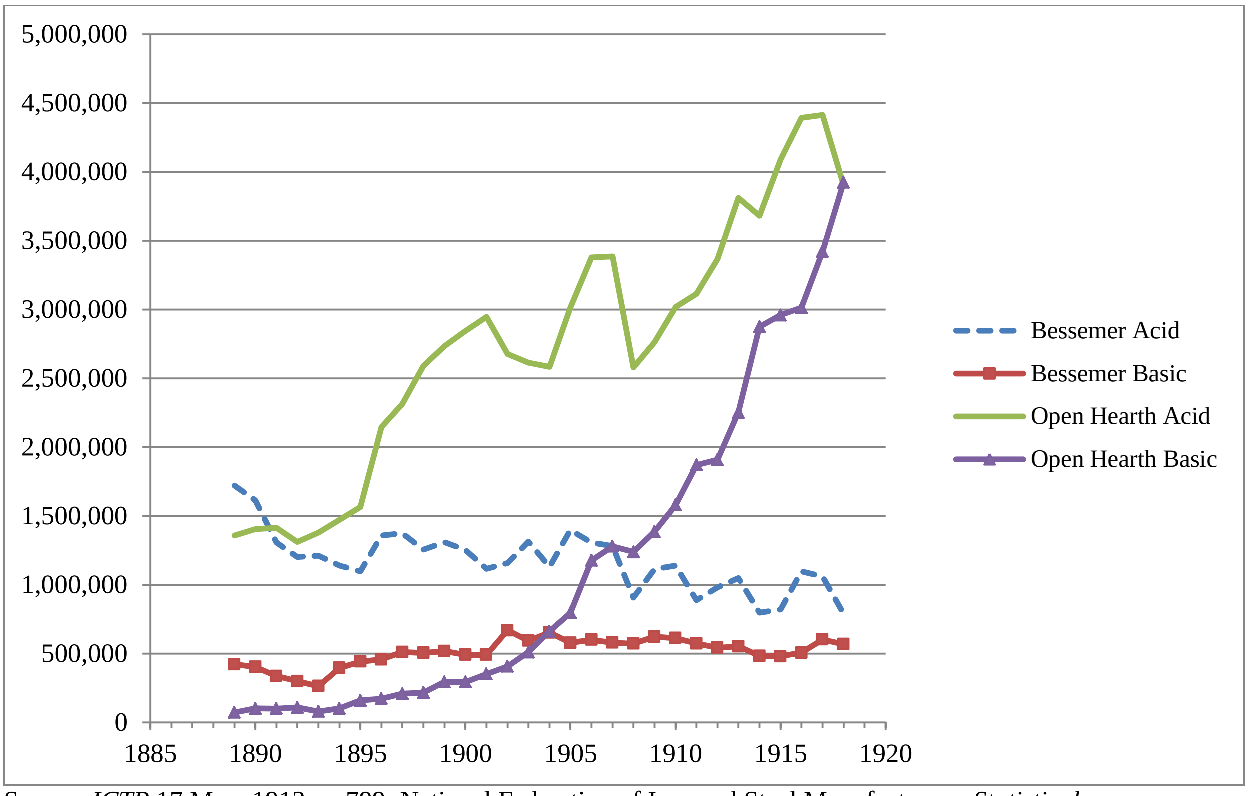
For Cleveland, and Britain as a whole, however, basic Bessemer was only a partial and temporary solution to the falling away of the demand for iron. Problems with the quality of Bessemer steel meant that it was no substitute for iron in the production of ship plates or girders, where ductility and tensile strength were important qualities. It was primarily for rail production that it was most suited. In 1880, of the one million tons of the Bessemer steel produced, almost three-quarters (732,000) went for rail rolling, and even after improvements that raised the quality of steel and increased the efficiency of production, by 1900 of the 1.8

million tons of rails produced, Bessemer rail output remained at much the same level as 20 years earlier (760,000 tons) and captured only 42 per cent of the market.

For makers of ship plate and other steel products where quality was important, the answer lay in the open-hearth process using acid-lined furnaces. This method had first gained acceptance with South Wales and Scottish firms, being pioneered especially by the Steel Company of Scotland in the late 1870s and early 1880s.[329] Expansion in the use of the acid open-hearth method came in the early 1880s following the resolution of cost and production problems and after the acceptance by Lloyd's Register that open-hearth plates were acceptable for shipbuilding (1877).[330] Scottish output expanded rapidly from 84,500 tons in 1880 to 240,000 tons by 1885 and 481,668 in 1890. In Wales the steel from acid open hearth producers was favoured by the tinplate industry, with production rising to almost 173,000 tons by mid-decade.[331] Cleveland's adoption of the process was slow, being delayed until 1885. But once Cleveland producers had committed to the process, production expanded rapidly, so that by 1890, at 460,115 tons, the district's output was about one third of the total UK acid open-hearth steel (1.46 million tons) and second only to Scotland.[332] In terms of the relative outputs of Bessemer and open-hearth steel, these developments led to production by the open-heath process overtaking the Bessemer process in 1894 (Figure 6.2). For Cleveland the position is summarised in Figure 6.3. The advent of the acid open-hearth process demonstrates how the Cleveland iron producers were able to turn round a seemingly disastrous slump in manufactured iron to one in which the district once again became, along with Scotland, the largest producer.

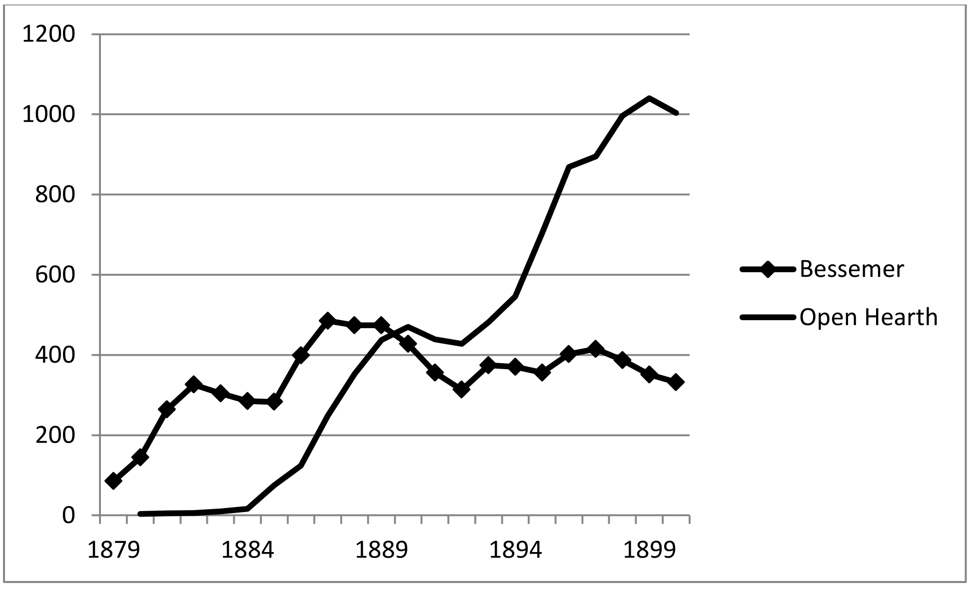
[329] Wengenroth, *Enterprise*, pp. 222-43.
[330] Wengenroth, *Enterprise*, pp. 226-232.
[331] Ibid., p. 229, Table 29. Wengenroth's figures refer to all open-hearth steel, but as there was very little produced in these areas at the time, they provide a good estimate of acid open-hearth output.
[332] Author's calculations from BITA data. See Table 6.2.

Figure 6.2: British Steel Output, 1889-1918 (tons)



Source: *ICTR* 17 May, 1912, p. 799; National Federation of Iron and Steel Manufacturers, *Statistical Report* 1918 (July 1919), p. 5.

Figure 6.3: Bessemer and Open Hearth Steel Output in Cleveland, 1889-1900 (thousand tons)



Source: *ICTR* 12 April, 1901, p. 770; *ICTR* 21 June, 1901, p. 1302.

As with basic Bessemer, the acid process in its turn was an unsatisfactory long-term answer to the problems of supplying high quality steel since it meant that Cleveland's firms were dependent on imported hematite ore. It also left the still substantial local ironstone resources under-utilised. At the time, except for its use in the basic Bessemer process, which was shut out of many of the important steel markets, the only outlet for Cleveland pig iron was for forge and foundry iron and the shrinking remnants of the puddled iron sector. Only with advances in the development of the basic open-hearth method that permitted the use of poorer quality ores could Cleveland's full steelmaking potential be unlocked. However, it was not until the 1890s and early 1900s that sufficient progress was made in the techniques of manufacturing in the basic open-hearth furnace. This was initially in north east Wales (Brymbo Steelworks, Wrexham) and in Staffordshire (see below). In 1890 Cleveland's basic open-hearth production was, at 9,823 tons, negligible and even by 1900 just 25,000 tons were being made. This was barely 9 per cent of the UK, the total of which was less than 30,000, and just 6 per cent of UK steel production. But as with the changeover from iron to acid open hearth steel, the expansion of basic open hearth production was extremely rapid once the technical problems had been surmounted. Cleveland was not the only district whose firms adopted the method – basic open-hearth furnaces were installed across Britain's steelmaking areas – but it was in Cleveland that the most dramatic expansion occurred. By 1907, even though basic open hearth steel still accounted for only 6 per cent of national steel output, total production had expanded four-fold since 1900 and Cleveland's production had expanded almost sixteen-fold to over 400,000 tons, 35 per cent of the country's total. By 1918 output exceeded 1.1 million tons, 75 per cent of the district's total steel, 40 per cent of all basic open-hearth output and almost 11 per cent of all types of steel produced in Britain. Nationally, the acid open hearth process continued to provide the largest proportion of Britain's steel, and it was not until 1918 that basic overtook acid open hearth production. Nevertheless, basic open hearth steel was the most important contributor to the growth in total output. The magnitude of this shift can be illustrated by using a simplified shift-share calculation. Between 1906 and 1914, of the 1,699,000 ton increase in basic open hearth output (144 per cent) just 234,000 tons (20 per cent) can be attributed to the overall growth in steel production. The rest, 1,465,000 tons (124 per cent), was the result of a decisive move away from the other steel processes to the basic open hearth, and Cleveland's industry was at the centre of this transformation.

6.3: From Iron to Steel

It had become evident by the end of the 1860s that iron, Cleveland's speciality, was under threat from the new product, steel, which for the first time could be manufactured in bulk at a competitive cost.[333] And while many Cleveland producers stuck to iron through the 1870s and

[333] Bell, 'Evidence', p. 323-4.

into the 1880s, if they survived, some firms in the district did take early steps into the steel market, experimenting with the new processes. This section provides a brief outline of the adoption of three of the four steel processes – acid Bessemer, basic Bessemer and acid open hearth – as a background to the investigation of the later shift into basic open hearth steel. It also aims to show that throughout the period there was a process of continuous adaptation by the iron and steel firms of the area.

It was established fairly soon after its invention that Henry Bessemer's pneumatic process needed a low phosphorus iron to produce steel of a reliable quality, and that the end product was best suited to rails.[334] Early production was dominated by Sheffield firms, and later some railway companies installed Bessemer converters (e.g. the London and North Western Railway at it works in Crewe). But even though demand grew, the expansion in output was limited by shortages of low phosphorus ore.[335] The ore constraint was eventually released by the development of the Cumberland and North West Lancashire hematite industry and by imports from Spain. Both these had the effect of shifting the focus of the industry away from Sheffield to the north west and to coastal districts, notably south Wales and the north east.

The first north east firm to show an interest in the Bessemer process was Weardale Iron and Steel, under the direction of Charles Attwood. This was a short-lived venture that started in 1861 but abandoned by 1864.[336] The main north east entrant into the Bessemer rail market was Cleveland's largest iron producer and Britain's largest iron rail manufacturer, Bolckow Vaughan. Aware of the growing inroads into the rail market being made by steel as the relative price fell and domestic rail companies increasingly looked to the longer-lasting material for replacement rails, the firm was especially vulnerable to shifting market demand. The company announced in 1870 that it would be erecting a Bessemer plant to produce 500 tons of rails per week, with the option of doubling capacity. Since Bolckow Vaughan was keen to enter the market as soon as possible, as a temporary measure they bought up a small existing plant in Manchester, the Gorton Steelworks, from the liquidated Lancashire Steel Company.[337] The shortage of suitable ore for a Bessemer works, or equivalently the high price of British-mined hematite, also prompted Bolckow Vaughan to look to Spain for their supplies of low-phosphorus iron. In conjunction with John Brown, the Sheffield steel firm, they acquired mining rights near Bilbao, a strategy followed by numerous other firms at the time, including

[334] K.C. Barraclough, *Steelmaking, 1850-1900* (London: 1990), pp. 44-6; Wengenroth, *Enterprise*, pp. 33-5.
[335] Barraclough, *Steelmaking*, pp. 60-68.
[336] J.K. Almond, 'Steel production in north east England before 1880' in Hempstead (ed.), *Cleveland Iron*, p. 163-2. Weardale's Bessemer converters were later use by Lowthian Bell for experiments into basic steel production (Almond, 'Steel production', p.164).
[337] BVAR 1870, pp. 7-8.

Consett, Dowlais and, in Germany, Krupp's.[338] It was, however, some time before the plant was built, the plans being hampered by the downturn in the rail market after 1873 (although this did not affect steel as much as iron rails), the attempts to make the Gorton works profitable and the disruption to the development of the Spanish ore supplies caused by the Third Carlist War.[339] Production at Gorton was eventually abandoned (1874), as was the plan to move the plant to Cleveland, and by 1875 Bolckow Vaughan had begun to build new works at Eston, a short distance to the east of Middlesbrough. These were eventually completed and in operation in 1877, with three new blast furnaces supplying four 8 ton converters. Incorporating many of the improvements to Bessemer plant design made in the US in the 1870s, it had a capacity of 1,000 tons of rails per week, approximately 50,000 tons per year, and was reputed to be one of the lowest cost producers in Europe.[340] The 1878 annual report stated that the plant was in 'full operation for the whole year' and that the results (i.e. profits) were 'fairly satisfactory'. This not particularly enthusiastic tone belies the importance of the move into Bessemer for Bolckow Vaughan. It was at a time when the demand for steel rails remained buoyant while the iron rail market collapsed; the company's two iron rail mills at Middlesbrough and Witton Park had been idle from 1876. Moreover, unlike its Durham rival, Consett, Bolckow Vaughan had not moved the focus of its manufactured iron production into ship plate at this stage.[341]

The other advantage to Bolckow Vaughan of being a relatively early entrant into Bessemer production is that fortuitously it had plant available and experience with Bessemer's method, and was thus ready to move into *basic* Bessemer steel as and when the process was developed. Indeed, this next advance in steel technology came just eighteen months or so after the new works were completed, and the company was at the forefront of the new process's commercial application.

Wengenroth makes the interesting case that the contrast between Bolckow Vaughan and Consett was that the latter's strength was partly based on its access to high quality local coal reserves and that it was unencumbered by Cleveland ironstone interests. Consett therefore was not tied to using its own ore in the production of iron. Consequently, the switch to steel using bought-in, imported hematite could be made more easily. Bolckow Vaughan on the other hand had extensive ironstone mines and so there was every incentive to use the output from these. When Windsor Richards, the firm's general manager, learned at the Paris Meeting of the *ISI* in 1878 of

[338] BVAR 1872 ; Wengenroth, *Enterprise*, p. 234.
[339] BVAR 1873; BVAR 1874.
[340] BVAR, 1877; Wengenroth, *Enterprise*, p. 109. At this time technical and plant layout improvements developed in the US produced significant cost reductions in the acid Bessemer process, the result of the intensive use of the capital. See Barraclough, *Steelmaking*, pp. 233-5, and U. Wengenroth, *Enterprise*, pp. 59-74.
[341] BVAR 1877, 1878. For Consett see Warren, *Consett Iron*, p. 30; Wengenroth, *Enterprise*, p. 108.

Thomas and Gilchrist's breakthrough in producing good quality steel from high phosphorus iron in a basic-lined Bessemer converter, he was quick to persuade Bolckow Vaughan directors to offer Thomas and Gilchrist the opportunity to develop their process commercially. Thomas and Gilchrist's advance seemed to provide an ideal solution to the difficulty of using of Cleveland's moderately high phosphorus iron in steel making, and with it came the prospect of not just making steel with what was claimed to be the cheapest iron in the world, but to transfer the district's dominance in the one metal to the other.[342] In late 1878 Bolckow Vaughan attracted the two inventors away from south Wales where Gilchrist had been conducting experiments under Thomas' direction at Blaenavon and Dowlais, providing experimental facilities at Middlesbrough and Eston and offering terms for licensing their patents.[343] Despite some initial difficulties in making the process technically and commercially viable, by the end of 1879 Bolckow Vaughan had decided to build a new two converter plant at Eston to produce steel using the new basic Bessemer process.[344] It is a measure of their optimism that over the next two years these plans were extended to include three new blast furnaces and four more 15 ton basic converters.[345] As the directors' annual report for 1880 stated: 'during the past year the perfecting of [the] process has absorbed a large portion of the time and ability of Mr Richards, your Works General Manager, and it is largely due to him that the invention can now be declared an entire success.'[346]

The buoyant mood, no doubt partly a result of announcements by Bolckow Vaughan of the progress of the trials, was reflected in the national press. The *Times* for example in a lengthy article describing recent advances in steel production, stated:

> The last remnants of doubt concerning the entire success of the Thomas-Gilchrist process should now be dispelled by the confidence with which it is being applied by practical iron and steel manufacturers all over Europe…Altogether, indeed, there are now working on the process a dozen to twenty Bessemer converters, and it is probable that many more will be got to work within the next few months. Few innovations have enjoyed such a ready application; few have involved so few difficulties in their adoption; few have been of more general or more extensive use; few have been attended

[342] *Times*, 14 Mar. 1879.
[343] J.K. Almond, 'Making steel from phosphoric iron in the converter – the "Basic-Bessemer Process" in Cleveland in the years from 1879', in Hempstead, *Cleveland Iron*, pp. 183-90.
[344] BVAR 1879.
[345] BVAR 1879, 1880, 1881; Wengenroth, *Enterprise*, p. 168.
[346] BVAR 1880, p. 7. Later, in 1920, J.E. Stead, who as a young chemist had worked with Richards on turning the basic Bessemer process into a commercial proposition, commented: 'only those working with him [Richards] in the inner circle knew that at times he was so much discouraged as to feel inclined to discontinue the experiments and give up hope'. J.E. Stead, 'ISI Presidential address', *JISI*, 51 (1920), p. 58.

> with such important results; and few have given the promise of yielding their authors such a rich reward.[347]

In Cleveland the early enthusiasm for and success in using local iron in the steel production along with the ever-present and growing threat to the manufactured iron industry prompted, in 1881, the formation of a new firm specifically to produce steel by the basic Bessemer method. This was the North-Eastern Steel Company (NESCo). The original directors included a selection of Teesside industrialists: an ironmaster (A.J. Dorman of Dorman Long), an engineer (Thomas Wrightson of Head Wrightson) and a ship owner (R.C. Denton), along with two metallurgists who had been at the forefront of the process's development, Sidney Thomas, the originator, and Edward Riley. Thomas's co-developer, Percy Gilchrist, joined the Company's board a short while later. It is clear that most of the original promoters had a considerable interest in the success of the new process, either as patent holders or because the new steel offered either a challenge to their business – Dorman Long operated a large puddling plant – or for the opportunities to supply equipment – Head Wrightson built part of the plant.[348] Under the guidance of Arthur Cooper as general manager, who had already had experimented with basic Bessemer production at Brown, Bayley and Dixon in Sheffield, the firm built its new works in the centre of the Cleveland ironmasters' district close to blast furnaces to supply Cleveland pig iron and to rolling mills to process the output. The plant itself was laid out along American lines and comprised four 10 ton converters with a capacity of 100,000 tons of steel a year and included mills for rolling blooms, rails and angles. There was also an expectation that the steel could be rolled into ship plate and find a market with north east shipbuilders; as the Prospectus notes: 'The close neighbourhood of the Middlesbro', Hartlepool, and Sunderland shipyards gives additional value to the position, having reference to the increasing use of steel for shipbuilding.'[349] Delays in construction, however, meant that the plant was not in operation until mid-1883.[350]

Basic Bessemer in Cleveland failed to fulfil its early promise and after NESCo no further works were built on Teesside. Of the three other converter plants that were initially intended for basic operation, Erimus Steelworks (sited between Middlesbrough and Stockton), Darlington Iron Company and the Cleveland Iron and Steel Company at Guisborough, only the first two were built, but were worked as acid converters.[351] Bolckow Vaughan and NESCo continued basic

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[347] *Times*, 10 Sept. 1880.
[348] 'NESCo Prospectus', *Daily News*, 27 Jul. 1881. Other directors included F.W. Bond and Alexander Hay, both of whom were London metal traders. They also became directors of Dorman Long on its flotation in 1889.
[349] 'NESCo Prospectus', *Daily News*, 27 Jul. 1881
[350] Almond, 'Making steel', pp. 207-11; Barraclough, *Steelmaking*, pp. 232-3.
[351] Almond, 'Making steel', pp. 173-5.

Bessemer production well beyond the turn of the century, accounting between them for up to as much as 80 per cent of Britain's output when working at full capacity.[352] But both firms encountered technical problems and considerable difficulties in marketing their output as widely as they had wished. And for neither firm was the process as profitable as first anticipated. Thus NESCo, admittedly in its prospectus, suggested that a 17s 6d per ton difference in the cost of hematite pig compared to the cheaper Cleveland pig would give a cost advantage to the basic over the acid process of 10s a ton. These projections, however, were based on prices for Cumberland hematite rather than the costs of hematite pig available from Cleveland producers, which over the 1880s became considerably cheaper as ore imports from Spain and hematite pig production expanded.[353] Interestingly, this outcome had been predicted in an early assessment of the prospects for the basic Bessemer process by Transenster. He suggested that the principal factor determining the districts in which it would be a success depended of the hematite-basic pig iron price differential; he concluded that because of Cleveland's coastal site and the access to high quality, low phosphorus Spanish ore, the process was unlikely to be profitable in the district.[354] Nevertheless, NESCo was a profitable firm, although not especially so. Bolckow Vaughan's directors at various times expressed disappointment and looked at alternative steel production methods (see below), although the company persisted with the process until 1911.

It was not just the price difference between hematite and Cleveland (or basic) pig that hampered the basic Bessemer producers. Much of the problem lay in the technical difficulties of producing a satisfactory quality of steel. Despite the expectations, basic Bessemer never penetrated the ship plate market. The product was too brittle to be acceptable for shipbuilding, and even methods to reduce the phosphorus and sulphur contents were unsuccessful in manufacturing a suitably mild metal. It was later discovered that the brittleness was due to nitrogen in the steel introduced during blowing, something that affected both Bessemer processes. The presence of high levels of silicon in Cleveland iron also made the steel hard,

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[352] In the early 1890s Bolckow Vaughan had a capacity of 175,000 ton (Abé, 'Technological strategy', p. 58) and NESCo a capacity of 100,000 tons, rising by 1905 to 150,000 tons. British output of basic Bessemer steel in 1891 was 335,776 tons. Assuming a combined output of the two companies of 275,000 tons, this represents 82% of total output. Of course, this overstates the Cleveland contribution, as it assumes Cleveland plants at capacity and other plants operating below. Even so, it demonstrates the significance of Cleveland firms' contribution.

[353] 'NESCo Prospectus', *Daily News*, 27 Jul. 1881. The 10s difference implies a cost difference in the conversion of iron to steel by the basic process of no more than 7s greater than the acid process. This is probably a slight understatement. Transenster, cited by Wengenroth calculated that the differences to be 8.48 marks, which at an exchange rate of 20.429 marks to the pound, gives a difference of 8s 3.6d. See Wengenroth, *Enterprise*, pp. 158-9

[354] Wengenroth, *Enterprise*, pp. 158-9. The predicted profitable areas were Alsace-Lorraine and eastern France.

acting like carbon. These factors meant that the product's markets were limited, and for British firms largely confined to the production of rails.[355]

There was, however, a more fundamental problem facing the basic Bessemer process in Cleveland; it was that of providing a suitable pig iron for the converter, and it was a difficulty that was never fully solved. [356] The problem can be stated in the following way: heat was needed in the converter to keep the metal liquid and this was produced by the oxidation of the impurities during the blowing process. For acid Bessemer converters the heat came mainly from silicon in the iron, and conveniently the low phosphorus pig used in acid converters tended to have a high silicon content. The silicon was also compatible with the acid lining of the converter. In the basic process, however, the silicon destroyed the basic lining, and since adding more basic material (lime) as slag to the converter to offset the silicon increased the quantity of slag and cooled the iron, a low silicon (and low sulphur) iron was required. In a basic converter, the alternative to the silicon for the production of heat was to use a high phosphorus iron (2 to 2.5 per cent), which oxidises at the end of the conversion process just at the point when the heat is most required. The problem for the Cleveland producers was that Cleveland iron had an intermediate phosphorus content (1.4 to 1.6 per cent), as well as a high level of sulphur, and to produce a satisfactory steel required expensive adaptations to the process. These included the addition of manganese in the blast furnace to produce basic pig, or the use of the duplex process, which involved the treatment of the metal first in an acid converter followed by finishing in a basic one. [357]

In other words, using Cleveland iron in the basic Bessemer method proved more costly and the product less marketable than first anticipated, and despite improvements in the process by using mixers, adding high phosphorus puddler's tap to produce basic pig and the contribution made to revenues by selling the high phosphorus slag by-product as a fertiliser, the spread of the technique in Britain was limited. Indeed, given the technical difficulties and the boom in the demand for iron ship plate, it is unsurprising that there was only a limited take-up of the process in Cleveland in the early 1880s. Moreover, it is not generally the case that the response of Cleveland's firms was determined by their local ore interests, as Wengenroth maintained (see above). In fact it was only Bolckow Vaughan that fitted this pattern; NESCo had no mineral

[355] On nitrogen see McCloskey, *Economic Maturity*, pp. 49- 50. German success in producing mild steel from the basic Bessemer process is largely due to the higher manganese content of the iron, counteracting the effects of the silica. Wengenroth, *Enterprise*, pp. 176-7.
[356] Barraclough, *Steelmaking*, pp. 216-8.
[357] Basic pig also has low levels of sulphur and silicon. See W. K. V. Gale, *The Iron and Steel Industry; A Dictionary of Terms* (Newton Abbot: 1971), p. 18.

interests or pig iron producing capacity at the time.[358] For other firms, product and process choices were very much market-led, at least in the years up to the turn of the century. The home market rail production, for which Bessemer was most suited, offered little opportunity for expansion, and the main engine of growth of demand, and therefore output came from shipbuilding. Thus, following the success principally of the Scottish steel producers in supplying the ship plate market with steel from the acid open hearth process, a number of manufactured iron firms on Teesside changed over to this slower, but more reliable method for manufacturing mild steel, albeit rather later their Scottish counterparts.[359]

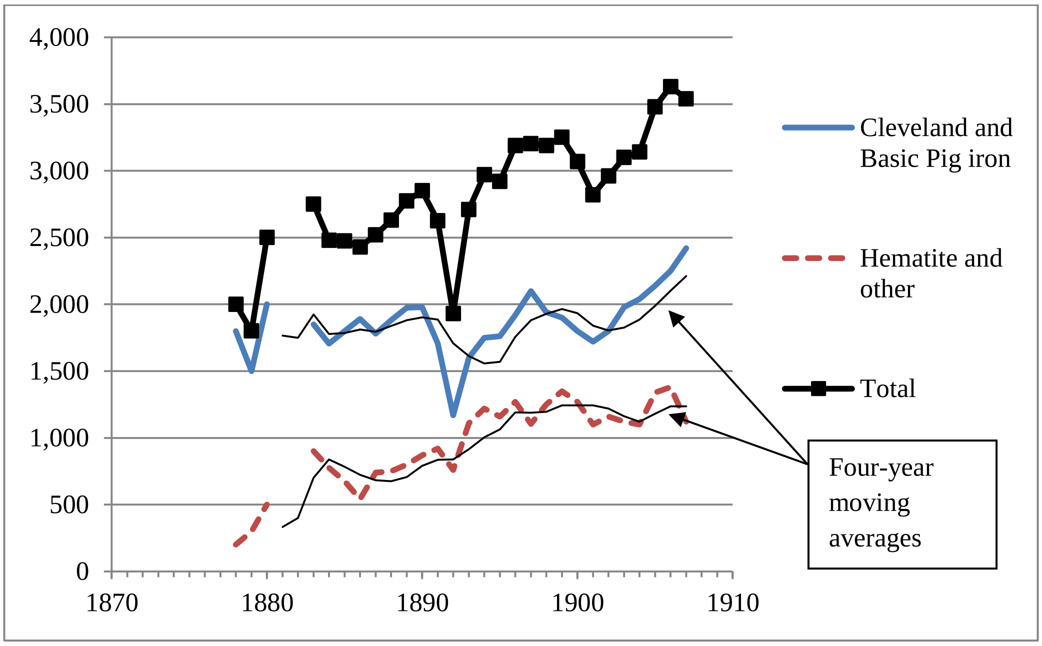
Apart from small scale open hearth production at Weardale Iron and Steel in the late 1860s, the first post-1880 changeover in north east was at Consett in 1883 where two acid open hearth furnaces working on pig produced from low phosphorus Spanish ore were installed to manufacture ship plate. Initially introduced as a stop-gap while the firm considered building a Bessemer plant, the success of this temporary measure led to further expansions in capacity so that by 1890 Consett was the largest open hearth manufacturer in the region, producing 160,000 tons, 11 per cent of the national total.[360] For Cleveland's producers the tipping point seemed to be when the ratio of the price of steel to iron plates fell below 1.2; at this point the market for iron plates evaporated as quickly as that for iron rails had in the 1870s as shipbuilders changed over to steel.[361] Dorman Long scrapped its huge 120-furnace puddling plant at the Britannia Works in 1886 and replaced it with seven acid open hearth furnaces. Two years previously Bolckow Vaughan decided to add acid open hearth plant in order to be able to supply ship plates. Capacity was quickly expanded so that by 1890 it was operating seven furnaces of between 10 and 25 tons.[362] Once underway, the transition from iron to acid open hearth steel was rapid and by the early 1890s there were at least five works in Cleveland operating the process, including Moor Iron Company and Stockton Malleable Iron Company in Stockton and the West Hartlepool Steel and Iron Company. There were also a number of foundries with small Siemens-Martin furnaces (e.g. the Cast Steel Works in Middlesbrough). It is difficult to determine precisely the output of acid steel in Cleveland at this time, but in the north east as a whole by 1890 acid open hearth production was 460,000 tons, accounting for about one-third of the British total. Along with Scotland, it was the largest producing region. After taking into account Consett's output of 167,000 tons and production at works on the Tyne and Wear (e.g. Palmers Shipbuilding at South Shields), it seems likely that the production in Cleveland

[358] The company took over the Acklam Ironworks' blast furnaces in 1893.
[359] For the developments in the acid open hearth process in Scotland, and also south Wales, see Wengenroth, *Enterprise*, pp. 195-215.
[360] Wengenroth, *Enterprise*, pp. 235-9; For British output see *ICTR*, 17 May, 1912, p. 799.
[361] McCloskey, *Economic Maturity*, Table 2, p. 51 and pp. 50-3.
[362] BVAR 1890; Wengenroth, *Enterprise*, pp. 240-1.

amounted to up to one-half of the north east total, about 230,000 tons (or 16 per cent of Britain's production).[363]

The importance of the acid open hearth steel process to Cleveland is also indicated by the effect on pig iron production. As Figures 6.4 and 6.5 show, the production of Cleveland and basic pig iron stagnated for much of the last two decades of the century, rising only seven per cent between 1883 and 1903; it was only the growth in hematite (and 'other kinds of pig') that maintained the overall growth in output. Hematite production grew by 24 per cent over the same period, and by 1892 accounted for about 40 per cent of total pig production. This is best shown by the 4-year moving averages in the Figure 6.4. The impact of hematite is also reflected in the working of the blast furnaces on the different ores. According to Hawdon, in 1883 eighty-four of the 117 furnaces in blast, almost three-quarters, were producing Cleveland pig or basic iron with most of the rest producing hematite. By 1893 the ratio had changed to approximately half working on Cleveland pig (43 blast furnaces) and half on other ores, again mainly hematite (41furnaces).[364] The effect also meant stagnation in Cleveland ore mining while imports boomed, as shown in Figure 6.6. The implications of these trends are considered in more detail below in the discussion of the pressure for the development of the basic open heath process.

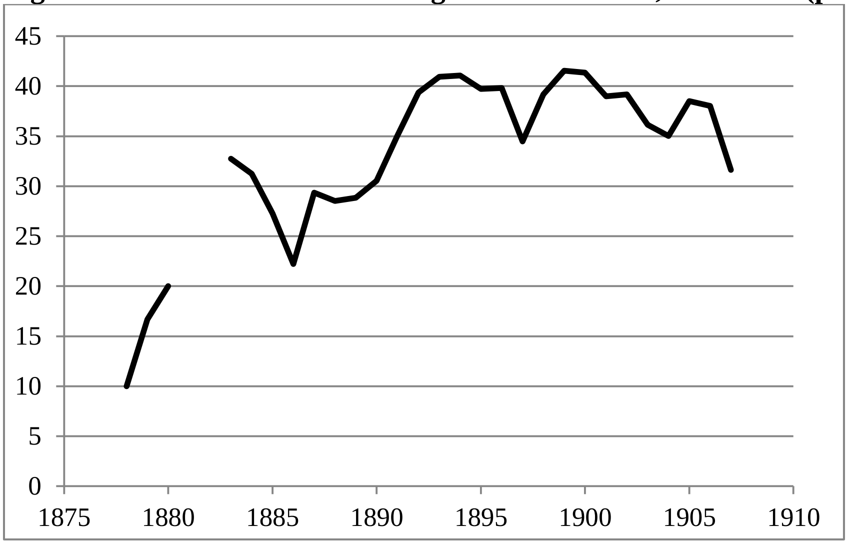
Figure 6.4: Cleveland and Hematite Pig Iron Production, (1883-1907, thousand tons)



Source: W. Hawdon, 'President's address', *CIE*, (1890-3); Hawdon, 'Iron and steel industries'.

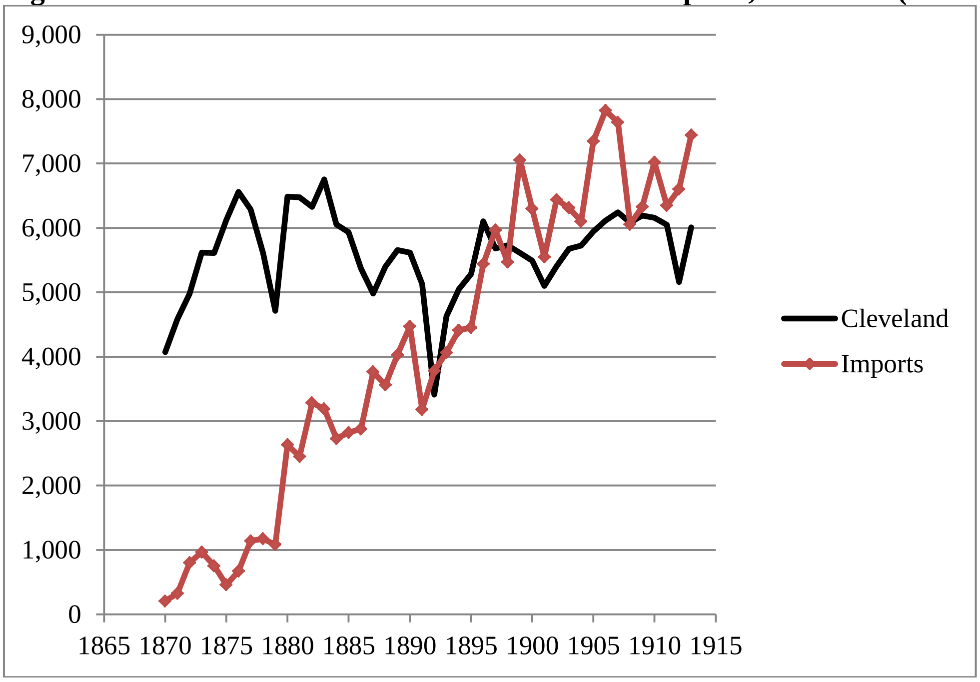
[363] Wengenroth, *Enterprise*, p. 239, n. 363; BITA, *Annual Statistical Report*, 1890, p. 107; *ICTR*, 17 May, 1912, p. 799.
[364] W. Hawdon, 'The iron and steel industries of the Cleveland district during the last quarter of a century', *JISI*, 39 (1908), p. 30.

Figure 6.5: Cleveland Hematite Pig Iron Production, 1883-1907 (per cent of total output)



Source: W. Hawdon, 'President's address', *CIE*, (1890-3); Hawdon, 'Iron and steel industries'.

Figure 6.6: Cleveland Ore Production and UK Ore Imports, 1870-1913 (thousand tons)



Source: W. Hawdon, 'President's address', *CIE*, (1890-3); Hawdon, 'Iron and steel industries'.

Although acid open hearth continued to expand nationally up to the end of the First War, and in the north east until 1905, the process left the district's producers dependent on imported ore and thus vulnerable to adverse shifts in the relative cost of hematite and Cleveland pig. What is more, the use of the acid process did not solve the problem of the under-utilisation of local ore. As Hawdon pointed out in his Presidential Address to the Cleveland Institute of Engineers in 1892, if, in 1890 Cleveland pig had been substituted for hematite, then at the prevailing output this would have required an additional 2.7 million tons of Cleveland ironstone and would have employed an extra 2,500 men, increases of 64 per cent and 46 per cent respectively. The other benefits he noted were the additional railway employment and the extra 120,000 tons of phosphoric slag produced that could have been sold as fertiliser. Clearly, the answer to the problem was to expand basic steel output, but given the well-known drawbacks of basic Bessemer steel, this would have to wait until the basic process could be adapted for use in the open hearth furnace. Hawdon commented thus: 'This revolution is not likely wholly to come about, but in part, *why should it not do so*?'[365] As discussed in the next section, this did come about, but it was more of an evolution than a revolution, though one that produced a thorough-going change.

6.4: The Development of the Basic Open-Hearth Process

Although Cleveland's iron and steel firms were unable to take complete advantage of Thomas and Gilchrist's basic process immediately, the importance of their invention over the long-term should not be understated. As Wengenroth notes, the modest level of basic Bessemer output in Britain disguises the profound impact it was to have on steel production throughout the world.[366] This became evident from the 1890s in the US and from 1900 in Britain. But like so many technical developments, it took time before its full benefits could be realised and required not only a series of supporting technological innovations but also changes in economic circumstances in the steel market.[367]

Attempts to produce open hearth steel in Cleveland using pig iron from local ore pre-dates the basic process by some 10 years. There were early experiments using Siemens furnaces at Richardson, Johnson and Co.'s Stockton Ironworks in 1868, with investment in the venture from a number of local ironmasters. Prominent among these was Bernhard Samuelson whose Newport Ironworks was, at the time, one of the newest and largest plants on Teesside. The failure to produce steel of an acceptable quality led to the rapid termination of the project and resulted in significant losses for some of the principal investors. Samuelson is reputed to have lost £30,000.[368]

[365] Italics in the original. W. Hawdon, 'President's address', *CIE* (1890-3), p. 19.
[366] Wengenroth, *Enterprise*, p. 222.
[367] To some extent, this is reflects the distinction between macro and micro innovations. See J. Mockyr, *The Lever of Riches* (Oxford, 1990), pp. 13-4.
[368] Jeans, *Pioneers*; Almond, 'Steel production', pp.167-8. There were also trials in Darlington, see J. Hargreaves, 'The manufacture of iron and steel from Cleveland ores', *CIE Proceedings* 1868, reported in *Stockton and Darlington Times*, 21 Mar. 1868.

The problems arose from the impurities in Cleveland pig and the ore from which it was made, with the three troublesome elements being phosphorus, sulphur and silicon. Thomas and Gilchrist's breakthrough of applying a basic lining to the Bessemer converter so that steel could be produced from high phosphorus iron rapidly stimulated interest in extending basic linings to open-hearth furnaces. It took almost 25 years, however, to solve the problems that would enable open-hearth steel to be made from Cleveland iron of a quality and on a scale that was commercially viable. There were several barriers to basic open-hearth development that had to be surmounted. First, there was a need to understand the process by which the impurities could be eliminated and sound steel produced. This would enable steel with comparable properties to acid steel to be manufactured, properties that included tensile strength, elongation, ductility, ease of welding, absence of cracking when riveting among others. Second, the steel had to gain acceptance from users, the civil and mechanical engineers, naval architects and shipbuilders who ordered the steel from the makers. Ultimately, this depended on the bodies that set down the required minimum standards, including the Admiralty, the Board of Trade and Lloyd's. As a relatively new material, at least in the mass manufactured form rather than as a specialist metal for instruments and tools that was made by the crucible method, this took some years. Third, the basic open-hearth process had to be adapted to the specific conditions of production in each area. Only then could it be produced with the available inputs and in a way that costs were low enough and the volume of production sufficiently high for it to challenge the dominance of acid open-hearth steel. As will be explained, this required further technological advances and adjustments to the process of manufacture.

The early developers of the basic open hearth method in Britain were all outside Cleveland. The district's producers were heavily committed to iron, and later to acid steel, and the experience of the late 1860s had made them cautious of using local pig in the basic open hearth. In any case, there was already, in the late 1870s and early 1880s, heavy investment and considerable optimism in the potential for basic Bessemer converters. It was therefore left to iron and steel masters in other district, where there were high phosphorus iron ores, or where the costs of transporting hematite pig from north west England or a suitable port were too high to make acid steel a viable proposition. These works were mainly in the west midlands or south Wales. The first British use of a basic open-hearth seems to have been at the Farnley Iron Company, near Leeds, in 1882.[369] At this works, Thomas Gillott was already producing acid steel with hematite pig in open-hearth furnaces, but had been unsuccessful when he attempted to combine the hematite pig with high phosphorus (of 0.2% or more) wrought iron scrap. Explaining that he was 'instructed to apply…the process which Messrs Thomas and Gilchrist

[369] T. Gillott, 'The basic, open-hearth, steel process', *ICE*, 77 (1884), pp. 297-308.

had at that time just succeeded with in the Bessemer converter', Gillott re-lined the furnace with a basic material.[370] This enabled him to use low silicon and sulphur but high phosphorus Farnley pig (P = 0.601%) and scrap iron (P = 0.2%) to produce 'soft steel of great purity' with maximum ductility when cold. As he noted in his report, the product was good enough for specialist use such as for boiler plates requiring difficult flanging. While Gillott maintained that the basic open hearth was suitable for steel of 'exceptional qualities', production was on a very small scale; the furnaces he used were of just 2 to 2¾ tons and the charge was no greater than 2½ tons. Moreover, it was an expensive process, principally because of the high cost of the preparation and the regular repairs that needed to be made to the furnace lining.[371]

Gillott's work was significant in demonstrating the potential of the basic open-hearth process, but suggested that it had limited application, to the production of the highest quality steels only. As J.W. Wailes (of the Patent Shaft and Axletree Company) noted at an Iron and Steel Institute meeting in 1889, he could make 'a very beautiful material [but] ...doubted it as a commercial enterprise.'[372] Production at Farnley was also based on the combination of pig and scrap, a process more widely used in continental Europe where scrap was more abundant and consequently available at a lower price.[373] The preferred basic open-hearth approach that developed in Britain was the pig and ore method that was pioneered by J.H. Darby at the Brymbo Steelworks near Wrexham.

Trials at Brymbo stared in 1883.[374] Darby's firm were prompted by the problem of producing a low phosphorus pig iron using local (north Wales) coal. The coal's high phosphorus content made it unsuitable for producing hematite pig and hence ruled out the acid process. Moreover, as Darby remarks in his paper to the Iron and Steel Institute, he wanted to determine whether the success of the basic open-hearth process in Germany could be repeated in Britain, but modified to use pig and ore instead of scrap in the charge.[375] The initial experiments on a 5 ton Batho furnace proved successful; a good soft (i.e. mild) steel could be produced from a high phosphorus pig (P = 0.3%), and this was despite problems with the operation and maintenance of the furnace, which needed frequent, expensive repairs. On the strength of the quality of the steel, capacity was expanded considerably to six basic-lined furnaces, four of 12 tons and two of

[370] Gillott gives no indication of who provided this advice.
[371] Gillott, 'Basic open-hearth', p. 297, p. 301, pp. 307-8
[372] *JISI*, 20 (1889), p.90.
[373] Scrap was more plentiful in Continental Europe because of the widespread use of Bessemer converters that produced significant quantities when the metal was poured into ingot moulds. Bolckow Vaughan's initial use of the basic open-hearth method was to process the scrap from its Bessemer plant. See p. 204 below and Barraclough, *Steelmaking* p. 230.
[374] J.H. Darby, 'The manufacture of basic open-hearth steel', *JISI*, 20 (1889), pp. 78-83.
[375] Scrap was used but in much smaller proportions.

20 tons, with the works producing about 180 to 200 tons of ingots per week, approximately 10,000 tons per year by the late 1880s. In his paper, Darby reported that they were also able to manufacture mild steel that 'works and welds freely with a small addition of manganese'. But he added that 'a suitable pig is as necessary in the basic as in the acid process.'[376] As at Farnley, de-phosphorising high phosphorus iron had been successful only when the pig contained low levels of sulphur and silicon. At Brymbo the sulphur content was 0.04 per cent and the silicon content 0.4 per cent; at Farnley the equivalent figures were 0.013 per cent and 1.245 per cent respectively. It was clear that at this early stage that the basic open hearth process was more problematic when used with iron that had high sulphur and silicon content as this made the elimination of the phosphorus considerably trickier. And it was precisely this difficulty that faced those interested in using Cleveland pig in steel production in the basic open hearth. The ironstone from which Cleveland pig was made contained 1.13 per cent phosphorus, 0.9 per cent sulphur and 11.87 per cent silicon.[377] The equivalent for the hematite 'Rubio' ore from Spain was 0.1 per cent, 0.03 per cent and 10 per cent respectively.[378] It became clear that the methods developed at Farnley and other plants especially Brymbo, would not be directly transferable to the Teesside producers without further technological advance or understanding of the process.

Farnley and Brymbo are just two of the earliest examples of the application of the basic open hearth process in Britain, but they are not the only ones. By 1890 there were about fifteen to seventeen plants where the process was in operation or had been tried (Table 6.3). Although production was on a small scale, often experimental, and high cost, with an emphasis on high quality, mild steel, the spread of the technique does indicate that there was not only considerable interest in the new technique, but also a willingness to experiment and to perfect it. It was not, as has been suggested by some authors, that the process was neglected.[379] Indeed, the low total output figures belie the development work that was going on. This is also shown by the number of papers on the topic presented at the Iron and Steel Institute and other technical organisations in England, including engineering institutes in Staffordshire and Cleveland. For the period 1883-1893 Dawson lists thirteen principal papers on the subject, and there were many more as is indicated in the abstracts of technical papers in the *JISI*.[380] The published records of these papers show that there was a lively interest in basic open hearth steel, with good attendance at the meetings and detailed discussions following the papers during which experience and ideas were exchanged and examined. For example, at Darby's paper in London in 1889 there were

[376] Darby, 'Manufacture', p. 83.
[377] I.L. Bell, *The Chemical Phenomena of Iron Smelting* (London, 1872), p. 4.
[378] T.H Burnham and G.O Hoskins, *Iron and Steel in Britain* (London, 1943), pp. 296-7.
[379] D. Burn, *Steelmaking*, pp. 173-82 ; Burnham and Hoskins, *Iron and Steel*, p. 180; Abé, 'Technological strategy', p. 54-6.
[380] B. Dawson, 'On different types of open hearth steel furnaces', *CIE*, (1893-6) p. 42.

contributions from seventeen named contributors, all but one of whom worked for or owned an iron and steel firm and had had experience of the basic process.[381]

In spite of these early investigations, the development of the basic open hearth steel production was slower in Britain than in the US and in continental Europe. In Europe interest was stimulated mainly by easy access to high phosphorus ores and a shortage of hematite that made the acid process uncompetitive.[382] Even though the emphasis was on basic Bessemer, which accounted for 63.6 per cent of German steel production in 1900, almost 31 per cent was basic open hearth, and only 5.7 per cent was acid steel (Table 6.4).[383] The abundance of scrap metal also meant that most firms employed the scrap and pig method, a very different situation to that in Britain where the shortage of scrap posed, according to Gilchrist, 'particular problems' and meant the pig and ore process 'alone was applicable'.[384] Gilchrist produced details of a representative German plant, Hoerde, where in 1890 there were nine furnaces in operation, two of 7½ tons and seven of 15 tons. The charge was 70 to75 per cent scrap and the rest ore, and with these proportions the basic open hearth process could produce steel for plates and angles with a phosphorus content of 0.025 per cent using a high phosphorus pig of 2.5 per cent.[385] At around this time there were also some significant pioneering practices introduced at other continental plants. These included the use of molten pig fed directly from the blast furnaces to open hearth furnaces, as at Witkowitz (in Moravia); and the introduction of the combined Bessemer and open hearth, or Duplex method, where the metal is first treated in a Bessemer converter before the final refining in an open hearth furnace. This approach was used at Ruhrort in the late 1880s and also at Witkowitz.[386] Third, there was the invention of the Bertrand-Thiel two-stage process at the Kladno plant, near Prague, that was later improved at the Hoesch works in Germany, where it became something of a feature.[387]

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381 Darby, 'Manufacture', pp. 78-111.
382 Thielen, *JISI*, 20 (1889), p. 103; Daelen, *S&E*, 1904, pp. 507-14.
383 *ICTR*, Feb 9, 1912, p. .
384 Gilchrist, *JISI*, 20 (1889), p. 95. Also see note 353.
385 Gilchrist, *CIE*, 1890-91, p. 153. Gilchrist also gives details of correspondence with Massenez, a metallurgist and engineer at Hoerde, who stated that to produce ingots for crucible steel suitable for guns and tools, a low phosphorus iron was required, and that the plant used hematite pig for such purposes.
386 Thielen, *JISI*, 20 (1889), p.103; Dawson, 'Open hearth furnaces', p. 38.
387 Stead, 'ISI presidential address', pp. 65-7.

Table 6.3: Firms using or Experimenting with Basic Open-Hearth Production up to the mid-1890s

Date	Works/Firm	Engineer/ Manager	Comment	Source
1882	Farnley Iron Co, Leeds	Thomas Gillott	Small scale.	1
1883	Brymbo, Wrexham, North Wales	J.H. Darby	First to use the pig and ore method.	2
By 1884	Weardale Steel, Tow Law and Tudhoe, Co Durham	C.J. Bagley	Discussed steel furnace size and steel quality.	3
c1884	Patent Shaft and Axletree Co, Wednesbury	J.W. Wailes	Wailes stated in 1889 that he had been developing the basic open-hearth process "for about five years". Wailes was later (1891) at Calderbank steelworks Scotland.	4
1888	Parkgate Iron and Steel, Rotherham	J. Davis and Stoddart	Operated two basic open-hearth furnaces, producing 145-175 ingots per week, approx. 7,000 per year.	5
1888	Round Oak Works, Brierley Hill, Staffordshire	R. Casson Smith		6
1888	The Patent Shaft and Axletree Co, Wednesbury.	G.A. Millward		7
1888	Frodingham, Nr Scunthorpe	Maximilian Mannaberg	Gilchrist advised the firm on the use of the basic process.	8
1888-9	Benjamin Talbot and Sons, Castle Works, Wellington, Shropshire.	Benjamin Talbot	Talbot presented his results to the South Staffordshire Institute of Iron and Steel Works' Managers.	9
Before 1889	Eston Steelworks, Bolckow Vaughan, near Middlesbrough	E. Windsor Richards	Described trials with different shaped furnaces.	10
Before 1889	Chesterfield, probably Staveley Ironworks	William Galbraith	Reported on suitable iron and furnace linings.	11
Before 1889	Dowlais, South Wales	E.P. Martin	Used hematite pig in basic-lined furnace.	12
By 1889	Firm not identified	F.W. Paul	Contrasted experience of basic Bessemer and open-hearth.	13
By 1889	Firm not identified	Joseph Cooper	Discussed type of iron and furnace linings used.	14
1889	Clarence Ironworks, Bell Brothers, Middlesbrough	I.L. Bell and others	See text, pp. 173-6.	15

By 1890	Possibly Lilleshall Ironworks, Shropshire	Bernard Dawson	Dawson was an experienced furnace designer as indicated by his comment on the basic open hearth process at the discussion of Davis' 1890 CIE paper and his own CIE paper in 1894.	16
By 1890	Staffordshire Steel Co	Not identified, possibly Thomas Turner	Submitted steel samples to Gilchrist for testing 1890. The firm produced basic Bessemer, but may have experimented with open-hearth.	17
By 1894	Dorman Long, Middlesbrough	W.H. Panton	Reported having been making steel for "a few weeks".	18

Sources for Table 6.3

1. T. Gillott, 'The basic, open-hearth, steel process', *ICE*, 77 (1884), pp. 297-308.
2. J.H. Darby, 'The manufacture of basic open-hearth steel', *JISI* (1889, no. 1), pp. 78-83.
3. *CIE*, 1894-5, p. 48.
4. JISI, 1889, no. 1, pp. 89-92.
5. J. Davis, 'On the manufacture of basic open-hearth steel', *CIE* (1890-3), pp. 88, 91.
6. *CIE* 1890-91, pp. 136-7.
7. *CIE* 1890-91, pp. 139-41.
8. G.R. Walshaw and C.A.J. Behrendt, *The History of Appleby Frodingham* (The United Steel Companies, 1950).
9. *JISI*, 1889, no. 1, pp. 341-2.
10. *JISI*, 1889, no. 1, pp. 105-6.
11. *CIE* 1890-91, pp. 120.
12. *JISI*, 1890, no. 1, p. 94.
13. *JISI*, 1890, no. 1, p. 98-104.
14. *JISI*, 1890, no. 1, p. 109-10.
15. See pp. 173-6.
16. *CIE*, 1890-91, pp. 137-39; *CIE*, 1894-5, pp. 10-47.
17. *CIE*, 1890-91, p. 165; Aberconway, *The Basic Industries of Great Britain: an Historic and Economic Survey*, (London, 1927).
18. *CIE*, 1894-5, p. 48.

Table 6.4 Steel Output by Process, 1900 and 1910 (per cent of total national output)

	Basic Bessemer	Basic open hearth	Acid open hearth	Acid Bessemer
1900				
Britain	10.0	6.0	58.4	25.6
US	--	25.2	8.5	66.3
Germany	63.6	30.7	2.3	3.4
1910				
Britain	10.7	26.3	44.1	18.9
US	--	59.0	4.7	36.3
Germany	60.3	37.3	1.1	1.3

Source *ICTR*, 9 Feb. 1912.

In the US, as in the UK, there was greater interest in the acid process, with little development in basic open hearth practice until the latter part of the 1880s. Samuel T. Wellman, after a visit to Europe in 1885 set up a small experimental basic open hearth furnace at the Otis Steelworks in Pittsburgh the following year. This operated in secret for about four months, successfully supplying good quality steel, but was discontinued because of the slowness of the process compared to acid production and, to quote Wellman, the 'pressure brought by the selling department for more steel.'[388] The first successful commercial production was in 1889 at Carnegie and Phipps' Homestead Works, near Pittsburgh, and by 1890 there were five plants in operation, three in Pennsylvania (Homestead, Steelton and Pottstown), and two in the South (Chattanooga, and Henderson Steel and Manufacturing Co, Birmingham, Alabama) but annual production had reached only 90,000 tons, barely 5.7 per cent of total open hearth output.[389] Subsequent expansion was rapid, however, with basic soon displacing the acid open hearth process and eclipsing acid Bessemer production. In 1900 basic open hearth steel accounted for 25 per cent of US output and 59 per cent in 1910.[390]

This was a phenomenal rate of expansion, the more so given the overall growth rate of the industry, and was achieved not only by the extension of the process to existing plants and the building of new ones, but also by an enormous increase in the capacity of the furnaces. As Wellman points out, in 1901 the average size of a furnace was 40 to 50 tons, but 100 ton furnaces were under construction and there were plans for some of 200 ton capacity.[391] In addition to the size of furnaces, the growth was made possible by advances several areas. These included; a greater understanding of the de-phosphorisation process; and improvements in the design of furnaces, the layout of works and in operating equipment. Chief among the latter were the use of mechanical chargers for the furnaces and feeders for the gas producers, and in the development of the tilting furnace. Tilting, or rolling, furnaces were first developed by H.H. Campbell at the Steelton Works, Pittsburgh in 1889 and taken up by Wellman at the Illinois steelworks, Chicago (1895). They allowed the slag to be removed intermittently during refining and this permitted more effective heating. It also enabled more efficient mechanical tapping (teeming), as the furnace could be tilted by about 25 degrees from the horizontal. It was this last advance that led to Benjamin Talbot's innovative continuous steel process that he first introduced at the Pencoyd Steelworks in 1898 and which was to become a major feature of basic open hearth practice in Cleveland at a number of works, most notably at Cargo Fleet.[392] In passing it is useful to note that in an important respect the early US conditions for producing

[388] S.T. Wellman, 'The early history of open-hearth steel manufacture in the United States', *Transactions of the American Society of Mechanical Engineers*, 23 (1901), pp. 96-7.
[389] F.L. Toy, 'The basic open-hearth process', *Yearbook of the American Iron and Steel Institute*, (1920), pp. 320-3; Wellman, 'Early history', p. 97.
[390] Toy, 'Open-hearth', p. 322; *ICTR*, Dec 12, 1912, p. 219-20; C.H. Macmillan, 'On the manufacture of open hearth steel', *CIE*, (1902-04), p. 128.
[391] Wellman, 'Early history', p. 98. But as will be considered below, care has to be taken in making comparisons as Talbot tilting furnaces were substantially larger than fixed furnaces that produced the same output.
[392] Barraclough, *Steelmaking*, pp. 265-70; B. Talbot, 'The open-hearth continuous steel process', *JISI*, 31 (1900), pp. 33-61; B. Talbot, 'The development of the continuous open-hearth process', *JISI*, 34 (1903), pp. 57-94; B. Talbot, 'Presidential address', *JISI*, 59 (1928), pp. 33-49.

basic open hearth steel differed somewhat from those in Britain. As Darby points out, the original basic open hearth furnaces at Homestead used *low* phosphorus pig iron. In Britain it was coping with high phosphorus *and* the other impurities that was the problem. The benefit of using a low phosphorus iron in a basic-lined furnace was that even more of the phosphorus could be removed than in the acid process and a very high quality of steel assured. The steel, according to Darby, was 'acknowledged to be the best steel for plates and other purposes made in America.'[393]

The position on the basic open hearth steel in Cleveland, while not reflecting precisely the experience of other steel districts in Britain, was very similar. There was a keen interest shown in the developments elsewhere and recognition of its potential benefits for Teesside, but there do not seem to have been any steps taken in the district in the early 1880s to investigate the extension of the idea of a basic lining to the open hearth. Interestingly, and perhaps this is a sign of the attitude on Teesside, there was no explicit discussion of the process in Lowthian Bell's 1884 *Principles of the Manufacture of Iron and Steel*, although he does discuss the methods of de-phosphorising high phosphorus iron as well as the acid open hearth process at some length.[394] This initial lack of urgency to develop the basic open hearth process arose for three main reasons. First, there was a buoyant iron plate trade that was only just peaking (Figure 6.1). Second, the iron and steel firms had ready access to imported hematite and were thus able to follow the trend in Scotland to invest in acid open hearth capacity. And third, much of the early effort to use Cleveland iron went towards developing the basic Bessemer process, as noted in section 6.2.

Nevertheless, by the late 1880s there is clear evidence that Cleveland's firms began to experiment with the basic open hearth furnaces, notably at Bolckow Vaughan and Bell Brothers. Trials appear to have begun at Bolckow Vaughan sometime before 1889, with the general manager of the time, E. Windsor Richards, directing the experiments first with a circular and then an elliptical furnace, probably of the Batho type. This interest was stimulated after Richards had attended a lecture given by J.W. Wailes of the Patent Shaft and Axletree Co. at Owen's College in Manchester. Both furnaces proved to be expensive failures, with Richards commenting: 'if [I] had not heard that paper read by Mr Wailes, it would have saved a good deal of money and considerable vexation of spirit.'[395] Richards then reverted to using a traditional rectangular Siemens furnace and with a charge of Cleveland ironstone, pig and scrap,

[393] Darby, in a written comment on Davis' 1890 paper to the Cleveland Institution of Engineers, *CIE*, session 1890-1, vol. 1890-3, p. 126.
[394] I.L. Bell, *Principles of the Manufacture of Iron and Steel* (London, 1884), p. 383, pp. 388-404.
[395] A.W. Richards, *JISI*, 20 (1889), p. 105.

and adding ferro-manganese to raise the carbon content to 0.12 per cent, was able to produce steel of high enough quality to meet Lloyd's requirements for tensile strength, i.e., a minimum of 24 to 25 tons per square inch. Gilchrist also reported on tests he had carried out on Bolckow Vaughan's basic open hearth steel plates and rivets, and again indicated that that the tensile strength was in the range 22.4 to 30.5 tons, mostly in the upper range.[396] Despite these favourable results, Bolckow Vaughan must have abandoned the experiments as the comments in 1891 from Le Neve Foster, an engineer from the firm, strongly suggest that they were no longer using the process.[397] He gave no indication of why Bolckow Vaughan stopped its trials, although it is likely that it was either on cost grounds or because of limited demand, and it was not until almost ten years later that they were resumed, this time using the American Monell method.[398]

Even though Bell seems to have overlooked the application of the basic process to the open hearth furnace in his *Principles* book, he was only too aware of its possibilities. While not explicitly distinguishing basic Bessemer from basic open hearth, he wrote in his evidence to the *Royal Commission on the Depression of Trade* that 'the basic process … relieves us from all difficulty [of dealing with phosphoric pig]…the world need not fear that its demand for steel runs any danger of being limited by the want of the necessary raw material.'[399] In reply to a question from the Committee on whether the UK steel industry was entirely dependent on hematite ore, he replied:

> No, and I would go further than that, for admitting some difference in the quality, I do not despair of science and practice in this country being able to obtain steel by the basic process fit for all purposes for which steel is made by the acid process can be or is used at present.[400]

Bell's early research into the use of Cleveland iron in the production of steel was primarily aimed at the removal of phosphorus and other impurities (at the time referred to as metalloids) from the pig before refining, either in the blast furnace or before transfer to the steel furnace. He was not therefore specifically concerned with the basic open hearth method. These processes included 'washing' the iron to remove the silicon, a process that was also developed

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[396] P. Gilchrist, *CIE*, (1890-91), pp. 167-8.
[397] H. Le Neve Foster, *CIE*, (1890-91), pp. 141-2.
[398] A.W. Richards, *CIE*, (1902-3), p. 142.
[399] Bell, 'Evidence', p. 324. Bell's statement was in reply to concern that future steel production would be constrained by a shortage of hematite ore.
[400] Bell, 'Evidence', p. 53.

independently by Krupp in Germany at the same time.[401] However, by the late 1880s his firm, Bell Brothers, turned its attention to basic open hearth production and started experiments with two basic furnaces in January 1889. This was probably prompted by the lack of success in his other methods of purifying pig iron; but also, as he commented in a discussion at the Cleveland Institution of Engineers, he was responding to the decline in the malleable iron trade, something that seriously affected Bell Brothers as a large pig iron producer.[402]

The Bell Brothers cost accounts show records for two six month periods during which the trials took place – October 1890 to March 1891 and April to September 1891 (Tables 6.5 and 6.6). The experiments reveal two interesting features. First, rather than lining the furnace with dolomite, the usual basic material, Bell used chrome (a neutral material), an approach that had been practised at the Alexandroski steelworks near St Petersburg.[403] Second and possibly related to the first given his extensive European experience, the firm employed Alexandre Pourcel, the famous French metallurgist who had been involved in the early refinements of the Siemens-Martin open hearth furnace at the Terre Noire works at St Etienne.[404] It appears that Lowthian Bell and his son Hugh, who was the firm's managing director, were using their connections in the iron and steel industry to tap into expertise that had been developing outside Britain, especially in Europe where the basic open hearth method had been more extensively investigated and developed than elsewhere.

Stead presented some results for the composition for steel from a typical cast. These show that on purely technical grounds the firm had some success in making a product of acceptable quality. The steel, with 0.08 per cent carbon, contained low levels of phosphorus (0.02 per cent), sulphur (0.03 per cent) and no silicon. These were, much the same as the results obtained by Davis at Park Gate, Rotherham (Table 6.3) some years before, but from a charge that contained a far higher proportion of phosphoric pig (64 per cent) and less scrap – iron and steel scrap were 20 and 16 per cent respectively.[405] In fact it seems that the firm experimented with different proportions of pig, ore and scrap in the charge (Table 6.5) and also from the details in a paper reporting on the trials at the Metallurgical Congress in Paris in 1889.[406] But while the quality of the steel may have been satisfactory, at least in its chemical composition, there is no analysis of its physical properties. Also the cost data clearly show that the experiments were not

[401] Stead, 'ISI presidential address', p. 64.
[402] Bell, *Principles*, pp. 142-3.
[403] A.W. Richards, *JISI*, 20 (1889), p. 106.
[404] J.E. Stead, 'ISI Presidential address', p. 64; 'Obituary: Alexandre Pourcel' *JISI* 65 (1934), pp. 473-5.
[405] Stead, 'ISI presidential address', pp. 64-5; J. Davis, 'On the manufacture of basic open-hearth steel', *CIE* (1890-3), pp. 88, 91.
[406] *JISI*, 20 (1889), p. 433. The proportions reported at the Congress were 62.5% pig, 18.75% iron scrap, 12.5% steel scrap and 6.26% ore.

economically viable. Production cost were, in the first six months period, 39.2 shillings per ton *above* the average selling price, a loss of almost 50 per cent. And even when production switched to using higher yielding hematite and less impure pig and scrap in the second six months, the losses were still substantial – 27.9 shillings – with costs 28 per cent above prices. Over the 1890 to 1891 period for which there are records, the cumulative loss amounted to £6,783 on an output of just over 4,000 tons. It is hardly surprising that the trials were abandoned for the time being, especially as Bell Brothers was also making heavy losses on its pig iron trade.

Table 6.5: Bell Brothers Basic Open-Hearth Steel Experiments (1889-91) – Average Charge Composition

	October to March 1891		April to September 1891	
Input per ton of steel	cwt.	%	cwt.	%
Clarence pig	13.75	52.60	5.05	23.10
Hematite pig and other metal	0.22	0.01	4.50	20.59
Scrap iron and steel	9.26	35.42	9.31	42.59
Ferro- and Spiegel	0.34	0.01	0.43	0.20
Oxide	2.03	0.08	2.47	0.11
Chrome ore	0.54	0.02	0.10	< 0.01
Total	26.14		21.86	

Source: Bell Brothers Profit and Loss Accounts, Balance Sheets, Auditors Reports and Cost Accounts No.5 (BBA vol. 5), p. 503.

Table 6.6: Bell Brothers Basic Open Hearth Steel Experiments (1889-91) – Costs, Revenues and Output

Costs and revenues per ton	October to March 1891 Shillings	April to September 1891 Shillings
Charge		
Clarence pig iron	28.89	10.55
Hematite pig & old metal	0.71	9.58
Scrap iron and steel	25.42	27.72
Ferro and spiegel	3.01	3.43
Oxide	1.42	1.73
Chrome ore	1.74	0.40
Other costs		
Fuel: Coal/ Coke	11.79	9.13
Limestone	0.87	1.40
Wages and Salaries	22.53	15.40
Other*	13.61	6.48
Depreciation of steelworks	4.72	13.51
Cost per ton	114.64	99.38
Average price per ton	75.32	71.47
Profit or loss per ton	(-) 39.32	(-) 27.91
Revenue from scrap per ton	3.52	2.27
Totals+	£	£
Sales Revenue	11,728	4,174
Cost of manufacture	17,058	5,625
Profit or loss	(-) 5,329	(-) 1,452
Steel ingots made (tons)	2,976	1,132

Notes
*Other costs include: stores, royalty, rents, rates and taxes.
+ Totals are given in £ and may not add up due to rounding.
Source: BBCA vol. 5, p. 503.

The commercial failure at Bell's Clarence works, however, did not dampen the interest in basic open hearth methods in Cleveland. Judging from the papers and discussions at the Cleveland Institution of Engineers meetings as well as attempts at other plants on Teesside, it seems that there was a growing sense of urgency in the need to overcome the problems with the process. This is clearly indicated by the presentation of a number of papers and the subsequent follow-up discussions at the Cleveland Institution. In 1890, Davis, from the Park Gate Ironworks in Rotherham, set out his experience of producing basic open hearth steel and at the same meeting Edward Saniter elaborated on his desulphurising process that he had developed at Wigan, and already presented to the ISI's autumn meeting.[407] Later, in 1894, Bernard Dawson read a long and detailed assessment of the nature and operation of different types of open hearth furnaces.

[407] E. Saniter, 'The desulphurising of iron and steel by the calcium oxy-chloride process', *CIE*, (1890-3), pp. 43.

Dawson is described by some of the discussants at the meeting as a 'master of furnace engineering, who had extensive knowledge of steelmaking in Britain, the US and on the Continent.[408] He also had a connection with Middlesbrough, where he grew up and trained as an engineer.[409] Furthermore, both Hawdon (1892-3) and Stead (1894-5), in their president's addresses to the CIE made direct reference to the basic open hearth process, with Hawdon particularly emphasising the potential for using it in Cleveland and how important it was 'to make up our minds that the basic process is to be the steel refining process of the future in this district.'[410] Stead, as might be expected given his technical expertise as a chemist, stressed the way in which Saniter's new process helped in the reduction of the impurities in iron before final refining in the open hearth furnace. In each of these cases the speakers expressed the view that it was now possible, or at least soon would be, as well as highly beneficial, for Cleveland's steel producers to adopt the basic open hearth process. Thus Davis wrote:

> '…any firm who are (sic) not using up native pig for steel and desirous of making basic steel from Cleveland or other native ores, may do so very easily by flowing out the acid bottom and ramming in the basic lining, and making basic additions [to the charge]'.[411]

Similarly, while acknowledging the current cost differences between acid and basic open hearth methods, Dawson urged steel producers to be prepared to switch to basic open hearth if circumstances changed.[412] Indeed, the view that the process would be imminently adopted in the district was voiced by a number of others, including Saniter, who noted the importance of his process for Cleveland, as did Stead and Dawson.[413] Another president of the CIE, C.J. Bagley, also emphasised that the future for Cleveland lay in the production of basic open hearth steel, remarking in his introduction to the discussion of Davis's paper:

> Basic material must come for plates as surely as it came for rails. I hope this discussion will remove all prejudice against it. It would be a great advantage to have plates made from Cleveland ore, even if they are not cheaper than those made from hematite ores.[414]

Earlier, in a summing up after Davis's paper, Bagley said that he hoped that the discussion would produce evidence as to 'why the same [i.e. the use of the basic open hearth furnace] is not

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[408] Turner, *CIE* (1894-5), p. 46.
[409] Dawson, 'Open hearth furnaces', p. 13.
[410] Hawdon, 'CIE president's address', pp. 20-21; Stead, 'CIE president's address', *CIE*, 1894-5.
[411] Davis, 'Open hearth', p. 96-7.
[412] Dawson, 'Open hearth furnaces', p. 12
[413] Saniter, 'Desulphurising', p. 43; Stead, 'ISI presidential address' pp. 76-79; Dawson, 'Open hearth furnaces', p. 39.
[414] J. Bagley *CIE* (1890-91), p. 128.

done in this district as Mr Davis is doing in Rotherham', adding that 'we really ought to tackle this question in a business-like way.'[415] Some years later, in 1903, C.H. Macmillan, an American engineer from British Westinghouse in Manchester, read another paper on the basic open hearth process for which he drew on his extensive experience in the US.[416] It was, however, at a time when the switch to basic open hearth production had become a central part of the strategies of several steel producers in Cleveland, and so while it can be seen as yet another indication of the local interest in the process and part of the means by which information was transmitted, Macmillan's influence in bringing about the change is probably limited.

These papers and discussions which followed show that there were a number of concerns the iron and steel producers, metallurgists and engineers had in common and which led them to step up their interest in the process. One was the reliance on imported hematite ore from Spain that was needed for the acid process. Fears were expressed that this dependence left the district vulnerable to supply disruptions should an outbreak of war interfere with international trade.[417] A more widely held concern was the effect that the ore imports were having on the output of Cleveland's ironstone mines and production of Cleveland pig. Hawdon in particular emphasised the under-utilisation of local resources and the effect this had on the area and at a couple of meetings presented data to illustrate the effects.[418] He even made a rather vague reference to the 'economic advantage of the country' of using domestic ores.[419] Among others, Dawson was of a similar opinion about the failure to use local resources: 'does it not appear a questionable practice to comparatively ignore the resources at our feet and seek them afar off?'[420]

There are a number of ways of looking at these of concerns. One is to view them as rather vague expressions of rudimentary mercantilist or even nationalistic attitudes. Alternatively, they may simply reflect the interests of the Cleveland iron makers who not only produced the pig iron but also had extensive ironstone mining interests and were keen to find a new outlet for their product in the face of stagnating demand. Hawdon, for example, worked for Samuelson's which had a large blast furnace plant and owned ironstone interests at Slapeworth and Spa Wood. A number of other blast furnace firms, e.g. Bell Brothers, Cargo Fleet, Bolckow Vaughan, had similar interests. Nevertheless, discussions at the Cleveland Institute reveal a

415 Davis, 'Open hearth', p. 97.
416 Macmillan, 'Manufacture', pp. 120-36.
417 Dawson, 'Open hearth furnaces', p. 11; J. Head, 'On recent developments in the Cleveland iron and steel industries', *IME*, 45 (1893), p. 245
418 Hawdon, 'President's address', pp. 18, 21; CIE (1894-5), pp. 43-4.
419 Hawdon, *CIE*, (1894-5), p. 45.
420 Dawson, 'Open hearth furnaces', p. 11. See also Howson's and Head's comments on Hawdon's president's address, *CIE* (1892), p. 23; and Head's comments on Dawson, *CIE* (1894-5), p.50.

deep anxiety about the future of district's iron and steel industry. These anxieties stemmed from the decline in the iron ship plate trade and the fact that the basic Bessemer process offered limited scope as a substitute because of concerns over the quality of Thomas steel. The switch to acid open hearth, while successfully filling the gap for some firms still left acid producers exposed to rising hematite prices. As Jeremiah Head commented in 1894 at a Cleveland Institution meeting, the iron and steel trade 'is not in a particularly happy position at the moment'.[421] This was exacerbated by the growing awareness of the competition from the German and Belgian basic open hearth producers whose steel had gained greater acceptability with the British regulatory authorities than that from home manufacturers.

It is not surprising, therefore, that many in the Cleveland industry, along with industry experts such as Head, saw the exploitation of the local ores as the best way of restoring prosperity.[422] But it was widely recognised that a successful shift to basic open hearth depended on demand, and this in turn was dependent on two factors. The first was to reduce the relative production costs of basic open-hearth compared to acid steel, and this relied on finding a commercially viable solution to the technical problems of making steel with Cleveland iron. The second was to gain acceptability for the product among consumers – the mechanical and civil engineers and the shipbuilders.

The question of the quality of basic steel was one that dogged the industry for a number of years, and judging from many *ISI* and *CIE* discussions, caused some resentment among the steel firms as there was an earlier acceptance of basic open hearth steel from continental producers. It is difficult to estimate the extent to which the slow rate of recognition of basic open hearth steel in Britain delayed its development, but it is likely to have something of a disincentive, at least up to the mid-1890s. Most important was the large ship plate market that from the 1880s was dominated by acid open hearth steel, which had replaced iron as the preferred metal. To open up this crucial market the producers needed to convince users of the quality of basic steel and in particular to obtain the official recognition from the insurers (Lloyd's Register), the Board of Trade and one of the largest commissioners of ships, the Admiralty. As Head stated in 1889, 'he was glad to hear… that there was a prospect of getting steel made by the basic Siemens process of quality to fulfil Lloyd's and the board of Trade tests; because until that was done a large market … would be closed.'[423]

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[421] J. Head, *CIE*, (1894-5), pp. 49-50.
[422] See Richard Howson's on Hawdon's address, *CIE* (1894-5), p. 23; and J. Head, *CIE* (1894-5), p. 50.
[423] J. Head, *JISI* (1889, no. 1), p. 107.

Lloyds' first introduced minimum specifications for steel used in shipbuilding in 1877.[424] The standards mainly referred to tensile strength, elongation and the minimum thickness of plates, and initially there was no distinction between or restrictions on the process by which the steel was made (Table 6.7).[425] This last came in 1900 when Lloyd's Registry Rules were made explicit: 'steel for shipbuilding should be made from the Open Hearth process, acid or basic.'[426] Until 1900, therefore, the acceptability of steel for plates was dependent on the ability of the product to withstand the tests, which were applied firm by firm, and was not restricted by a general ruling from Lloyd's against the basic process of either type. This left the market potentially open to competition between different processes, and as McCloskey and Wengenroth have shown, once Martell, the Chief Surveyor at Lloyd's, concluded that steel ships were as cheap to build and operate as those of iron, the rate at which the shift to steel occurred depended ultimately on the relative price of iron and steel plates.[427] But in the case of basic open hearth steel, the acceptance was not as straightforward as it was for its acid equivalent.

Table 6.7: Official British Minimum Standards for Steel Plates, c1896

		Tensile strength, tons per square inch	Elongation, per cent in 8 inches*
Lloyd's Registry	Ship	28 to 32	20
	Boiler	26 to 30	20
Admiralty	Ship	26 to 30	20
	Boiler shells	26 to 30	20
	Boiler fireboxes	24 to 26	26
Board of Trade	Boiler shells	27 to 32	20
	Boiler fireboxes	26 to 30	20

* In 10 inches for Board of Trade standards. Source: Head, 'Steel plates', p. 155.

At first in the 1870s acid and basic Bessemer producers had high expectations of the ship plate market as an outlet for their mild steel and there were some early users in Scotland and in the north east.[428] By 1884 both the Cleveland basic Bessemer specialists, Bolckow Vaughan and NESCo, were supplying plates but this was to be a short-lived market for them. Lloyd's tests on NESCo plates in January 1884 indicated an unacceptable variability in quality, with at least one of the samples failing to meet the standards required. Worse was to come when Lloyd's also tested plates at a north east shipyard and found that the product was of 'catastrophically poor

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424 Wengenroth, *Enterprise*, p. 236.
425 J. Head, 'American and English methods of manufacturing steel plates' *ICE* 126 (1896), pp. 132-55.
426 Clarke, J.F. and Storr, F., *The Introduction of Mild Steel into Shipbuilding and Marine Engine* Industries, Occasional Papers in the History of Science and Technology no. 1, Dept. of Humanities, Newcastle upon Tyne Polytechnic, 1983, p. 81; and p, 82 for the rules in 1907-8.
427 McCloskey, *Economic Maturity*, p. 50-3; Wengenroth, *Enterprise*, pp. 228-9.
428 An early user of Bessemer steel was the Clyde shipbuilder William Denny, although by the mid-1880s, the firm had changed over to acid open hearth steel. Clarke and Storr, *Mild Steel*, pp.61,82; *INA*, 1886,vol. 27, p. 137.

quality'. The reports in Britain did not name the firms, but they were identified in *Stahl und Eisen*, and one was Bolckow Vaughan.[429] This led Lloyd's to rule in December 1885 that they would not accept ships of basic steel for registration 'until exhaustive tests from a large number of charges that a reliable and uniformly ductile material could be made.'[430] The problem was one of brittleness in the steel caused not by phosphorus, most of which had been removed in the Bessemer converter, but by nitrogen.[431] The damaged reputation of basic steel received a further blow in 1888 when Martell identified fractures in German produced plates destined for shipbuilders.[432]

Although most of these tests, and all of the failures, applied to basic Bessemer steel, Lloyd's did not at first, distinguish between the two the basic processes. Consequently, the adverse publicity was a major setback for the basic open hearth process and occurring at such an early stage of its development enabled the acid process to secure its leading position in the plate market. Indeed, it was only from the mid-1880s that basic open hearth producers began to apply to Lloyds and the Admiralty for their product to be tested. For the Admiralty, William H. White, the Director of Naval Construction, reported that extensive tests had been conducted in 1886 on both basic Bessemer and basic open hearth steel after representations from a number of firms.[433] The results were set out in a paper read to the Institution of Naval Architects at their Sunderland meeting in 1887.[434] The Admiralty's position was much the same as Lloyd's: they were willing to accept steel by any mode of manufacture 'as long as it met the required standards after proper experiments'. A wholesale acceptance, however, was not forthcoming. This was partly because the testing of basic open hearth steel had not been complete; in particular, although the tests for tensile strength and ductility were 'quite successful', there had been no inclusion of rivet samples, and past experience had shown that even when the other tests had been passed, those for riveting had not. By 1891 the Admiralty had accepted some basic steel, mainly open heath, for shipbuilding, but White emphasised that its current status was equivalent to that of acid Bessemer steel. It could be used, but not for 'the most important parts of the structure of ships'.[435] Two years later at an Institute for Mechanical Engineers meeting, White referred to later Admiralty tests and voiced greater support for basic open hearth steel. He explained that the Admiralty would use it if 'they could get such a material they could trust'.[436] And although he attempted to offer support for basic open hearth steel, saying 'in the

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[429] Wengenroth, *Enterprise*, pp. 171-2.
[430] Clarke and Storr, *Mild Steel*, p. 83.
[431] Wengenroth, *Enterprise*, pp. 228-9; McCloskey, *Economic Maturity*, p. 48.
[432] Clarke and Storr, *Mild Steel*, p. 87; *INA*, 29, p. ; *JISI* 20 (1889), pp. 155-6
[433] W.H. White, *CIE* (1890-91), pp. 146-9.
[434] *INA*, vol. 29.
[435] W.H. White, *CIE* (1890-91), p. 148.
[436] W.H. White, *ICE* (1896), pp. 266-69; *JISI* 23 (1892), p.32.

Admiralty service there had been a continuous endeavour to encourage the basic process of steelmaking from native ore. Admiralty officers had done their best to test the matter on the side of its possibilities', his comments reveal a deep-seated feeling against basic steel of both kinds. He announced that basic Bessemer was not to be used in ships for any purposes and basic open hearth was not to be used for boilers. In fact, he stated explicitly an Admiralty preference for acid open hearth steel as it was both cheaper and had all the right qualities.

The situation for basic open hearth steel was also not helped by some inconsistency between the authorities, and even by the Admiralty itself. Thus at a Cleveland Institution meeting in January 1891 Percy Gilchrist reported that following enquiries to the Board of Trade about the use of the steel, the department had replied that it was not prohibited for use in the boilers of passenger steamships 'if it is found suitable'. This was, quite clearly, a case of two government departments sending out confusing signals and was hardly conducive to encouraging a market for basic open hearth steel. Gilchrist, however, made no mention of the Board of Trade's attitude to ship plates.[437] Gilchrist also revealed that as well as sanctioning some German basic open hearth steel plates, the Admiralty had accepted boiler plates from Belgium and Russia and ship plates from France. He did, however, did point out that the tests on the materials were extensive and of the same standards as applied in Britain.[438] In fact it is difficult to determine Gilchrist's intentions from the report of the discussion; his comments can be read either as a complaint about preferential treatment for European competitors or as an encouragement to British producers to emulate their continental counterparts.

To some extent Lloyd's appear to have been more supportive of, or at least conciliatory towards, basic open hearth producers, perhaps because of mounting pressure from the firms who had adopted the process or who were potential producers. Martell, at the Iron and Steel Institute meeting discussing Darby's 1889 paper, indicated that they had had a 'very large number of inquiries' and felt obliged to explain to the meeting the conditions for the acceptance of the material. The report of his contribution to the discussion noted: 'this [the conditions for acceptance] was what he particularly wished to bring before the meeting, because they might not know so well as he did matters of that kind, which came officially under his knowledge'.[439] Perhaps Martell also felt under pressure as there was concern among British firms that Lloyd's had accepted basic open hearth steel for shipbuilding from continental producers – eight to ten German firms in 1889. At the same meeting he also indicated that basic plates of up to ½ inch thickness produced by the Glasgow Iron Company were regarded as acceptable, although he

[437] P. Gilchrist, *CIE* (1890-91), pp. 131-2.
[438] P. Gilchrist, *CIE* (1890-91), pp. 129-33.
[439] B. Martell, *JISI* 20 (1889), p. 85.

failed to say whether they were of open hearth or Bessemer steel. Later, at the January 1891 Cleveland Institution meeting J.J. Milton, Martell's successor, was also defensive of Lloyd's policy. He rejected criticism that Lloyd's did not accept basic steel, stating that for the past three years plates and boilers had been accepted from a number of British works. He also pointed out that there was a considerable difference between the basic open hearth steel produced in Britain and Germany since the German metal made at Hoerde for example was made with purer raw materials – 75 per cent scrap, 25 per cent non-phosphoric pig and no rail iron, which tended to be high in phosphorus. This gave the German producers an advantage over their British rivals who used high phosphorus pig. He did on the other hand reiterate the position that if the steel made in Britain met the necessary tests, then the '…the Committee of Lloyd's Register will be very pleased to pass it equally with acid steel.'[440]

Despite some variation in official attitudes, and some misunderstanding by those in the industry, by the mid-1890s the position on basic open hearth finally appears to have been settled; it was acceptable as long as it met the necessary standards. Indeed, in the discussion of Dawson's paper at the Cleveland Institution in 1894 there was no mention of Lloyd's or the Admiralty, and unlike earlier meetings, no representatives appear to have attended, or at least if they did, they made no contribution to the discussion.[441] This left two remaining impediments to the widespread adoption of the process. One was the attitude of the users and the other was the costs of production.

The unwillingness of shipbuilders to use basic open hearth steel for ship and boiler plates can be explained partly by the poor reputation of basic Bessemer steel. As Burn states, to north east shipbuilders basic Bessemer was 'like a red rag to a bull'.[442] But why the shortcomings of Bessemer steel should have extended to open hearth steel is not clear. For some it may have been pure prejudice, the result of ignorance of the differences in the metals and the manufacturing processes. This was the opinion of a number of steel producers, including Arthur W. Richards the steelworks manager at Bolckow Vaughan.[443] Macmillan similarly attributes the reluctance to use the steel to ignorance of the metallurgical properties of the metal, noting comments such as that it was believed to be 'too dry' and 'washed out', and some users thought that there was a 'mysterious something about acid steel that made it better'.[444] Interestingly, Burn inadvertently identifies a surprising source of such misunderstanding and confusion between the two basic processes – the famous civil engineer, Sir Benjamin Baker.

[440] J.J. Milton, *CIE* (1890-91), pp. 151.
[441] Dawson, 'Open hearth furnaces', pp. 48-63.
[442] Burn, *Steelmaking*, p. 175.
[443] A.W. Richards, *CIE*, (1903), p. 142.
[444] Macmillan, 'Manufacture', pp. 127-8.

Burn cites Baker as an example of one of the 'consulting engineers [who] regarded it unsuitable for bridges, etc.,'.[445] He quotes Baker's comment at an Institution of Civil Engineers meeting: '[I] had more trouble and anxiety over the use of basic–steel plates for about six months than [I] had in twenty year's use of acid steel.'[446] However, as Jeremiah Head noted in his response to Baker, the ICE president was referring to basic Bessemer 'which had come from the Continent, especially Germany', and not to open hearth plates.[447] Gilchrist offered a different explanation: he attributed the reluctance of ship owners and builders to use basic open hearth as a misunderstanding of the Admiralty and Lloyd's attitudes and guidance rather than ignorance of the steel's properties.[448]

Although resistance by users on the grounds of prejudice, a lack of knowledge or a misunderstanding of the official position are all possible, none is entirely convincing. As has been pointed out, over time the Admiralty, Lloyd's and the Board of Trade accepted basic open hearth steel, and made it known that they did. It is unlikely that users would have remained ignorant for long, especially given the basic open hearth producers' promotion of the steel with the authorities, and they are unlikely to have overlooked a product that offered the same qualities as acid open hearth steel. Some of the explanation must therefore lie with the steel producers themselves. As William White explained in 1896, 'there was nothing to prevent any maker from tendering for open hearth steel instead of open hearth acid…[but]… the invitation had not been responded to'.[449] He went on to say:

> The Admiralty, as a large purchaser, had allowed the use of basic steel by the open-hearth process, and the manufacturers had not availed themselves of the opportunity. [I] presume the only conclusion to be arrived at was that under existing conditions, and with existing plant it had been commercially preferable to continue the acid process.[450]

To some extent this is supported by Head's own assessment of the situation in 1896. The hesitation on the part of steelmakers to commit to the basic open hearth process can be explained by risk aversion. That is, having committed to the acid process 'the steelmakers were reluctant to run the risk of trying new experiments and so had followed suit one after another in employing the acid process.'[451]

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445 Burn, *Steelmaking*, p. 175.
446 B. Baker, *ICE*, (1896), pp.172-3.
447 J. Head, *ICE*, (1896), p. 177.
448 P. Gilchrist, CIE (1890-3), pp. 131-2.
449 W. White, *ICE*, (1896), pp. 171-2.
450 W. White, *ICE*, (1896), p. 172.
451 Head, *ICE*, (1896), p. 177.

Given the rather confusing picture of users', the authorities' and the producers' attitudes, it is almost impossible to disentangle the root cause of the slow adoption of basic open hearth steel in Britain, putting technical difficulties aside. Whether it was the result of the shipbuilders' or the steel producers' preferences is unclear; in reality, it was probably an interaction of the two that gave rise to a self-reinforcing effect. The initial poor quality of basic Bessemer plates damaged the reputation of the basic process, even if basic open hearth steel was implicated only by association, and the availability of a high quality acid open hearth product coupled with an official preference for the acid process produced a strong bias in its favour among consumers. This in turn encouraged steel makers to invest heavily in acid open hearth furnaces, and even though the authorities came to stress their neutrality between the two open hearth methods, as long as the steel passed the appropriate tests, the commitment to acid steel made producers wary of risking a new and, in Britain, largely untried process. Such risk-averse behaviour is understandable given the recent loss of the iron plate trade; former iron masters who had switched over to acid open hearth were unlikely to forego the benefits of a rapidly expanding market from the highly successful successor to iron. To have shifted again to a new process that they could not be certain their customers would accept was too much of a gamble. And on the consumers' part, the continued preference for acid open hearth steel would last as long as they were assured of a supply of a product of the appropriate quality at a competitive price. Being offered an alternative, basic open hearth steel, but in very limited quantities and at a higher cost was unlikely to encourage them to experiment.

Ultimately, what had to change to switch demand towards basic open hearth steel, and induce the makers in Cleveland to supply more, was a shift in the relative costs of acid and basic steel. This depended on two factors: the costs of imported hematite ore from Spain and solving the technical problems of using Cleveland iron in the open hearth. As John Gjers, a Cleveland ironmaster but not a steel manufacturer, astutely remarked in 1889, because of transport costs hematite pig was 12 shillings per ton less in Cleveland than in Staffordshire, and as a result the price difference between acid open hearth and basic open hearth steel in Cleveland was so small that there was no incentive to develop the basic version of the process in the district. By contrast, such a price differential was an important inducement for West Midland's steel firms to develop basic open hearth steel using local phosphoric pig, as was done at Brymbo and Round Oak (Dudley). It could be expected, therefore, that once hematite ore and pig prices began to rise in Cleveland, the scales would begin to tip in favour of basic steel. Yet, as Table 6.8 shows, while the price of imported ore did rise from the mid-1890s, relative to Cleveland ore prices there was no discernible trend. In fact, by 1890, relative import prices actually fell and continued to do so until 1900. Consequently at the time there seem to be no major supply-side signals to producers to speed up the development of the basic process, unless there was an anticipation of future price rises. Although ore price increases never materialised before 1914, there were upward pressures on hematite pig production costs and therefore prices as a result of declining ore quality.[452] It is perhaps not surprising therefore that in the mid-1890s experiments in Cleveland using the local iron were resumed.

Table 6.8: Iron Ore Prices, 1870 – 1913 (shillings per ton)

	Cleveland	West Coast Hematite	Imports (average)	Imports/Cleve-land price ratio
1870	4.00	12.50	--	--
1875	4.00	15.50	25.42	6.4
1880	3.50	14.58	21.16	6.0
1885	3.25	9.58	13.83	4.3
1890	3.83	11.16	16.08	4.2
1895	3.25	10.00	13.42	4.1
1900	4.83	16.16	17.83	3.7
1905	3.83	13.50	16.33	4.3
1910	4.33	16.16	17.42	4.0
1913	5.08	17.83	18.83	3.7
1920	15.83	59.25	50.00	3.2

Source: Burnham and Hoskins, *Iron and* Steel, p. 110.

The firm involved this time was Dorman Long, an acid open hearth steel producer that specialised in girders and some ship plate. It is not clear where the initiative came from, but at the February 1894 director's meeting, the Chairman and joint managing director Arthur Dorman, is recorded as introducing a discussion about experimenting with the Siemens basic process. It was agreed that trials should begin by converting one acid lined furnace to a basic lining once it had been 'ascertained that Lloyd's are favourable.'[453] There are no further references in the directors' minutes to this trial, but it appears to have been technically successful. W.H. Panton, the general manager, reported at a Cleveland Institution meeting in 1894 that year that the company had been making steel from Cleveland white iron in an acid furnace with a basic dolomite lining 'for a few weeks', and that the product was of a reliable quality. At the same meeting, Charles Bagley (Weardale Iron and Steel) added that his company had used the steel and found it 'very satisfactory'; being more regular, softer and

[452] W. Whitwell, 'Presidential Address', *JISI* 32 (1901), pp. 37-40; H.H. Campbell, *The Manufacture and Properties of Iron and Steel* Second Edition, (New York, 1904), pp. 706-7. Available at: http://archive.org/stream/manufactureandp07campgoog#page/n0/mode/2up
[453] DLDM, 6 Feb. 1894, pp. 135-7.

having better elongation, it gave better results than acid steel when rolled into thin plates.[454] Later that year, Stead, in his president's address at the Cleveland Institution made a point of referring to the Dorman Long experiments, and noted that the iron had been treated by the Saniter desulphurisation process.[455] This use of the Saniter process perhaps offers a clue as to why Dorman Long should have resumed basic open hearth experiments at a stage when there seemed to be no major price pressures to move to Cleveland rather than hematite iron and the firm itself had no incentive to use Cleveland's ironstone resources as at the time the company had no ironstone mines of its own. Saniter had recently presented papers on his process at the Iron and Steel Institute and at the Cleveland Institution of Engineers in November 1890 and perhaps the firm was influenced by the favourable results or even persuaded to experiment.[456] The use of white iron, however, indicates that while the quality problems may have been overcome, the technical difficulties of removing the impurities to make commercially viable steel remained. White iron is a superior quality iron, low in carbon, and especially silicon, that is usually used in the puddling process (i.e. to produce malleable iron). Costs were therefore likely to have been greater than if ordinary Cleveland iron had been used, and consequently the potential profitability of the basic steel much lower. It is possibly for this reason that the experiments ceased – or at least there is no further record of the process in Cleveland – for the next three years.

It was in February 1897 that Dorman Long resumed their work on basic steel, this time at the Cast Steel Foundry (Roseberry Foundry), a small works they rented from R.P Dorman and Co, a partnership between Arthur Dorman and his brother (see Chapter 7). The trials continued through the year but without much success as the furnaces being used were too small.[457] As Dorman and Panton explained to the board, however, they were convinced of the importance of the process to the future of the firm especially given Dorman's expansionary ambitions. 1897 had been a better year for Dorman Long, and the industry as a whole, after a lean period from 1894; profits rose sharply and in his optimistic Annual Statement to Shareholders Arthur Dorman set out the necessity of future investment 'to keep abreast of the times' and to be able to meet competition from America and Germany. He explained to shareholders, though was not precise about the details, that 'a considerable extension of the works was being planned' if it was justified by further investigations. This last point may be read as a reference to the Board's plans, agreed at a directors' meeting immediately preceding the AGM, that arrangements should be made with Bell Brothers to use their two basic open hearth furnaces at the Clarence Works to

[454] W.H. Panton and C.J. Bagley, *CIE*, 1894-5, pp. 48-9.
[455] Stead, 'CIE President's address', p. 76-9.
[456] Saniter, 'Desulphurising'.
[457] DLDM vol. 1, 12 Aug. 1897, pp. 217-7.

continue the experiments.[458] This time the venture was a success and by the following November (1899) Dorman Long proposed a further agreement will Bell Brothers to build new furnaces at Port Clarence that Dorman Long would lease, initially for two years. It was a significant investment, comprising two 45 ton basic Siemens furnaces and a 300 ton mixer.[459] In passing it is interesting to note that at this time Dorman Long was still hedging its bets between the two processes as they had already planned a new acid open hearth furnace at the Britannia Works, although this was subsequently cancelled as the commitment to the basic open hearth method deepened.[460] On the other hand, the link-up with Bell Brothers can be seen as part of Arthur Dorman's expansion strategy: as well as supervising the building of the Clarence steel furnaces and then leasing from Bell's, Dorman Long agreed to take a fifty per cent stake in the firm. It was the first stage of a full takeover that was completed in 1902 and a sure sign that the company believed the future lay in basic open hearth steel.[461] The acquisition of a firm that had one of Cleveland's premier blast furnace plants and sizeable ironstone and coal royalties was a central part of this growth (Chapter 7).

At the same time as tapping in to Bell Brothers' expertise, experience and equipment, Dorman Long maintained a tight control over production at the Clarence Steelworks. Panton was brought in as superintending engineer, as well as keeping his position as general manager at the Britannia plant, and Dorman Long, not Bell Brothers, hired Ernest Saniter to implement his desulphurising process. Some indication of the results of the tests can be found in Bell Brothers cost and production records, but only those for the first two years have survived; they are summarised in Table 6.9. In comparison with the earlier cost accounts, they show a considerable improvement on the 1890-1 experiments, and although profitability was marginal, and highly sensitive both to scale, prices and the composition of iron inputs (Tables 6.9 and 6.10) the results demonstrate that ordinary Cleveland forge or foundry iron could be used to produce good quality mild steel. According to Stead, this was the first time it had been achieved.[462] The improvement was largely due to the Saniter process and the use of a mixer as an intermediate step between the blast furnace and the open hearth steel furnace. Mixers had been originally developed in the 1890s for use in the basic Bessemer process to mix iron from different blast furnaces before it was fed to the converters. This was to ensure uniformity in the quality of the iron as different blast furnaces tended to produce iron with different characteristics, and to provide a reservoir of molten iron that could be fed continuously to the converters. These so-called inactive mixers were adapted for the basic open hearth process as

458 DLAR 1897.
459 DLDM, vol. 1, 8 Nov. 1898, p. 38; *ICTR*, 24 May, 1901, pp. 1081-2.
460 DLDM, vol. 1, 18 Oct. 18, p. 38.
461 DLDM, vol. 1, 9 Dec. 1898, p. 253-4.
462 Stead, 'ISI Presidential address', p. 71.

active mixers in which preliminary treatment of the iron could take place. In the mixer the sulphur and silicon content could be reduced and this permitted a more effective removal of the remaining impurities, especially phosphorus, in the open hearth furnace.[463] It was at this intermediate stage that the Saniter process was used, with the silicon level reduced from 2.2 per cent to 1.2 per cent. As Stead notes, this did away with the need either to use the higher quality, low silicon white iron or having to add expensive manganese. The plant worked on No. 4 Forge and Foundry iron, with molten iron being fed directly to the mixer from the blast furnaces.[464]

Table 6.9: Clarence Steelworks Basic Open Hearth Production - Costs, Revenues and Output (shillings), 1901-02

	1899	1900	1901	1902
Output (tons)	8,181	16,063	42,733	32,761
Cost per ton (s)	89.11	106.18	76.23	76.20
<u>Receipts per ton (s)</u>				
Steel	82.46	107.42	76.15	74.12
Basic slag	1.10	0.44	0.68	0.73
Ingot ends	--	--	--	1.22
Total receipts per ton (s)	83.56	107.86	76.73	76.07
Profit(loss) per ton (s)	-5.55	1.68	0.5	-0.13
Total profit or loss* (£)	- 2,270	1,349	1,068	-212

* Totals may not add up due to rounding. Source: BBA, vol. 6, p. 502

Table 6.10: Clarence Steelworks Basic Open Hearth Charge Composition, 1899-1902 (cwt. per ton of steel)

	1899	1900	1901	1902
Clarence pig	13.86	13.57	10.75	2.04
Mixed metal	--	--	5.88	16.77
Sundry pig and scrap	2.60	4.08	3.00	0.46
Ingots and blooms	3.89	3.38	0.03	-
Total	20.35	21.03	19.66	19.27
Clarence pig %	68.11	64.53	54.68	10.59

Source: BBA, vol. 6, p. 502.

In February 1900 the decision was taken to convert the furnaces at the Britannia Works 'at once', and later that year it was reported that two furnaces – G and H – were working

[463] For a contemporary explanation, see Hood, *Iron and* Steel, pp. 56-7.
[464] Stead, 'ISI presidential address', p. 71; *ICTR*, 24 May 1901, pp. 1081-2.

satisfactorily on Cleveland iron.[465] In addition, some of the basic steel from the Clarence Works, about 50,000 tons per year, was sent for rolling to the mills at Britannia. This was a clear indication that the market had shifted decisively in favour of basic-open hearth steel and of Dorman Long's commitment to the new process. The degree to which the company had now staked its future on the basic open-hearth process is demonstrated by the fact that over the following five years the firm persisted with the changeover, and this was despite the difficulties of transition and the higher than expected investment costs. Reported (gross) profits fell from a healthy £163,000 in 1900 to barely £11,000 in 1905, and although this can be explained in part by the cyclical downswing in the iron and steel market, some of the deterioration was due to repeated interruptions in production. There were, for example, major problems at the Clarence Steel works and it was not until 1905 that the new furnaces and rolling mill were fully operational. There had difficulties with new rolling mill equipment, but there was also a delay as a result of experimentation with different approaches to the open hearth process.[466] Once these had been resolved, however, the completed works had a capacity of 100,000 tons of finished steel and had cost approximately £300,000.[467]

At the Britannia works, although some existing furnaces were working on the basic open hearth process in 1900, the complete switchover from acid to basic was similarly delayed. This was partly due to disputes (in 1901) with steelmelters over wages for working with Cleveland iron, a long, drawn out stoppage at the rolling mill (in 1905), which closed the whole works for several months, and, as at Clarence, technical problems with new rolling mill. It was therefore not until the end of 1905 that the teething problems were completely settled and the plant was in full production. By then it had been entirely 'remodelled', with the old acid furnaces replaced by basic ones as well as the installation of new, modern material handling and rolling plant. The changes at the Britannia may not have been as extensive as the rebuilding of the Cargo Fleet works (see below), often regarded as the only new large scale works on Teesside at that time, but it was a thoroughgoing modernisation of the plant and a major investment by Dorman Long.

Apart from the operational problems, the other main reason for the delays, both at Clarence and Britannia was that the company took some time to decide on which of the alternative basic open hearth processes to opt for. By 1900 there were five options and it was not obvious at the time which would be the best investment for the conditions facing Cleveland steel producers. The alternatives were: first, the cold pig approach using furnaces that were charged with cold pig

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465 DLDM, vol. 1, 7 Feb. 1900, pp. 290-2; DLDM, vol. 2, 6 Nov. 1900, pp. 27-30.
466 DLDM, vol. 2, 5 May 1902, pp. 103-5; 7 Oct. 1903, pp. 203-8; 3 Aug. 1904, pp. 248-50 7 Mar. 1905, pp. 272-4. On the Clarence rolling mill, see *ICTR* 6 Jan. 1905.
467 DLAR 1905, p. 14.

iron, usually manually; second, the direct method of feeding the steel furnaces with molten iron from the blast furnaces, though usually through a mixer; third, the Talbot continuous steel process; fourth, the Bertrand-Thiel two-stage process; and finally, the Monell method. Dorman Long spent time investigating the alternatives, consulting industry experts and visiting other plants using the different processes in Europe and the US. This was in addition to continuing with their experiments.

In 1902 the company' managing directors – of which there were now two, W.H. Panton and Charles Dorman – and the chairman (Arthur Dorman), consulted Benjamin Talbot, the British metallurgist and engineer, who was later to be part of the related Cargo Fleet and South Durham Steel companies (see below). Talbot had returned from the US in 1900 where he had developed his continuous steel process at the Pencoyd Works of A&P Roberts (later one of the constituent companies of US Steel). Talbot's process involved feeding molten iron directly into a large titling furnace (sometimes involving the use of a mixer as an intermediate stage), with the refined steel being periodically tapped by pouring off approximately one-third of the refined metal. Tilting also enabled the removal of excess slag. The process was continuous in the sense that the refining furnace was never fully emptied, and when refilled the molten iron was poured through the basic slag lying on top of the remaining bath of metal, a procedure that restarted the chemical reactions needed for refining. Talbot had set out his ideas at an Iron and Steel Institute meeting in May 1900, and subsequently they had been published in the Institute's journal.[468] In the same year he established a new company, The Talbot Continuous Steel Process Limited, to promote his newly developed process and manage the licences associated with the patents. Also, he had already been engaged by Frodingham Iron, Scunthorpe, to build a new steel plant with a 100 ton tilting furnace, which was in operation by 1902.[469] It was after consulting with Talbot several times in 1902 that Dorman Long decided to remodel the Britannia works and to build new basic open hearth furnaces rather than simply convert the existing ones.[470] As Arthur Dorman explained in reporting on the meetings with Talbot to the February board meeting, the aim of the changes were to 'bring the plant up to the state of efficiency to meet present day competition', and that the cost would be approximately £100,000. However, a decision on the actual process was not reached, being deferred for 'further investigation as to the various systems of steelmaking which are being tried at some important works in this country.'[471] Discussions continued and there was further conferral with Talbot on the different processes,

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[468] Talbot, 'Continuous steel process', pp. 33-6.
[469] G.R. Walshaw and C.A.J. Behrendt, *The History of Appleby Frodingham* (The United Steel Companies, 1950), pp. 69-70; Barraclough, *Steelmaking*, pp. 286-7.
[470] DLDM, vol. 1, 7 Feb. 1900 pp. 290-2; vol. 2, 8 Jan. 1902, pp. 82-5; 11 Feb. 1902, pp. 88-90; 12 Mar. 1902, pp. 93-95.
[471] DLDM, vol. 1, 11 Feb. 1902, pp. 88-90.

but it is not clear from the directors' minutes whether or not a decision was reached at that time. Panton put forward proposals that were considered at a meeting in March 1902 and £80,000 was voted for the improvements, but there is no indication of whether the company had settled on Talbot's process, another process, or whether the decision had been deferred again. Whatever the outcome of that particular meeting, one matter was confirmed; this was to use of hot metal to supply the steel furnaces rather than using the traditional cold pig approach, a far more time consuming and energy and cost inefficient system.[472] The obvious source of the molten iron was the blast furnaces of the neighbouring Samuelson's Newport ironworks. Negotiations started with Samuelson's in May 1902, but it seems that a final agreement was not concluded until after October 1903.[473] Other possibilities were also investigated, including shipping hot metal across the river in barges from the Clarence Ironworks – a suggestion that does not appear to have been pursued, for obvious reasons.[474]

Whether or not Dorman Long's directors and managers considered Talbot's process, and given their contact with him it see more than likely that they will have, at the May 1902 directors' meeting the company finally settled on the Bertrand-Thiel process, or so it appears from the directors' minutes. This followed a visit by two board members, Charles Dorman and Charles Lowthian Bell, to the Kladno works (near Prague), where the method had been developed. It was a two stage process that involved a primary furnace, operating at a lower temperature, that was used for eliminating most of the phosphorus and silicon and from which the metal was tipped to a secondary furnace. This worked at a higher temperature that was needed to remove the last of the phosphorus and complete the refining. As Macmillan explained in his 1903 Cleveland Institution paper, it was more costly than the direct method but was suitable for iron with high levels of impurities.[475] Why Dorman Long chose Bertrand-Thiel over Talbot is not made clear, but it should be noted that at the time the issue of which was the best process for Britain had not been settled. The Bertrand-Thiel process was already in use at Brymbo, where Darby, in conjunction with the Round Oak Works, had bought the British licences, so there was already some British experience.[476] Talbot's process required larger furnaces, usually a minimum of 100 tons as opposed to the 40 to 50 tons of the other methods. Thus it needed a higher initial capital outlay, and being more 'lumpy', was a less flexible or adaptable system. It is also possible that Talbot asked for too high a royalty, as was the case in his negotiations Bolckow Vaughan where the process was seriously considered but rejected (see below).

[472] DLDM, vol. 1, 12 Mar. 1902, pp. 93-5.
[473] DLDM, vol. 1, 7 Oct. 1903, pp. 203-8.
[474] DLDM, vol. 1, 4 June 1902, pp. 106-7.
[475] Hood, *Iron and Steel,* p. 60-2.*;* Stead, 'ISI presidential address', pp. 65-7; Macmillan, 'Manufacture', p. 131.
[476] Stead, 'ISI presidential address', p. 66

Moreover, although Talbot's ideas had been well received in some quarters, being described by one eminent metallurgist as 'the greatest advance that has been made in the manufacture of steel for some years', it had also been unfavourably compared to the Bertrand-Thiel method in an *ICTR* leading article.[477] One other factor is that the site at Britannia, being something of a wedge shape, may not have been ideal for the Talbot designs. The optimum shape for the continuous process was a long narrow site.

Approval to proceed with the Bertrand-Thiel process and making the appropriate adjustments to the plant was given at the May 1902 board meeting, but it seems that the company still kept an open mind on which process should be eventually adopted. It was agreed that the changes to the plant were to be 'subject to any modifications consequent on experiments in progress at Clarence works'.[478] These must have been significant as by April 1905 the licences agreed with Darby for the use of the process had been revoked. In the end Dorman Long opted for the direct method of production as at Clarence, using an active 300 ton mixer to feed a series of fixed (as opposed to tilting) furnaces, with the molten iron being supplied from the Newport ironworks. Most of the remodelling of the works seems to have been finished by mid-1904 at a cost of almost £200,000, double the original estimate, although full production was delayed until the following year by the labour disputes and rolling mill engine problems already mentioned.[479] By 1905 Dorman Long's basic open hearth steel capacity had reached around 250,000 tons per year, 150,000 at Britannia and 100,000 at Clarence. In the following year actual output was 234,000 tons for the two plants, approximately two-thirds of basic open hearth steel in the North East coast region and 20 per cent of the whole of Britain.[480]

That Dorman Long successfully switched from an acid to a basic open hearth producer and subsequently expanded capacity not only marked a full acceptance by user industries of the steel, it also underlines the importance of the firm's decision for the future of steel production in Cleveland. It demonstrated that firms no longer needed to be dependent on supplies of imported hematite and thus subject to cost pressures that were difficult to control and that could quickly undermine competitiveness. Further, it was a clear indication that steel producers in Britain could manufacture steel competitively and on a large scale using a more flexible process that tolerated iron ore and pig iron of a far wider range of qualities. At Dorman Long a second stage of expansion followed between 1906 and 1908 shortly after the initial changeover as the firm

[477] *ICTR*, 27 Jul. 1900, p. 898.
[478] DLDM, vol. 1, 8 May 1902, pp. 103-5.
[479] DLDM, vol. 1, 4 May 1904, p. 223.
[480] DLAR 1905, pp. 15-6; DLAR 1910, p. 13. New mixers had also been installed at the NESCo plant. That they could be adapted for basic open hearth use is an indication of Dorman Long's commitment to the process.

found that ingot production was unable to keep up pace with the rolling mills. As Arthur Dorman commented in his 1907 annual statement, 'the mills are idle for want of steel'.[481] Additional, larger furnaces and mixers were added at both works and annual capacity was increased by another 100,000 tons or more. In 1908 the Clarence Steelworks comprised a 400 ton mixer and eight open hearth furnaces, all supplied from the Clarence blast furnaces. The works concentrated on producing specialist steels ranging from soft (mild) steels with low carbon content (0.08 per cent) suitable for locomotive pipes and high-conductivity wire, to high carbon (1.5 per cent) hard steels for tools and wire rope. On the Britannia site there were 11 open hearth furnaces – two of 80 tons, three of 50 and the rest of 40 – supplied by two mixers, the original of 300 tons and a new one of 400 tons. According to a *JISI* report on a visit to the works, these and the ancillary equipment (e.g. charging machines) were of the 'the most modern and up-to-date practice'.[482] Annual output had risen to 362,000 by 1910 and capacity continued to be expanded, though at a slower rate, right up to 1914. The 1913 annual report gives Dorman Long's production for 1912-13 from its three steel plants as 651,768 tons, approximately 10 per cent of British output. Assuming an output level at the NESCo basic Bessemer works of 240,000 tons, production of basic open hearth steel at Britannia and Clarence amounted to about 400,000 tons, almost 20 per cent of the country's total for this type of steel.[483]

In some respects Dorman Long-Bell Brothers can be regarded as the pioneers of the basic open hearth in Cleveland, but it was not the only firm to adopt the process. There were three others and they took rather different routes. These were: Cargo Fleet Iron Company and its sister, later parent, company, South Durham Steel and Iron; Skinningrove Iron Company; and Bolckow Vaughan. The first and last have been analysed in some detail in earlier studies and it is sufficient here to provide a brief outline of their experience.

Cargo Fleet is often regarded as the prime example of how the British steel industry, could have regained its competitive position against the American and German producers.[484] It was the only completely new, fully integrated, single site plant built on Teesside in the decade and a half before the First War. And it was one that demonstrated the greatest influence of an American approach to investment in the industry; that is, the tendency to reconstruct plants fully as technology changed. The company was acquired in 1900 by Sir (later Lord) Christopher

[481] DLAR 1907, p. 12.
[482] DLDM, vol. 3: 8 Aug. 1906, p. 23-4; 11 Sept. 1906, p. 25-7; 12 Feb. 1907, p. 41-3 ; 7 Aug. 1907, p. 59-62; 10 Dec. 1907, p. 76-7 ; 'Visits to Works', *JISI* 39 (1908), pp. 444-5, 447-50.
[483] DLAR 1910, p. 13; DLAR 1913, pp. 12-3.
[484] Burn, *Steelmaking*, p. 272; Carr and Taplin, *History*, p. 266; G. Boyce, 'The development of the Cargo Fleet Iron Company, 1900-14: entrepreneurship, costs, and structural rigidity in the Northeast coast steel industry', *BHR*, 63, (1989), pp. 869-70.

Furness, who had built up a sizeable shipping and shipbuilding business (Furness Withy and Co) based in Hartlepool. From 1899 he had begun to expand into iron and steel to secure supplies of ship plate through investments in Weardale Steel and South Durham Steel (see Chapter 5).[485] Cargo Fleet in 1900 was a defunct blast furnace works, but offered an ideal site on which to build a new steel works, with its riverside position close to the Tees estuary, just two miles east of Middlesbrough, and of a shape that would permit the construction of a linearly organised plant. There was the additional attraction: along with the old works the firm acquired the Liverton ironstone mine, a source of Cleveland ore that was an essential input into the basic process. The plan was to build a plant with an annual capacity of 125,000 tons using the Talbot continuous process, and initially two 175 ton Talbot tilting furnaces were installed, supplied directly by two new blast furnaces. Talbot himself at first acted as a consultant and, after problems at the works, joined Furness' Expert Committee in 1903 to advise on their solution. He later became a board member of both Cargo Fleet and South Durham (1904) and eventually Cargo Fleet's managing director in 1907.

Talbot did much to sort out the technical and managerial difficulties that plagued the plant, but they meant that it did not begin operations until 1906, and was not fully productive until 1909. By that time capacity had been increased to four 175 ton Talbot furnaces. The problems meant that costs were higher than anticipated and profits poorer than expected: the firm never made more than £100,000 per year gross profit less interest up to 1914 and paid no dividends from 1907 to 1914. As Burn noted, 'its full earnings power and competitive strength were not fully demonstrated before the war.'[486] The poor performance, however, did not arise from Talbot's technology but from other areas, and the works demonstrated the potential superiority of the basic open hearth process in general and of Talbot's invention in particular. The other steel company in the Furness group, South Durham Steel, also considered changing over from acid to basic open hearth production using the Talbot process at two of its three plants. But before 1914 it was only at the West Hartlepool site that a Talbot furnace was installed as a convenient supply of molten iron could be obtained from the adjacent blast furnaces of the Seaton Carew ironworks – a company the South Durham eventually took over in 1919. The other plant, the Stockton Malleable Works, was hampered by a lack of blast furnace capacity close by, and although South Durham twice considered building tilting furnaces at the works, the proposals were rejected. In 1912 for example the estimated cost, including new blast furnaces, was

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485 Willis, W.G., *South Durham Steel and Iron Co Ltd* (Middlesbrough, 1969), pp. 5-10; Boyce, 'Cargo Fleet Iron', pp. 869-70.
486 Burn, *Steelmaking*, p. 272; Boyce, 'Cargo Fleet Iron', p. 816-9, Table 7, p. 871.

£700,000. Given the profitability of the business at the time and that it was using acid open hearth furnaces very effectively, it would have been a costly and risky venture.[487]

Another Cleveland firm that decided to adopt the basic open hearth process in the 1900s was Skinningrove, a much smaller enterprise than Dorman Long, Cargo Fleet or South Durham. It was a specialist Cleveland pig iron producer that decided to expand into steel partly, according to Boyce, because it feared being squeezed out of the iron market. The threat arose from the integration of iron and steel plants, particularly with the advent of the basic open hearth process where the use of molten iron was essential if benefits of the continuous process were to be realised.[488] The company drew up plans for a 250 ton Talbot tilting furnace with an output capacity of 1,600 to1,700 tons of steel per week, approximately 80,000 tons per year, to be supplied with iron from its five existing blast furnaces. In the event, the plant was not completed and operational until 1911 and then the furnace was slightly smaller – 240 tons – and production lower than originally planned, 1,100 to 1,200 tons per week (60,000) per year. Improvements in the plant up to 1913 saw the large furnace converted into a mixer and two smaller Talbot furnaces (120 tons each) installed. This helped to raise efficiency and enabled the production of higher quality steel.[489]

The third firm to consider is Bolckow Vaughan. Of all the iron and steel companies on Teesside at this time, it is Bolckow Vaughan's whose decisions are most difficult to understand. It was the slowest of the large firms to change to the basic open hearth process to any great extent and because of this Abé, for example, identifies it as a classic case of late Victorian entrepreneurial failure.[490] Thus, although it was one of the largest pig iron producers in Britain from both Cleveland and hematite ores – Abé estimates output was 800,000 tons in 1905 – and had access to one of the richest sources of Cleveland ironstone, it was not until 1913 that it became fully a basic open hearth producer.[491] Indeed, it could be argued that the firm was in an ideal position to take advantage of the basic open hearth process and that the relatively small scale of its steel output compared to the size of the firm – output was about 200,000 tons from all four processes – and its narrow specialisation in rails represented a major missed opportunity. This was in stark contrast to its earlier history when Bolckow Vaughan quickly adopted the Bessemer and basic Bessemer processes (see above, section 6.2).

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[487] G. Boyce, 'Corporate strategy', pp. 53-4. The other South Durham plant, Moor Ironworks, Stockton, was shut down in 1907 (Willis, *South Durham Steel*, p. 9). Palmer's, the Tyneside shipbuilders and also owned by Furness, installed a Talbot furnace before 1914.
[488] Boyce, 'Cargo Fleet Iron', p. 820.
[489] 'Visits to Works', *JISI* (1908, no. 3), pp. 451-2; Carr and Taplin, *History*, p. 217.
[490] Abé, 'Technological strategy', *BH*, 38 (1996), pp. 45-76.
[491] Abé, 'Technological strategy', p. 48.

Abé maintains that Bolckow Vaughan did not consider the basic open hearth steel until the turn of the century after E. Windsor Richards, a director and former managing director, had visited Carnegie's Homestead Works where he had observed large scale furnaces in operation. In fact, the firm had investigated the process a decade earlier, and as general manager, Richards had visited other steel plants that were being developed. These included the Alexandroski steelworks near St Petersburg, on which he reported the details of the process used there to an Iron and Steel Institute meeting.[492] Although Bolckow and Vaughan's early trials had been discontinued in the late 1880s, by 1901 concern over competition led the company to reconsider the process. At board meetings in 1901 and 1902 there were discussions over the relative merits of the Talbot and Monell processes, with the final decision in favour of the Monell approach that had been developed at Homestead. This was despite support for Talbot by two highly knowledgeable and experienced directors, Windsor Richards and Arthur Keen, chairman of Guest, Keen. The rest of the board regarded Talbot's royalty as too high, and although he was bargained down from one shilling per ton to ninepence, he was undercut by an offer from Carnegie, owners of the Monell patent.[493] The firm subsequently converted five acid open hearth furnaces to basic and the steelworks manager of the time, Arthur W. Richards (E.W. Richards' son) reported that the firm had been able to make good quality steel from Cleveland pig at a lower cost than the acid process. Unlike at Dorman Long, however, there was not a full commitment to the new process, and at a Cleveland Institution meeting in 1903 Arthur Richards stated that the firm had stopped using it as the process was 'only an auxiliary to our Bessemer department for using our scrap.'[494] It is not clear why, in 1903, Richards said the process did 'not suit us at present', or how long the process remained unused, but it must have been in operation from time to time. In 1908 the firm was reported to be operating all four steel processes and of the seven open hearth furnaces, five were basic – two of 25 tons and three of 60 tons. In a way this can be seen as a rather half-hearted attempt to introduce the basic open hearth processes and the lack of commitment to, or possibly disappointment with, the Monell process is shown in 1905 when the firm decided to improve its basic Bessemer production by introducing advances developed in Germany by Massenez. Once again the results were disappointing, mainly because the high levels of silicon in Cleveland iron made the process unsuitable; basic Bessemer production was abandoned altogether in 1911. It was only then that Bolckow Vaughan finally made the decision to changeover completely to the basic open hearth process, investing approximately £300,000 to convert the plant, eventually installing two mixers and fifteen fixed furnaces.[495]

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[492] E.W. Richards, *JISI* 20 (1889), p. 106.
[493] Abé, 'Technological strategy', pp. 57-60.
[494] A.W. Richards, *CIE* (1902-04), p. 142.
[495] Abé, 'Technological strategy', p. 58; Stead, 'ISI Presidential address', p. 73.

Abé ascribes the failure of Bolckow Vaughan to make the change to basic open hearth steel as due mainly to a lack of technological expertise and the result of a conservative product policy that relied excessively on rails and pig iron production. The lack of technical understanding can perhaps been seen in the two successive mistakes in the choice of technology, the continued emphasis on basic Bessemer production and the wrong choice of basic open hearth process – Monell – that like the Massenez method, needed low silicon iron and was therefore also not suited to the local ore. However, it is difficult to see how the failures can be attributed wholly to a lack of technical knowledge. As will be argued below, understanding of the basic process was widespread and growing, and expertise could always have been brought in, as other firms had done. Rather, it seems that the board made misjudgements, first by taking the cheaper Monell option over Talbot and second by attempting to follow the German advances rather than American success with basic open hearth. While the second error is probably inexcusable, the result of inept management as Abé put it, given the history of disappointments with the basic Bessemer converters in Britain, the former is more understandable.[496] In 1901-02 the best basic open hearth process for use with Cleveland pig had not been settled as the experience at Dorman Long and Cargo Fleet demonstrate. Both companies had difficulties getting their new plant to operate efficiently, and at Britannia Dorman Long had not even made a final decision on which process to use. That one company on Teesside made the wrong choice is not surprising. As regards the firm's emphasis on pig iron production, it is possibly explained less by a strategic decision to concentrate on this, the most elementary of iron products, but can be seen as one of necessity; it was the only way to compensate the poor performance on steel and thus to maintain profits. Between 1905 and 1911 pig iron production was reasonably profitable, sometimes highly, if Bell Brothers data is at all representative.[497]

6.5: Networks and the basic open hearth process in Cleveland

A close inspection of the way in which Cleveland's steel producers groped their way towards a solution to using Cleveland iron in the basic open hearth process reveals the importance of the links between those involved in steel production. Whether these networks actually had an impact on the spread of information about the basic open hearth process and helped its development depend on four conditions being satisfied. The first concerns the extent to which the different parts of the industry and the firms within it were actually connected. The second is whether there were mechanisms for information to pass between the members of the networks. Third, firms needed to use the networks in an active way to acquire information and expertise.

[496] Abé, 'Technological strategy', pp. 61, 71.
[497] BBA, vol. 9.

And fourth, it has to be shown that firms acted on the intelligence they acquired. These are examined in turn.

There appear to be two important sets of linkages involved in the spread of information about the basic open hearth process. One was between firms in common ownership, with the two most notable in Cleveland being the Dorman Long group and the South Durham Steel-Cargo Fleet combination. For example, in the case of Dorman Long, developments at the Bell Brother's Clarence plant were later adopted at the Britannia works; this is hardly a surprising result for a group of firms that, although nominally separate, were run as a single group of businesses, as will be argued in the next chapter.

Second, and of greater significance, were the connections between members of the community of steelworks managers, chemists, metallurgists and engineers, that is the links between professionals below the level of the firms' owners and directors. These networks cut across firms' boundaries and operated in the way that any professional association would; that is, through the reading of papers and the sharing of ideas at formal meetings and conferences, and the subsequent publication of papers with technical details in association journals, often with the minutes of the ensuing discussions. There would, of course, be the more informal contact as a result of friendships, and conversations in which experiences were shared. The main forums for this were the technical institutions, with the principal one at the national level being the Iron and Steel Institute, but also included the Institution of Civil Engineers and Institution of Mechanical Engineers. Just as important were the regional bodies such as the Cleveland Institution of Engineers and the South Staffordshire Institute of Steel Works Managers, among many others. Indeed, all the iron districts had at least one such technical association. The papers and discussions cited earlier in this chapter testify to the importance of these organisations. The role of the industry's main trade journal, the *Iron and Coal Trades Review*, also should not be underestimated. Published weekly, it not only covered the business aspects of the industry, but also reported on technical matters including the proceedings of ISI conferences and reports on the developments published in American and European journals, e.g. *Iron Age* and *Stahl und Eisen*.

Another aspect of the industry was the growing number of professional chemists, metallurgists and engineers who were employed as technical specialists within firms. These were in addition to those who made careers as consultants, providing expertise to a number of companies. As they moved from firm to firm they were able to take their knowledge and experience with them and thus they provided an important route through which details of the experiments and technological improvements in the basic open hearth process (as well as other developments) could spread through the industry. By the end of the nineteenth century there appear to be three routes through which information could be transmitted between firms in this way: the movement of specialist employees; the use of individual consultant, many of whom eventually settled at one firm; and the growth of firms of consulting engineers and chemists who remained independent and served many firms throughout their careers. Ernest Saniter (1863-1934), the chemist and metallurgist, is an example of the first group of mobile employees, a relatively new phenomenon for the time. Born originally in Middlesbrough and trained at the laboratories of John Stead, Saniter first worked as an assistant chemist at NESCo's basic Bessemer plant. He later moved to Wigan Iron Works Company where he was recruited specifically to find a way of to reduce the sulphur content of iron, work which resulted in the development of his desulphurisation process.[498] In 1898 he was attracted back to Middlesbrough by Dorman Long in order to apply his ideas to the basic open hearth process being developed at Bell's Clarence steelworks. Saniter's *JISI* obituary credits him with 'demonstrat[ing] the suitability of common Cleveland iron for making high-class open hearth steel'. He then left Dorman Long, in 1904, to take up a post as chief metallurgist with Steel Peach and Tozer (later United Steel Company), again recruited for his expertise in the open hearth process. Other examples of technical specialists who moved from firm to firm at this time include Edward Crowe (Davy Brothers, Sheffield and South Durham-Cargo Fleet), Arthur H. Cooper (NESCo, Dorman Long and later Partington Steel, Sheffield), and Walter Crooke (North Lincolnshire Iron, Frodingham, Cargo Fleet, J. Summers and Lillieshall).[499]

The second group, that of consulting engineers who initially worked for a series of iron and steel firms but eventually either established their own or settled with one company after being offered a directorship, was a much more traditional pattern. Benjamin Talbot, a highly influential figure in the spread of the basic open hearth process, fits this mould.[500] After the collapse of his family iron firm in 1888-9, Talbot worked as a superintendent at several companies in America, developing his ideas on basic open hearth production. This eventually resulted in Talbot's continuous steel process using a tilting furnace that was first installed at Pencoyd Steelworks, Pennsylvania. Returning to England in 1900 he set up a company, initially based in Leeds, and later Middlesbrough, through which he promoted his new process, and acted as a consultant to a number of firms, including, among others Frodingham, Scunthorpe, the first British firm to install the Talbot process, and also Dorman Long. It was his connection with South Durham and Cargo Fleet, however, which provided his main opening and a settled

[498] 'Obituary: Edward Saniter', *JISI*, 65 (1934), p. 471; Stead, 'ISI Presidential address', p. 70.
[499] 'Obituary: Edward Crowe', *JISI*, 55 (1924), p. 507; 'Obituary: Arthur H. Cooper', *JISI*, 45 (1914), p. 553; 'Obituary: Walter Crooke', *JISI*, 57 (1921), p. 378.
[500] See S. James, 'The career and influence of Benjamin Talbot, Steelmaster', British Steel Archive Project, Teesside University, 2011 for an outline of Talbot's career.

managerial position, first joining Christopher Furness' specialist advisory committee and later becoming a director of both firms. In some respects Talbot's career is reminiscent of a number of the earlier Cleveland ironmasters. For instance, in the 1860s and 1870s John Gjers, the Swedish blast furnace engineer, had worked for a number of companies in Cleveland before setting up his own (Gjers, Mills and Co)[501]. A later example is Arthur Cooper, A.H. Cooper's father. He moved from Brown, Bagley and Dixon in Sheffield to manage, and later become a director of, NESCo in 1883. Talbot's importance, however, lies not just in the development of the continuous process, or because he brought his direct experience of American ideas and practices to Britain; he was also linked closely to the scientific community of metallurgists, chemists and engineers associated with the iron and steel industry. Frank Harbord and Thomas Twynam, working as chemists at the Royal Indian Engineering College (Surrey) in 1900, acted as agents for Talbot's new process, and it seems were long-standing friends or acquaintances. They had all travelled to the US in 1890 when Talbot went to work in Chattanooga.[502] Harbord is likely to have known, or at least encountered, Talbot first in the late 1880s in Staffordshire when Talbot was conducting basic open hearth experiments at his family firm in Wellington (Shropshire) and at the Round Oak works in Brierley Hill (Staffordshire). At the time Harbord worked for the Staffordshire Steel and Ingot Company, also in Dudley. By 1900 Harbord had already become established as a distinguished metallurgical chemist and had undertaken numerous investigations into the basic process. Twynam was also a chemist with an interest in metallurgy. In his early career he had been an assistant first to Sidney Thomas and then Percy Gilchrist, the original developers of the basic process. In 1900 Twynam joined Talbot's company (The Continuous Steel Process Company Limited) and remained a director and its secretary until his retirement. Earlier in his career Twynam had also briefly worked with Edward Riley, an engineer and chemist who had experience with the basic Bessemer process at Dowlais in the 1880s, but was also associated with NESCo and the South Staffordshire Steel and Ingot Company as a director. Riley subsequently went into partnership with Harbord in 1905 to form a firm of consultant chemists.[503]

This brief outline of the careers of Talbot, Harbord and Twynam illustrates just how interconnected the world individual consultants and the firms they advised, was. Added to this, there were a growing number of consultant firms, of which Harbord and Riley was just one rather late example. Consulting firms were already well established in various branches of British engineering, especially in civil engineering, and a number connected to the iron and steel

[501] Harrison, *John Gjers: Ironmaster*.
[502] Willis, *South Durham*, p. 5.
[503] 'Obituary: F.W. Harbord, *Times*, 2 Jan. 1943; 'Obituary: Thomas Twynam' *JISI*, 62 (1931), p. 488; 'Obituary: Edward Riley', *JISI*, 45 (1914), pp. 255-6.

industry had begun to appear from the late nineteenth century to support the sector. The Middlesbrough firm of analytical chemists, Pattinson and Stead, formed in 1876 by John Pattinson and J.E. Stead was an early example. It specialised in metallurgical chemistry. As a young man Stead had worked for and trained with Pattinson in Newcastle before taking a post at Bolckow Vaughan. He later re-joined his former employer in the partnership. Stead's strength lay in his combination of practical industrial experience and pioneering chemistry, and he became highly influential in the iron and steel industry. For example, he is credited with discovering the 'afterblow' in the basic Bessemer process and contributed numerous technical papers in the *JISI*.[504] Given his knowledge of the industry and the fact that his work covered not just Cleveland firms, but spanned the industry nationally, he and his firm were likely channels through which developments in the industry were transmitted. His laboratory also trained other chemists who went to work for other iron and steel firms, and some also set up consultancies of their own. One such was Charles Ridsdale, who after spells with Bolckow Vaughan and NESCo formed Ridsdale and Co, another firm of analytical chemists.

On the engineering side of the industry there were similar developments, with Jeremiah Head and Son one of the more prominent firms. This was set up in the early 1880s by the Middlesbrough-based engineer and ironmaster Jeremiah Head (1835-99) after the closure of the iron rolling company in which he had been a former partner (Fox, Head and Co, Newport Rolling Mills). Initially as an individual consultant, and later through his firm, Head designed and installed plant for a number of iron and steel works, and through his membership of the Iron and Steel Institute, Institution of Mechanical Engineers, Civil Engineers and the Cleveland Institution, he presented numerous papers reporting on the developments in the industry both in Britain and abroad. Of particular significance were his links to the US where he made ten trips and from where he is reported to have brought back 'many back many valuable suggestions for practical improvements in engineering industries in this country.'[505] In the US he was a consulting engineer to the Otis Steel Company in Cleveland, Ohio, a company that was described as an 'English' firm and the first plant in America to be built specifically to produce open hearth steel (1876). In 1886, under the direction of S.T. Wellman, it was also the first to produce basic open hearth steel.[506] It is through his Otis connection that Head will have had contact with Wellman, one of the pioneers on basic open hearth steel in America, and possibly also A.L. Holley, one of basic open hearth steel's great advocates.[507] These connections with America were also evident in the career of Head's son, Archibald Head (1866-1905). He joined

[504] Stead's technical papers are listed in his *JISI* obituary, *JISI*, 54 (1923), pp. 365-9.
[505] 'Memoirs: Jeremiah Head', *IME*, (1899), p.138; 'Obituary: Jeremiah Head', *JISI*, 30 (1899), pp. 263-4.
[506] Wellman, 'Early history', pp. 92-96
[507] Holley is reputed to have said that basic open hearth steel will see the end of the Bessemer process.

the firm in Middlesbrough in the 1880s, became a partner when the business was moved to London in 1893 and the senior partner after his father's death. The younger Head had received practical training at Hawthorn, Leslie and Co. in Newcastle and later studied engineering at University College, London. He had links with numerous companies, for which he designed steelworks, including NESCo (Middlesbrough) Vickers, Sons and Maxim (Sheffield), Round Oak (Brierley Hill) in Britain, and also in France and the US. He acted as the European representative of Wellman's company (Wellman-Seaver, Morgan) and worked as a consultant to Otis Steel where he later became the managing director. He visited America twice a year to carry out his duties, a surprising arrangement for the time. These interests indicate that Archibald Head, like his father, would have had considerable knowledge of US developments across the iron and steel industry, both in general, and in particular of the rapidly expanding and increasingly dominant basic open hearth process. Indeed, Head demonstrated this knowledge by writing papers on the tilting furnace in 1899 and on the effect on the American iron and steel industry of the discovery of iron ore in the Lake Superior region.[508]

The significance of this brief investigation into the links that existed between professional and technical experts in the iron and steel industry is that it indicates that there were ample opportunities for the transmission of intelligence about the industry and many pathways through which that intelligence could flow. Meetings, publications, the movement of professional personnel between firms and the use of consultants all operated at the regional, national and international level. Thus the first two conditions needed for the effectiveness and importance of networks for the development of the basic open hearth process set out at the beginning of this section were clearly satisfied, viz. the presence of linkages and the transmission of information through them. As regards the other conditions, there is plenty of evidence that firms actively used their connections to acquire information and expertise, recruiting technical experts as employees and drawing on the services of consultants. Members of the firms also took active roles in the meetings and discussions of the technical associations and visited other works in Britain and abroad. The final condition, that of whether the firms used the information effectively is less easy to answer; it depends on making a judgement as to whether firms would have introduced the process sooner if they had relied solely on their own resources. In a sense, this is almost a trivial question as almost any detail about what was going on in other firms is better than none, although it is conceivable that some of the negative attitudes towards the basic open hearth process, which delayed its introduction, were transmitted. More important is that

[508] 'Obituary: Archibald Potter Head', *JISI*, 36 (1905), pp. 310-1; Obituary: Archibald Potter Head' *ICE*, 143 (1905), pp. 386-7; A.P. Head, 'Tilting open-hearth furnaces', *JISI*, 30 (1899), pp. 69-75; J. Head and A.P. Head, 'The Lake Superior iron-ore mines and their influence upon production of iron and steel', *ICE*, 137 (1899), pp. 72-102.

an examination of the networks has shown how information could be communicated and that firms were aware of the advances across the industry. There was not therefore a collective ignorance of the potential that basic steel offered; firms actively sought out the information and acted on it. This is shown by the repeated attempts to produce steel in basic open heath furnaces both in Cleveland from the late 1880s and from earlier in the decade elsewhere in Britain. It does not answer the question of whether the steel could have been mass-produced on a commercial scale sooner. This is better answered by the investigation of the demand and supply conditions that prevailed in the industry, as has been done earlier in the chapter.

Finally, there are some signs that the basic open hearth developments that led to its successful application in Cleveland were reminiscent of the earlier improvements in blast furnace practice that Allen called 'collective invention'.[509] Outwardly, there are some common features: the improvements were in small steps; details of experiments were made public through the professional networks; and the process had regional importance, that is it enhanced the competitiveness of Cleveland's iron and steel makers relative to those elsewhere. There are, however, differences in a number of critical areas. First, the advances in technology were made on a national and international level, rather than being specifically regional. Second, far greater use was made of patented ideas that were developed by individual inventors. Knowledge was not therefore entirely collective in the Allen sense that it was un-patentable, nor was it collectively developed, although once patented techniques were adopted there were considerable adaptations and improvements made to meet local conditions. Lastly, unlike the earlier period, when advances were essentially the by-product of the capital investment process, by the end of the nineteenth century firms were putting resources aside for experimentation. Thus although most iron and steel firms at the time did not have research and development (R&D) departments, they were undertaking experiments with the basic open hearth process, often on a small scale, alongside normal production. Dorman Long began tests into the basic open hearth process with small furnaces and continued with experiments at the Clarence steelworks whilst at the same time maintaining acid steel production at the Britannia plant. In other words, by this time investigation into new technologies was taking on something of a hybrid form that combined the traditional sole inventor along with the shared knowledge of collective invention as the patented processes were improved and adapted through repeated trials, and increasingly there were in-firm experiments that can be regarded as forerunners to R&D departments.

[509] Allen, 'Collective Invention', pp. 1-3.

6.6: Conclusions

An editorial in the *ICTR* in 1912 entitled 'The Decay of the Bessemer Process' commented that 'we are on the eve, if we have not already reached, practically the end of the Bessemer process as an important factor in the steel trade of this country'.[510] This was prompted by recent announcements by Bolckow Vaughan and NESCo that they were either installing or planning to install open hearth plant, and it marks the complete changeover in Cleveland to the production of basic open hearth steel. The process of transition from a specialist manufactured iron district to steel had taken place over a period of thirty years. As this chapter has demonstrated, from the 1870s Cleveland's iron and steel firms responded to technological advances in steel manufacture in a timely manner, adapting their production facilities as and when new developments were available. Thus Bolckow Vaughan was an early adopter of Bessemer converters, and two firms, Bolckow Vaughan and NESCo, were at the forefront of developing the basic Bessemer process. Similarly, the switch to acid open hearth steel was rapid after the shift away from iron plate by the shipbuilding industry. Most importantly, a detailed examination of the move into basic open hearth steel using Cleveland pig iron has shown that while this was slow compared to the US and continental Europe, there was active investigation of the process's potential from an early stage – sometime in the latter half of the 1880s. There were, however, both demand and supply reasons for the delay. On the demand side the market was constrained by the poor reputation of basic steel and the authorities' tardy acceptance of the material as suitable for shipbuilding. On the supply side the process remained uncompetitive compared to acid steel for two reasons. One was the continued low cost of Cleveland hematite pig that gave producers little incentive to search for a replacement process. The second stemmed from the particular difficulties that arose from the use of Cleveland iron, with its high silicon and sulphur and moderate phosphorus content, in the basic open hearth furnace. It was only when these technical impediments had been surmounted that investment in open hearth plant began in earnest– even then it took some years to perfect – but which ultimately improved the performance not only of Cleveland's largest steel producers, but of the district's industry as a whole.

The findings here, therefore, challenge some earlier studies and suggest that the basic open hearth process was not neglected, either in Cleveland or in Britain generally. Conditions differed markedly from those in the US and continental Europe, and not only were British steel producers fully aware of basic steel's significance, they also repeatedly experimented with the process. Moreover, McCloskey is not entirely correct in stating that Talbot's tilting furnace was

[510] 9 Feb. 1912, pp. 219-20.

‘the particular innovation that appears to have been responsible for the shift in the relative advantage [to the basic open hearth process]’.[511] The use of mixers with fixed furnaces, aided by the use of Saniter’s desulphurisation process, as at Dorman Long-Bell Brothers, also provided an effective answer that pre-dated the use of Talbot’s system on Teesside.

The steps towards adopting basic open hearth steel production also reveal the industry’s interconnectedness, with many details of the process, equipment, experiments and results transmitted through professionals working in the industry. Together this expanding knowledge contributed to overcoming the problems of using Cleveland iron in the basic open hearth in an incremental manner. And while there do appear to be some aspects of the developments that meet the conditions for collective invention, and there certainly seems to be a sense of collective purpose amongst the professionals involved, the actual process was more of a hybrid, combining patented inventions that were adapted to specific local circumstances, in-firm research and knowledge spillovers.

[511] McCloskey, *Economic Maturity*, p. 71.

Chapter 7: Case Study of Dorman Long

7.1 Introduction

In 1876, Arthur Dorman in partnership with Alfred de Land Long took advantage of the deep slump in the iron industry to take over the redundant plant of the West Marsh Iron Co. The acquisition of this small ironworks, which had been established in 1870 at the western end of the Middlesbrough Ironmasters' district, and had briefly been managed by Arthur Dorman until its closure in 1875, marks the beginning of the Dorman Long enterprise. The firm would become one of the largest iron and steel producers on Teesside, and survive until eventual nationalisation in 1967. Unlike many of the other sizeable Teesside firms, which grew almost exclusively through internal expansion, Dorman Long's growth was principally by means of takeover in conjunction with a judicious use of new investment, modernisation of ageing plant, and diversification. At least, that was the pattern up to 1914. By the early years of the twentieth century, Dorman Long's acquisition of five other iron and steel firms meant that it had become one of the largest businesses in Britain – fifty-second as measured by capital employed (1905) and forty-first when measured by employment (1907).[512]

This chapter looks at Dorman Long's growth up to the First World War. It suggests, contrary to some widely-held views of the iron and steel industry of the period, that the firm's expansion not only demonstrates a continuing vitality in entrepreneurship in Cleveland's industry, but also reveals serious attempts to adapt to the changing market and technological conditions. Close examination of the records of Dorman Long and its associated companies, especially directors' minutes, shows evidence that challenges a number of typical characterisations of British industry, notably that firms were backward in taking on new technology and failed to adapt management and organisational structures to the demands of larger-scale businesses.[513] In particular, it will be argued that there was a strategy underlying Dorman Long's growth that encompassed technological advance, vertical integration, diversification and a product distribution policy. Secondly, that despite not formally integrating the ownership of its constituent companies until 1923, there was an attempt to exert some common control and management over the business that was much greater than first appears. It seems that far from the entrepreneurial spirit having deserted Cleveland's iron and steel masters, it was still very

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[512] P.L. Payne, 'The emergence of the large-scale company in Great Britain, 1870-1914', *EcHR*, 20 (1967), pp. 539-40; P. Wardley, 'The emergence of big business: the largest corporate employers in the United Kingdom, Germany and the United States *c*.1907', *BH*, 41 (1999), pp. 102-5.
[513] See Chapter 4.

much present; the industry offered opportunities for those with the vision and organisational ability to build large and successful enterprises.

7.2 The Growth of Dorman Long in Outline

This section provides the main details of the firm's expansion as a background to a more detailed discussion of the organisational, marketing and strategic aspects of the company's growth in later parts of the chapter. The chronology of expansion is indicated in Table 7.1.

Table 7.1: The Expansion of Dorman Long's Interests, 1876-1914

1876	West Marsh Ironworks leased by Dorman and Long partnership.
1879	Leased Britannia Mills.
1889	Dorman Long incorporated.
1892	London girder yard established.
1898	Melbourne branch (office and stockyard) established. Construction and bridge building departments opened. Clarence steelworks leased from Bell Brothers.
1899	Sheet works bought from R.P. Dorman and Co and wire works from C. Dorman and Co.
1899-1902	Takeover of Bell Brothers.
1903	Takeover of North Eastern Steel Co Ltd. South African branch opened – office and stockyard in Cape Town
1906	South African business converted into a subsidiary company.
1909	South African branch converted into a joint venture, Wade and Dorman Ltd.
1911	Long-term supply contract agreement with Sir B. Samuelson and Co Ltd for the supply of molten iron.
1912	Takeover of Bowesfield Steel Co Ltd.
1913	Minority interest in The Channel Collieries Trust Ltd, stake increased in 1914.

Sources: DLAR 1890-1914; DLDM 1889-1916; Dorman Long, *Works*.

Dorman and Long's first venture as a partnership at West Marsh was a relatively modest start. The works, which had been built by the combined interests of the Stockton ironmasters Smith and Thomson, and the Middlesbrough (and later Glasgow) metal brokers J.E. Swan and Bros., consisted of twenty puddling furnaces and two rolling mills.[514] By early 1873 the firm had run into difficulties and the furnaces were blown out, but it was re-launched as a limited company, the West Marsh Iron Co Ltd, later that year, with one of the original partners, T.J. Thomson, as chairman. At the time the works was also extended to produce light rails. The revival was short-lived, however, and hit by the recession, the plant was again closed in late 1875.[515] The following year the newly formed Dorman and Long partnership leased the plant and restarted operations, specialising in the production of iron bars and angles for the growing shipbuilding industry, using puddled bars and old rails as inputs. A 10-inch finishing mill was added to the existing puddled bar rolling mill and the 14 inch finishing mill.[516] The works was later bought in 1889 when Dorman Long was floated as a limited company.[517] As the firm expanded, the West Marsh plant was updated until the late 1890s, with the addition of steel rolling and finishing. By 1898, however, the firm's interests had switched to investing in other plants, and although there were modernisation plans, to replace the heating furnaces and boilers in the middle of that year, these were soon cancelled. From that time there appear to have been no further improvements until the electrification of the rolling mills in 1907-8.[518]

Despite the depressed condition of the iron market and the increasing shift to steel, Dorman and Long clearly took an optimistic view of the industry, leasing the neighbouring Britannia Ironworks just three years after taking over West Marsh. This was a sizeable works of 120 puddling furnaces, a blooming mill and a rail mill capable of producing 33,000 tons of iron rails per year. It had been built by Samuelson's in 1868-70, opened in 1871 and floated as a limited company the following year, though Samuelson himself did not take any part in the new company. From the outset, it seems to have been a troubled business having been opened on the eve of the collapse of the early 1870s iron boom and, as a large capacity iron rail plant, especially vulnerable to competition from steel rails. Heavy losses were made in 1873-5 and the company was eventually liquidated in 1876, remaining idle until the takeover.[519] Initially Dorman Long's intention had been to use Britannia to produce puddled bars to supply the rolling mills at West Marsh, primarily to counter the effects of a shortage of old rails that had been used for angle production. Buoyant demand at the end of the 1870s and early 1880s meant that soon after reopening the puddling plant, the rolling mill was brought back into production,

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[514] Burnett and Hood, *Middlesbrough Directory*, (1871 and 1873); J.K. Harrison, 'The production of malleable iron in north east England and the rise and collapse of the puddling process in the Cleveland district', in Hempstead, *Cleveland Iron*, p.139.
[515] *Northern Echo* 26 Feb. 1873; 24 Sept. 1873; 24 Jan. 1876.
[516] The size of rolling mills at this time was usually given by the diameter of the roll. See Gale, *Iron and Steel Dictionary*, p. 187.
[517] *Northern Echo*, 5 Jul. 1876; *Prospectus*, DLDM vol. 1, p. 5.
[518] Dorman, Long and Co Ltd., *Description of the works of Dorman, Long and Co. Limited* (Middlesbrough, 1901), pp. 6-7; DLDM vol. 1, 26 Jul. 1898; 30 Aug. 1898. See below for electrification.
[519] *Birmingham Daily Post*, 11 April 1871, 17 Dec. 1872; *Northern Echo*, 20 Oct. 1876.

specialising in larger-sized angles. In 1881 and 1882 it was expanded further with investment in a new reversing engine and a second, larger, rolling mill.[520]

In addition to the improved climate in the industry compared to the mid-1870s, there are two main reasons for this early success. The first is the firm's specialisation in products for the growing areas of the iron and steel market. Largely keeping out of the crowded rail sector dominated on Teesside by the much bigger Bolckow Vaughan, Dorman Long was able to expand into a variety of product markets including ship plate, angles, engineering products, and especially into construction and building materials – joists and girders. Girders were to become a particular speciality and at the turn of the century the company claimed to be the most extensive producer in the country.[521] This choice was an important piece of market positioning for a British firm, since before Dorman Long began girder and joist production in 1883, most had been imported from Belgium and Germany. There was clearly an opening for a domestic producer. The second reason is that the company moved away from iron and into steel by the mid-1880s. In 1886, sixty puddling furnaces at Britannia were scrapped and replaced by seven Siemens-Martin acid open hearth steel furnaces. In operation by 1888, and with the rolling mills adapted for ship plate and constructional products, there was a significant improvement in profits in the eighteen months before incorporation.[522] Overall, the firm's results over the 1880s show that Dorman Long had made some astute decisions and as a result had been able to turn two moribund businesses into a profitable enterprise. It was an early sign of the adaptability of the firm's management and their ability to adjust to new technology (steel) and market demand (shipbuilding and construction). By 1888 annual sales had reached almost £½ million and profits £65,000, a return on sales of 14 per cent, rising to 22 per cent in the first part of 1889. The return on capital employed is estimated to have been almost 14 per cent in 1888 and exceeded 24 per cent a year later, levels the company would not achieve again until the First World War (see Table 7.2 below).

[520] Dorman Long, *Works*, p. 8.
[521] Dorman Long, *Works*, p. 12.
[522] The tendency to inflate profits before flotation may account for some of the improvement.

Table 7.2: Sales and Profits, 1882-1889

	Profits (£)	Sales (£)	Profit % of sales	Return on capital employed (%)*
1882-87 (annual average)	22,765	--	--	--
1887	27,040	313,628	8.6	--
1888	64,651	468329	13.8	13.9
1889 (first 9 months)	85,095	396,696	21.5	24.2
1889 (annualised)	113,460	528,928	21.5	24.2

*Capital employed is estimated from the purchase price of the company at incorporation - £467,000. Using the value of shares at incorporation (£350,000) would produce higher returns: 1888: 18.5%; 1889: 32.4%.
Sources: Prospectus, *Northern Echo*, 6 Nov. 1889; DLDM vol. 1, p. 3: Statement of profits prepared by R. MacKay and Co and pp. 5-8 (*Prospectus*).

It is difficult to determine exactly how this initial expansion was financed. Capital requirements were kept down at the start by leasing both West Marsh (a seven year lease) and Britannia (three years, with an option to buy). By 1882 Dorman and Long must have been reasonably certain of success because instead of renewing the Britannia lease, they exercised the option to buy the works for £50,000 – £5,000 deposit plus 5 per cent interest on the outstanding balance.[523] The £40,000 balance was paid to Samuelson in 1886, although this was quickly followed by a £12,000 mortgage also with Samuelson, probably to help finance the installation of the steel furnaces. It is interesting that Samuelson was willing to help finance the upgrading of the plant; it provides another example of the operation of the network of iron and steel masters and the interdependence of firms in Cleveland's industrial cluster. There were of course benefits to Samuelson: an expanded Britannia works would offer an outlet for pig iron from Samuelson's Newport blast furnaces that were located on an adjacent site. Later, as discussed below, Dorman Long and Samuelson's would develop an even closer supplier-customer relationship that eventually resulted in a take-over by Dorman Long in 1917.

Although Dorman Long enjoyed a period of significant growth and prosperity during the 1880s, by the end of the decade it was still a moderately-sized business compared to the larger Teesside iron and steel firms. With an annual output of 100,000 tons of manufactured iron and steel products, employing 1,300 men and just two plants specialising in finished goods, it was dwarfed by the integrated operations of Bolckow Vaughan.[524] Nevertheless, rapid expansion

[523] I.C. Malcolm, 'Dorman Long and Company Ltd, 1889-1967', *Cleveland Archaeologist*, no. 20 (1990), p. 34.
[524] DLDM vol. 1, p. 5-8 (*Prospectus*).

had enabled it to overtake some of the older, more established businesses such as Samuelson's and Head Wrightson, and this provided the basis from which Dorman Long could launch a further period of more ambitious growth. This next stage of expansion was to come in the latter part of the 1890s and early 1900s following its flotation as a limited company in 1889. The nature and effects of this expansion on Dorman Long's operations and the way in which it was managed are examined in the following sections. For the present it is sufficient to indicate the broad directions in which its activities were extended.

First, the capacity of the Britannia works was expanded with a series of modernisations, including investment in new plant (additional furnaces and rolling mill), the incorporation of new equipment for steel production and improvements through rebuilding existing plant. Initially this took the form of duplicating existing acid open hearth furnaces, but later these were replaced by basic open hearth furnaces. The firm also moved into downstream activities, establishing construction and bridge building departments (1897). This made use of one of its principal products, girders, and started the development of an expertise in an area for which the firm was later to become so famous – bridge building (e.g. the Tyne Bridge, Sydney Harbour Bridge, and Auckland Harbour Bridge). Second, the distribution network was extended using not only the traditional method of selling through agents, but establishing its own branches and stockyards managed and staffed by Dorman Long employees. The principal ones were on the Thames at Vauxhall in London (1892), Melbourne (1898) and Cape Town (1903). Third, the company embarked on a series of acquisitions between 1898 and 1903, two of which were of companies of substantial size – Bell Brothers (1899) and North Eastern Steel Co (1903) – and three smaller, but still significant, businesses. To some extent these acquisitions can be divided into the conventional categories of diversification, vertical integration and horizontal expansion, but there were some overlapping and other complicating elements. In each case it is likely that there was more than one motivating factor.

Diversification came in the form of buying the sheet works of R.P. Dorman and Co and the wire works of C. Dorman and Co in 1898-99. This extended the firm's product range from the basic output of ingots, angles, plates and girders to the finished goods of corrugated sheets and wire. It also provided a useful if small downstream use for Dorman Long's own steel. Interestingly, both these firms were already partly owned by Arthur Dorman, the former having been a partnership with his brother, Robert Page Dorman, which he took control of on Robert's death.[525] The other was a partnership with his eldest son, Arthur Charles Dorman (known as Charles). The incorporation of these works into Dorman Long was therefore not solely about

[525] Dorman, Long, *Works*, pp. 10-2; DLAR 1898.

diversification; the motivation was also organisational and financial as Arthur Dorman consolidated his business interests into the growing company. Later, in 1912, Dorman Long bought the specialised galvanised sheet producer Bowesfield Steel in Stockton, a company that had been established in 1896 to meet the rising demand for thin galvanised steel sheets.

The takeover of Bell Brothers between 1899 and 1902 has been seen as a classic case of vertical integration, and as one of the few in the iron and steel sector that did not involve merging with armaments companies.[526] At the time it was the largest combination in the Cleveland industry. Bell Brothers was a pioneering, high volume pig iron producer located on the north bank of the Tees at Port Clarence. Its works comprised twelve large blast furnaces producing over 300,000 tons of pig iron a year (326,793 in 1898), which generated sale revenue of over £660,000.[527] In addition to its smelting plant, the company had significant coal interests in south Durham, with collieries at Page Bank, South Brancepeth, Browney and Tursdale; and ironstone mines in Cleveland – Normanby, Skelton, Cliff, Carlin How and Lumpsey. There was also a limestone quarry at Stanhope. Much has been made of the desire to obtain a secure and reliable supply of raw materials as a motive for the link-up with Bell Brothers, and given the conditions in the coal market at the time (booming demand and rising prices) this can be regarded as one reason. But it is only one. The expectation of profit in the iron industry is another. Pig iron, although highly cyclical, could also be highly profitable, as proved to be the case in 1889 and 1900 when Bell Brothers made profits of £190,690 and £136,974 respectively on its iron business. However, the vagaries of the iron trade with its price fluctuations and the damaging effects on margins suggest that this was unlikely to be a major factor. Bell Brothers had made losses at the Clarence works through much of the 1890s (1890-97) and returned to making a profit, albeit a small one, only in 1898 (£12,120).[528] Certainly, an ironmaster as experienced and astute as Arthur Dorman would not have taken the temporary restoration of profitability as a signal for a takeover. Much more important was the plan to develop the basic open hearth steel process in order to find a commercially viable way of making steel from Cleveland pig iron. Bell Brothers had started trials in 1889 and the two firms had been cooperating on the development at least since 1897.[529] With extensive ironstone reserves and iron producing capacity, as well as its own steel furnaces, the acquisition of Bell Brothers would not only ensure a supply of inputs, but also give Dorman Long access to the new technology, experience and expertise. In its turn, Bell Brothers, which had accumulated large losses in iron making over the previous seven years, would have access to the finance to develop new plant and to the processing capacity. It would

[526] Payne, 'Large scale companies', pp. 533-4; H.W. Macrosty, *The Trust Movement in British Industry: A Study in Business Organisation* (London, 1907), pp. 27-31.
[527] BBA vol. 6.
[528] BBA vol. 6.
[529] See Chapter 6.

also have an outlet for pig iron that was not entirely dependent on iron market. As Arthur Dorman stated in his 1901 chairman's statement at the shareholders' annual meeting, the aims of the link up were "to combine with them (Bell Brothers) as first-class manufacturers of pig iron, having large reserves of coal and ironstone, for the establishment of works for the production of steel from Cleveland iron by the open-hearth process."[530]

The takeover of North Eastern Steel Co (NESCo) is less easy to account for. The product and the technology – basic (Thomas) steel from basic Bessemer converters – was very different from that being developed at the Britannia works or at Bell's Clarence works, i.e. open hearth. The company had been established in 1881specifically to produce steel from Cleveland iron using the basic Bessemer process, and its developers, Sidney Thomas and Percy Gilchrist were among the founding directors. By the turn of the century NESCo was a sizeable business with an annual output of 150,000 tons of steel from four Bessemer converters; its main products were rails, finished steel billets and bars.[531] Dorman Long had been interested in the business since at least 1901; the circular to NESCo shareholders from the board recommending the takeover states that negotiations had begun more than two years previously, but it is not obvious what the reasons for this interest were.[532] To some extent it can be seen as a horizontal expansion, increasing Dorman Long's steel capacity and position in the market. It can also be regarded as a way of diversifying the product range. Dorman Long saw its future as a producer of basic steel rather than acid steel, and at the time NESCo was one of only two firms with basic capacity in Cleveland. The other was Bolckow Vaughan. As there were continuing problems with the production costs, quality and market acceptance of open hearth basic steel, the success of the new product could not be assured. The acquisition of NESCo may therefore be seen as a way in which Dorman Long could hedge its bets in basic steel production in the event that the developments in the open hearth process using Cleveland pig proved unsuccessful. NESCo could then provide a way of emulating the German success with the basic Bessemer process. Perhaps Dorman believed that with the German dominance in Thomas steel, a growing acceptance of basic steel in general and the recent new capacity the NESCo plant to produce finished rather than just semi-finished sections, including tramway and electric rails, the firm was a useful addition to portfolio of businesses

As for other possible explanations, short-term profitability was unlikely to have been a major motivation. Although NESCo had been making profits up to 1900, they collapsed from £40,000 in 1899 to £4,000 the following year. In 1901 the position worsened: the company made loss of

[530] DLAR, 1901.
[531] DLAR 1903, pp. 14-15; DLAR 1905, p. 17.
[532] *Financial Times*, 20 May 1903, p. 3.

£14,000 as it was caught between rising raw material costs, especially coal, which it had to buy in the open market, and falling product prices as a result of German protection and dumping on the world market.[533] The immediate outlook therefore was poor; as Arthur Dorman noted in his chairman's statements of 1903 and 1904, even at the time of the takeover 'it is likely to be an unproductive investment for some time to come.'[534] Finally, it may be simply an example of the desire for expansion, a way of increasing the size of the company. Although NESCo was not performing well, the works was located in a good position on the Tees adjacent to the Britannia works, and as the company was in a difficult financial position, it was cheaper for Dorman Long to expand by buying a business than acquiring land and building a new works. Moreover, Arthur Dorman was, and had been since its inception, a major shareholder in NESCo, a member of its board and chairman until 1885.[535] Therefore he would have been fully aware of the benefits and difficulties likely to be encountered in taking over the firm. Buying NESCo may have been a way of consolidating his position and control over the company, and finding a means of co-ordinating the various branches of his iron and steel interests. It is interesting to note that ten years before the takeover NESCo had itself expanded, buying the Acklam ironworks of Stevenson, Jacques and Co in 1893.[536] With its four blast furnaces, this works supplied the bulk of NESCo's iron. The NESCo acquisition therefore is an example both of the movement towards vertical integration and of the increasing concentration of the industry in the district, as one firm extended its control over a significant portion of the Cleveland industry.

One final step Dorman Long took towards vertical integration in this period was to acquire an interest in the Channel Collieries Trust Limited. This was a company founded in 1910 to obtain rights to and explore the extent of the Kent coalfield. Although this was recommended to the shareholders on the basis of the likely coal reserves – Dorman described the Channel Collieries as having some of the best royalties in the Kent coalfield – part of the motivation was the potential for discovering new iron ore deposits. In his 1913 chairman's statement Dorman, referring to a report by Edward Riley on the Kent coalfield, suggested that there may be a bed of ironstone 'of a quality similar to the Cleveland stone'. Initially the investment was small, just £15,000 (30,000 £1 shares, 10 shillings paid) but this was more than tripled to £47,500. Dorman regarded it as 'of a somewhat speculative character', which is what it turned out to be. Indeed, it was something of a costly failure since the coalfield's development was delayed by the outbreak of war in 1914, and there proved to be no ironstone to exploit.[537]

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533 Macrosty, *Trusts*, pp. 29-3; Wengenroth, *Enterprise*, pp. 249-50

534 DLAR 1903 pp. 14-15; DLAR 1904, p. 18.

535 NESCDM vol. 1, 1881-1887.

536 *IME*, 1893 (Aug), pp. 344-5.

537 DLAR 1913, p. 13; DLAR 1914, pp. 8-9, 14. In passing it is interesting to note that the Cleveland companies' willingness to look to Kent for ore supplies suggests that they would also have been willing

7.3 Organisational and Management Developments

By the eve of the First War Dorman Long had been built up into a business of significant size, with a commanding, though not dominant, position in both the Cleveland and British iron and steel industry. The company had control over nine plants on Teesside under the ownership of four firms (depending on how they are counted), offices and stockyards in London and abroad, and a series of coal and ironstone mines. The combined output of the three steel plants was around 650,000 tons of ingots per year, much of which was processed into finished steel, ranging from rails, plates and angles to girders, joists and bridge construction. Upstream, production figures were also substantial: annual coal and ironstone output each exceeded one million tons, limestone 250,000 tons and 600,000 tons of pig iron. Employment at the Dorman Long plants alone exceeded 10,000.[538]

Such a growing and complex business required careful organisation and management in order to effect control and maintain efficiency. While the outward appearance is one of several disparate firms in which one, Dorman Long, held a controlling interest in two similar sized, but independent businesses – Bell Brothers and NESCo – this is deceptive. In practice there was much closer integration of management; there is also clear evidence of coordination between the different interests, with strategic control exercised particularly through Dorman Long's board.

Prior to flotation there is little surviving evidence of the way in which the Dorman and Long partnership operated. It appears that Arthur Dorman and Albert Long were joint managing partners, and in the early years after incorporation this arrangement continued, with the former partners working as joint managing directors. From the beginning it seems that Dorman was the dominant half of the duo, taking on the position of chairman and acting as the driving force behind the growth of the company. He was responsible most of the initiatives that are recorded in the board minutes and it was common for a board decision to leave matters in Arthur Dorman's hands 'to take action as he may consider desirable'.[539] As far as Long's position is concerned, he was very much in the background, taking the chair only in Dorman's absence. Over the eleven years from 1889 to 1900, when Long resigned, there is just one recorded case where he presented a proposal to the board; this was in April 1890 when he submitted estimates for a new engineering shop at the Britannia works.[540]

to use ores from Lincolnshire and Northamptonshire. This is another reason for rejecting Burn's criticism of Britain's steelmasters that they ignored indigenous iron ore supplies.

[538] DLAR 1910, p. 13; DLAR1912, p. 13; DLAR1913, p. 13

[539] DLDM vol. 1, 10 Nov. 1896, pp. 210-13.

[540] DLDM vol. 1, 2 April 1890, pp. 34-5.

In the familiar pattern of a company following incorporation, a general manager was appointed to take charge of the operation of the works in early 1891. This was W.H. Panton, an experienced engineer, who was 'to take over most of the managerial tasks' for a salary of £2,000 per year.[541] There are various reasons why at conversion to a limited company firms took steps to appoint a professional manager. These include: allowing time for the former partners to enjoy the wealth derived from the flotation; bringing in managerial and technical expertise that would guide the expansion of the firm; and giving the former owners, who usually kept control of the business as the largest shareholders, the time to concentrate on a more strategic role rather than getting caught up in the day to day operation of the company. In this case it seems that the last two best explain the appointment of Panton. Dorman and Long remained joint managing directors, but each accepted a salary reduction of £750 p.a. that was used to make up part of Panton's.[542] Immediately after his appointment, most of the proposals for capital investment and plant improvements came from Panton, and Dorman increasingly spent time developing the firm's prospects by building up a distribution and marketing network.

As might be expected, the two big amalgamations with Bell Brothers and NESCo, brought changes to the organisational and management structure. There were a number of ways in which Dorman Long as the parent company was able to maintain control over its subsidiaries. First of all there was considerable degree of overlap in the membership of the three boards. This is a process that had begun well before the takeovers. For example, three Dorman Long directors, Arthur Dorman, Alexander Hay and Frank Walters Bond, had all been directors of NESCo since its inception. Following the takeover the first two remained on the board, with the addition of Hugh Bell, who by that time was also a director of Dorman Long.[543] In the case of Bell Brothers, when Dorman Long acquired 50 per cent of the company, three directors were appointed to Bell Brothers – Arthur Dorman and Alexander Hay again, along with Charles Dorman, Arthur's eldest son.[544] Such appointments are hardly surprising as it would be expected that the parent company would want proper representation on, and control over, the boards of its subsidiaries. Perhaps more telling is that the process was not all one way: in both cases directors of the newly acquired subsidiaries were appointed to the Dorman Long board. Thus in 1899 Hugh Bell joined the Dorman Long and following the full takeover in 1902, four additional Bell Brothers directors were appointed – Lowthian Bell, Walter Johnson, Charles Bell and Maurice Bell.[545] For NESCo, three directors were appointed to the Dorman Long board – Richard Denton, the chairman, Arthur Cooper, the managing director, and J. Francis

[541] DLDM vol. 1, 3 Feb. 1891, pp. 56-7.
[542] DLDM vol. 1, 3 Feb. 1891, pp. 56-7; 7 Nov. 1894, pp. 149-51.
[543] DLDM vol. 2, 8 Jul. 1903, pp. 184-8.
[544] DLDM vol. 1, 1 Dec. 1898, pp. 250-52.
[545] DLDM vol. 2, 25 Aug. 1902, pp. 122-5.

Mason.[546] As Table 7.3 shows, from the beginning there was considerable overlap between the boards of three main businesses of the Dorman Long group, and this was one way in which coordination and control could be facilitated. Of course, membership of the Dorman Long board for members of the Bell family and some NESCo directors may well have been part of the takeover deals, but this does not negate the benefits of overlapping directorships.

It has been commented that a number of the mergers of the late nineteenth century and early twentieth resulted in excessively large boards. In 1905 for example, Imperial Tobacco had twenty-eight directors, and combinations in the textile industry resulted in even larger numbers: the Bleachers Association had fifty, Bradford Dyers forty-six and Fine Cotton Spinners' and Doublers' Association thirty.[547] With fifteen, Dorman Long seems large in comparison with other steel companies (e.g. Bolckow Vaughan seven, John Brown seven), but this was barely above the average of twelve for the fifty-two largest companies identified by Payne, and certainly nowhere near those of the unmanageably-sized textile companies. In fact, fifteen was the maximum size the Dorman Long board reached and by 1910, with the death and retirement of older members, the board numbers fell to thirteen, much the same as in other amalgamated steel firms (e.g. Vickers, Sons and Maxim – fifteen; Guest, Keen and Nettlefolds – eleven).[548]

[546] DLDM vol. 2, 8 Jul. 1903, pp. 184-8; DLDM vol. 2, 5 Aug. 1903, pp. 191-94.
[547] Payne, 'Large scale companies', pp. 539-40; D. Jeremy, 'Survival strategies in Lancashire Textiles', *Textile History*, 24 (1993), pp. 147-6.
[548] Payne, 'Large scale companies', pp. 539-40.

Table 7.3: Board Membership for Dorman Long, Bell Brothers and NESCo, 1903

Dorman Long	Bell Brothers	NESCo
Arthur Dorman**	Arthur Dorman	Arthur Dorman
Alexander Hay	Alexander Hay	Alexander Hay
Charles Dorman	Charles Dorman	
Hugh Bell	Hugh Bell	Hugh Bell
Sir I. Lowthian Bell*	Sir I. Lowthian Bell*	
Charles Lowthian Bell	Charles Lowthian Bell	
Maurice Lowthian Bell	Maurice Lowthian Bell	
Walter Johnson	Walter Johnson	
F. Waters Bond		F. Waters Bond
Richard C. Denton		Richard C. Denton*
Arthur Cooper		Arthur Cooper
J. Francis Mason		J. Francis Mason
Charles A. Head		Sir Thomas Wrightson
Henry Echalaz		Hugh Ripley
W.H. Panton		Edward Riley
		The Hon. Henry Parker
*Chairman. **Vice Chairman		

Sources: DLAR, BBAR and NESAR for 1903.

As far as composition is concerned, there are several common features of the boards of companies in this period that are regarded as working against management control and effective decision making. One is that on incorporation they often included well-known, but essentially token members, whose presence was designed primarily to attract investors to buy shares in the newly floated company. These ‘ornamental’ directors, as Payne called them, would receive their directors’ fees but contribute little, if anything to the operation of the business.[549] A second is that the boards of companies were often dominated by members of the founders’ families – sons, sons-in-law, nephews, grandsons and so on – irrespective of their suitability for a business career. Third, in cases of amalgamation, the original directors, again often from the founding families, retained directorships, perhaps as part of the merger agreement, to look after family interests and investments that were still tied up in the company, or simply as a mark of respect for a business’s pioneers.

[549] Payne, ‘Large scale companies’, p. 534. In fact, the claim that they were always an encumbrance may well be misplaced. If the presence of a well-known name in the list of directors contributed to the success of the flotation, perhaps because of their connections, then it can be regarded as a useful marketing device.

The appointment of Lowthian Bell, not only to the board and also as chairman at the advanced age of 86, is an obvious example of deference to the founding family; but in this case it is an understandable one. Lowthian Bell was the grand old man of iron and steel, both in Cleveland and nationally, and one of only two survivors from the start of the industry in the district.[550] His position as chairman was more than likely an honorary one, and although he did attend board meetings over the three and a half years of his membership until he died in December 1904, it was sporadic and he never presented the chairman's statement at an AGM.[551]

An interesting feature of the Dorman Long board, and those of its component firms, is that most directors seem to offer something to the company by way of connections, advice or performing some function or role, even if they did not have an executive position in the modern sense. And this seems to be the case from the outset. In addition to the two partners, the original directors (in 1890) were all connected with the sales and marketing side of the iron trade, reflecting an understanding by either Dorman or Long that having good outlets for finished products was essential. Both Alexander Hay and F.W. Bond were metal merchants or brokers in London and, at the time of incorporation in 1889, were already on the NESCo board.[552] Charles Head was the chairman of the Stockton engineering firm Head Wrightson, which both supplied Dorman Long with equipment and bought their iron and steel. His partner, Thomas Wrightson was on the NESCo board. Henry Echalaz, the sixth appointment to the board in 1891, was also an iron and steel merchant in Newcastle, with interests in the mineral broking business and general metal broking, as well as an agent for a life insurance company (The Economic). He was also involved in the iron exchange in Middlesbrough from at least 1880 as is indicated by his inclusion on the subscription list to the Middlesbrough Royal Exchange. [553] Bond and Hay also handled some of the financial affairs of the company in London. Thus in September 1891 Bond placed £25,000 on call in the London discount market and Hay similarly placed £10,000 on seven days' notice the following June.[554]

With the amalgamations and the expansion of the Dorman Long board, there was a strong representation from the Bell family. However, while Bell Brothers was very much a family business, there was a considerable amount of expertise in the firm, both of technical nature and

[550] The other was Sir Bernhard Samuelson, who died in 1905 shortly after Lowthian Bell.
[551] See DLDM vol. 2, meetings for 1902-4; DLAR 1902, 1903 and 1904.
[552] Bond was a partner in of Vivian, Younger and Bond, Leadenhall Street and Hay was with Naylor, Benzon and Co, Old Broad Street. See Dorman Long Prospectus, DLDM vol. 1, p. 5 and *Business Directory of London, 1884* (22 edition, London, 1884).
[553] DLDM vol. 1, 3 Feb. 1891, p. 56-7; The Middlesbrough Exchange Company Limited, Register of Shareholders, Members and Holdings, BS.MEX/2/1/6; *Ward's Directory of Newcastle upon Tyne, 1890* (Newcastle upon Tyne, 1890), p. 484, p. 488, pp. 494-5.
[554] DLDM vol. 1, 23 Oct. 1890, p. 48 and 3 June 1891, pp. 65-6.

especially in knowledge of the iron business. Hugh Bell and his younger brother Charles had both had a technical education, Hugh studying chemistry at the Sorbonne and then in Germany under the famous chemist Friedrich Wohler. He returned to Cleveland to work at the Clarence Ironworks in the 1860s, eventually taking charge as his father withdrew from active business involvement.[555] Charles similarly studied first in France, at the Paris School of Mines and later in Germany, after which he returned to work at the Clarence works under the management of John Thompson. He took over the management in 1885 on Thompson's retirement.[556] The other experienced addition to the Dorman Long board from Bell Brothers was Walter Johnson, a former career soldier. After retiring in his thirties he became an iron merchant in Middlesbrough, joining Bells first as an employee, and later as a director.[557] From NESCo, in addition to Bond the two directors who joined Dorman Long were Richard Denton and Arthur Cooper. Denton was a ship owner from Stockton, at least before his involvement with NESCo; he was one of the original directors and had been chairman of the company from 1885. He thus had considerable experience in running a steel business. Arthur Cooper also brought considerable experience and technical knowledge to Dorman Long's board, having been an engineer at a Bessemer steelworks in Sheffield (Brown, Bailey and Dixon) before taking up the position of general manager at NESCo with responsibility for building the works when the company was first set up. He later joined NESCo's board.[558]

All in all, it seems that there was considerable expertise at director level in Dorman Long at this time. But there were also two cases of the elevation to directorships of young, relatively inexperienced members of the founding families. These are the appointments of Charles Dorman, Arthur Dorman's son, and Maurice Bell, Hugh Bell's son. Each was very much part of a familiar pattern of bringing the eldest son into the business, providing training and experience as they acquired the technical and business skills. Charles Dorman, only 23, joined the board in 1898 at the time the sheet and wire works were bought by the company. He was already taking an active role in the business having had some responsibility at the two newly acquired works under their previous ownership by his father. However, it is clear that his apprenticeship was far from over and he was very much under the guidance of Panton, the general manager, with whom he toured American iron and steel works in 1898, and also his father's associates in the industry. For example, he again toured American industry with Thomas Wrightson, of the Stockton iron and engineering company in 1901.[559] Maurice Bell was

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[555] Obituary, *JISI*, 62 (1931), pp. 483-4.
[556] Obituary, *JISI*, 37 (1906), p. 275.
[557] Obituary, *JISI*, 46 (1915), pp. 460-1.
[558] Obituary, *JISI*, 63 (1932), pp. 426-7.
[559] Diaries and journals of American tours: BS.BB/8/1/1 – 4. Also I. Stubbs, 'Some brief biographical notes', *Cleveland and Teesside Local History Society*, pp. 39-48, date unknown.

a little older and more experienced in the industry. Like his father, uncle and grandfather he had been sent abroad after his British education (at Eton) to gain technical training, first to France and then to Germany. He returned to work at the Clarence works in 1893, joined Bell Brothers board soon afterwards and on the amalgamation joined the Dorman Long board at the age of 33. In each of these cases, of course, it may well be that family preferment brought in directors with limited talent or aptitude for a role that required both technical understanding as well as business acumen. However, it is not necessarily the case that the son and grandson of the founders lacked the desired skills and their inclusion on the board is not *prima facie* evidence for entrepreneurial failure. In fact, both Charles Dorman and Maurice Bell played an active part in the business, both as directors and in more direct managerial positions, and Dorman was known not to be keen to make appointments purely because of family connections.[560]

One final board member is worth mentioning although his directorship comes after the period covered in this study. This is Walter L. Johnson, the son of Walter Johnson who was one of the directors who joined the Dorman Long board from Bell Brothers (see above). Walter L. took his father's seat on the board when his father died, but like the Dorman sons before him, he had also had an active career in the business. By all accounts he was a talented engineer and was responsible for the management and operation of the Clarence steelworks from 1903.[561]

Monitoring and decision making

The size and composition of the board are important elements in accounting for a business's success as they can be regarded as indicators of the potential effectiveness of decision making; but more crucial is the actual role the board plays in directing business operations and policy. This takes on a greater significance since the complexity of business operations increases as a firm grows and diversifies. There is a greater need for effective mechanisms to monitor, control and coordinate the different parts of the organisation. For Dorman Long various monitoring and control systems were developed and extended over time, and some impression of the way in which they evolved and operated can be traced from the firm's records in the period following incorporation.

Although Arthur Dorman and Albert Long retained their positions as managing directors after the 1889 flotation, much of the day to day operation of the plants was delegated to the new

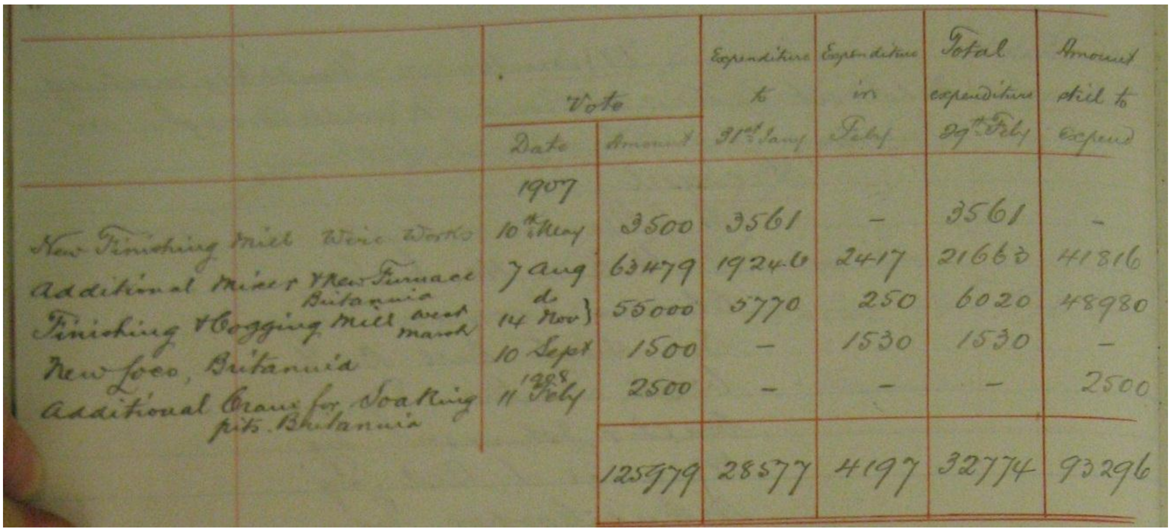
[560] Arthur Dorman had a reputation in his family for not being keen on employing family members in the firm. Richard Dorman, a nephew, was the only one. Having trained as an engineer with the Southern Railway, Richard joined the company after the First War. Source: interview with Dick Dorman (great nephew of Arthur Dorman), 16 April 2008.
[561] DLDL vol. 2, 4 Mar. 1903, p. 166.

general manager, WH. Panton. From 1891 Panton attended the majority of the monthly board meetings and made regular reports on the state of the business. Until 1900 these meetings were on average every two months, although each year the number and time between them varied according to the state of trade and the demands of the business. At first the nature and details of the reports recorded in the minutes also varied before a consistent pattern and method of monitoring was established. The early reports were primarily concerned with recommendations for improvements to the plant; for example major changes to the Britannia works in mid-1891. Panton put forward plans for new capital investment which the board then discussed, determined which of Panton's proposals they should proceed with and how much should be 'voted' for the investment. Considerable control was exercised by the board over expenditure since even modest investments were put to the directors. Panton subsequently reported back to the board on the progress of the new investments.[562]

As Dorman and Long were at this time, in the 1890s, joint managing directors and in regular contact with production at the plants, there was little need for detailed reporting on the performance of the works. There were a few exceptions, such as a discussion on how and when to reduce workmen's wages in November 1892. The board even became involved in settling a dispute with workmen from the Britannia works.[563] But in general the board concentrated on two major areas: capital investment decisions and the control of capital spending; and the finances of the firm. At one point in June 1893 the board stopped further expenditure on the 'plant account' because it was so high. This is a clear indication that control was exerted at board level and that it was willing to rein in what it thought was excessive expenditure, perhaps by an enthusiastic new general manager keen to update and improve the plant.[564] From about the same time it seems that the reporting and monitoring of the firm's operations became more regular and standardised. Indeed, it was at the same board meeting where concern was expressed over capital spending that the first cost reports, on the production cost of finished iron bars, was submitted. Unfortunately, no comments are recorded in the minutes except that the board agreed that in future monthly cost should be presented along with a comparison with the previous month's costs (in red).[565] By early 1894 the presentation of a monthly cost report and also a report on the company's financial position had become standard features of each meeting, with additional detail provided when specific issues were under discussion. For example, in the March meeting of 1894 Panton was asked to report on the comparative labour costs at Britannia and other similar mills at a time when wages were causing concern.[566]

[562] DLDM vol. 1, 4 Aug. 1891, pp. 69-72; 9 Sept. 1891, pp. 72-3.
[563] DLDM vol. 1, 9 Jan. 1892, pp. 103-6; DLDM vol. 1, 10 Feb. 1893, p. 192.
[564] DLDM vol. 1, 6 June 1893, pp. 118-9.
[565] DLDM vol. 1, 6 June 1893, pp. 118-9.
[566] DLDM vol. 1, 9 Jan. 1894, p. 134; DLDM vol. 1, 7 Mar. 1894, pp. 138-9.

Figure 7.1a: Capital Expenditure Monthly Returns – An Example from 1908



	Vote		Expenditure to 31st Jany	Expenditure in Feby	Total expenditure 29th Feby	Amount still to expend
	Date	Amount				
New Finishing mill Wire Works	1907 10th May	3500	3561	–	3561	–
Additional mixer & new Furnace Britannia	7 aug	63479	19246	2417	21663	41816
Finishing & cogging mill West marsh	do 14 Nov	55000	5770	250	6020	48980
New loco, Britannia	10 Sept	1500	–	1530	1530	–
Additional Crane for Soaking pits Britannia	1908 11 Feby	2500	–	–	–	2500
		125979	28577	4197	32774	93296

Figure 7.1b

	Vote		Expenditure to 31st Jany	Expenditure in Febry	Total expenditure 29th Febry	Amount still to expend
	Date	Amount				
New finishing mill, wire works	1907 10th May	3,500	3,561	--	3,561	--
Additional mixer and new furnace (Britannia)	7th Aug	63,479	19,246	2,417	21,663	41,816
Finishing and cogging mill, West Marsh	Do	55,000	5,770	250	6,020	48,980
New loco, Britannia	10th Sept	1,500	--	1,530	1,530	--
Additional crane for soaking pits, Britannia	1908 11th Febry	2,500	--	--	--	2,500
		125,979	28,577	4,197	32,774	93,296

Source: DLDM vol. 3, 3 Mar. 1908, pp. 84-6.

Gradually, over the years, this reporting became more extensive and comprehensive, reflecting the growing size and diversity of the business and the consequent need for detailed and complex information. From October 1894 the reporting of new contracts was added to the monthly finance and production statements, and detailed reporting on the progress of capital spending was increased over the course of the 1890s. From August 1896 there was a monthly statement of capital expenditure reported to the board and after September 1897 the progress of capital projects was presented in a tabulated form indicating each project that had been approved, the date of approval, the 'vote', the amount spent each month and how much was left from the budget (Figure 7.1).[567] In practice the actual monitoring of the day to day and week to week operations of the firm was even more strict and assiduous than the monthly reports to the board suggest as weekly reports were also prepared for the directors. There are no surviving records of the reports, and it is impossible to judge how extensive or useful this weekly reporting was, but the fact that they were prepared for the directors demonstrates a recognition of the importance of keeping track of the firm's operations as it grew. Indeed, as new businesses were acquired, they too were included. For example, in July 1899, shortly after the incorporation of the sheet and wire works into the company these two departments were also included in the weekly returns.[568]

While it is not possible to say exactly how the directors used this information to exercise control over the firm, it is evident that by the end of the 1890s, and before the major expansion of the company after the takeovers of Bell Brothers and NESCo, the company had in place an extensive information system that could in principle be used to inform and support decision making. The acquisition of two large companies prompted further changes in reporting and monitoring. Moreover, what is interesting about these developments is that they clearly put the Dorman Long board at the centre of the Dorman Long group of companies and suggests that far from continuing to operate independently, pursuing their own interests as if they were separate businesses, both Bell Brothers and NESCo were subject to careful scrutiny by the parent company. It did take some time for this to emerge, however. The first step was in March 1903 when the new manager at the Clarence steelworks, Walter L. Johnson, began to attend the monthly board meetings, and like his counterpart at Britannia, to prepare and present a report.[569] Second, and rather later, in 1905, the details of Bell Brothers' operations (pig iron and mineral output) were reported at the Dorman Long board meetings. This was followed in 1907 by monthly reports on NESCo's production.[570] These arrangements continued up to 1914 and beyond, and from time to time additional reports were added to the growing list. For example, in December 1908 the comparative costs of coke, pig iron and finished steel were presented to the board. It is not specified exactly which plants were being compared, but it seems more than likely given the nature of the firm by that date it was a comparison between the three main Dorman Long works – Britannia, Clarence and NESCo. If so, then this is an indication that the board was concerned with the comparative efficiency of its constituent businesses and presumably willing to take action should they get out of line.

[567] DLDM vol. 1, 3 Oct. 1894; 15 Sept. 1897, pp. 208-9.
[568] DLDM vol. 1, 14 July 1899, p. 272-5.
[569] DLDM vol. 2, 4 Mar. 1903, pp. 165-6.
[570] DLDM vol. 2, 11 July 1905, pp. 284-7; vol. 3, 6 Feb. 1907, pp. 7-9.

While reporting and monitoring are necessary for effective management, they are not sufficient: a firm also needs a clear organisational structure for control and decision taking. Once again, it appears that there was an awareness of the need for this, with an identifiable if embryonic management organisation and hierarchy emerging from the late 1890s. At various times reviews of the 'organisation of management' were undertaken and reported to the board. For example, one was conducted by Charles Dorman in 1903, and another in 1905. The precise content of these reviews is not known but the first review appears to be concerned with the whole Dorman Long group while the second refers solely to the Britannia works.[571] In each case the board accepted Charles Dorman's recommendations and a number of organisational changes followed, the most important of which was to set up a special management committee in 1903.

As with the regular collection and reporting of production data, the organisational changes began some time before the two main takeovers. After the incorporation of the wire and sheet works and the creation of the construction shop, the firm treated these as departments separate from the Britannia steel works and rolling mills. Further organisational changes followed the 1899 and 1903 takeovers, and while neither Bell Brothers nor NESCo can in any way be regarded as departments of Dorman Long in the way that the sheet and wire works were, the Dorman Long board did establish special committees to deal with matters affecting the company and its subsidiaries. The first of these was set up in early 1900 when a committee of directors was formed. Its principal function seems to have been to deal with the administrative details of the Bell Brothers takeover, including the allocation of shares, issue of certificates and similar tasks.[572] The committee lasted from January 1900 until November 1903, meeting once or twice each month and attended by Arthur Dorman, Charles Dorman, W.H. Panton, and, occasionally, Hugh Bell or Maurice Bell. It was wound up on the completion of the Bell Brothers takeover.

Of greater significance for the operation and overall control of the Dorman Long businesses was the creation of a managing committee. This was first instituted in October 1900 following the initial takeover of Bell Brothers. It was also at the time of Arthur Dorman's first retirement from the managing directorship and the appointment of Panton and Charles Dorman as joint managing directors. Arthur Dorman retained the chairmanship of the company. The committee was made up of Arthur Dorman, Alexander Hay and Hugh Bell and its role was to provide a group of directors 'with whom the managing directors may confer over the conduct of the

[571] DLDM vol. 2, 9 Sept. 1903, pp. 198-200; 11 April 1905, pp. 220-2.
[572] DLDM vol. 1, 13 Jan. 1900, pp. 285-6.

business…[and] to give advice and assistance.'[573] It seems likely that rather than primarily acting as a means of coordinating the Dorman Long and Bell operations, it was designed to oversee the performance of the new managing directors, and perhaps principally as a means by which Arthur Dorman could continue to keep a close control over the firm without becoming involved in the day to day production and trading activities. Nevertheless, the inclusion of Hugh Bell on the committee, unless it was in deference to his standing in the iron trade or in acknowledgement of his position as a major shareholder, suggest either that Arthur Dorman was keen to draw on Bell's knowledge of the iron trade or that this was an early attempt to link the control of the two firms at the highest level. Bell was after all the managing director of Bell Brothers. Although there are no surviving records of the committee's meetings, discussions or decisions, it was considered to be performing an important function. The members were well remunerated, with £1,000 p.a. paid to Arthur Dorman and £500 to the other two members in 1900, and raised by £1,000 in total the next year. Its formation and role also warranted a reference in the chairman's annual statement in 1900.[574]

This particular management committee was short-lived, however; it ended sometime in 1902. In the middle of that year there was a 'rearrangement of managements in several departments' which Charles Dorman presented to the board in his monthly report. It followed the full takeover of Bell Brothers that was completed in 1902 and led to Arthur Dorman taking up the managing director's position once again, which for a time he shared with the current managing directors before later taking on the position on his own. At the same time Arthur Dorman handed over the chairmanship to Lowthian Bell.[575]

The notion of a managing committee was revived less than a year later after the acquisition of NESCo. Comprising the managing directors of the three companies – Arthur Dorman, Hugh Bell and Arthur Cooper – it had a rather more explicit role than its predecessor: 'to transact any business they may think to the advantage of the *joint* concern'.[576] It is not certain how much this new committee or its objectives were influenced by Charles Dorman's earlier management reorganisation plan that he had presented to the board in 1903, which in turn may have been prompted either by the company's expansion or by Panton's resignation as joint managing director in August 1903. But bringing together the managing directors of the three firms in a single special committee not only facilitated greater inter-firm cooperation but was also conducive to the development of strategic thinking for the group as a whole. The committee's

[573] DLDM vol. 2, 10 Oct. 1900, pp. 21-3.
[574] DLDM vol. 2, 10 Oct. 1900, pp. 21-3; DLAR 1900 and 1901.
[575] DLAR 1902; Extraordinary Meeting of Shareholders, 1902, p. 2. See also the Notice of Extraordinary Meeting of Shareholders, 1902, and the Circular to Shareholders, DLDM vol. 2, 1 Oct. 1902, pp. 128-9.
[576] Italics added. DLDM vol. 2, 13 Jan. 1904, pp. 220-2.

formation was also indicative of the development of a Dorman Long group identity is shown by two other details. First, each of the managing directors on the committee was also on the board of all three companies, apart from Arthur Cooper who was not on the Bell Brothers board. The second is that there is an explicit reference to the three companies as a 'joint concern'. This is a clear sign of the beginnings of a Dorman Long group identity and that, in spite of retaining their original names, having different sites and separate financial structures, it was the start of each firm being regarded as different parts of one company, rather than 'a federation of distinct family firms'.[577]

It is difficult to assess the contribution of the committee to Dorman Long's operations; as with the earlier committees, there are no surviving minutes and no indication as to whether it met formally or informally, regularly or irregularly. In the directors' minutes, however, there are references to the board delegating the implementation of decisions to the committee, and also to granting the committee discretion over how the firm's policy should be carried out. Thus in April 1904 the ordering of a new engine for the Britannia mill was left to the managing committee, and in the following month it was empowered to make the arrangements for a new issue of debentures, including drafting the prospectus and determining the terms of the issue.[578] Similar discretion was given to the three managing directors for the 1911 debenture issue. But while these examples show that the managing committee was active in implementing the board's decisions, it does not necessarily show that it initiated the plans. However, given that as the managing directors, the committee members were in constant contact with, and in direct control of, the business it seems more than likely that they put forward many of the proposals that were brought to the board for approval. Depending on the nature of the decision, some of these were subsequently implemented by the committee. Moreover, given his forceful personality and his active involvement in the business, it is likely that many of the initiatives came from Arthur Dorman, either directly or indirectly through the committee. Indeed, if the board minutes in any way accurately reflect the relative influence of the different directors, it is clear that Arthur Dorman was very much a dominant presence and the source of many, if not most, of the strategic plans.

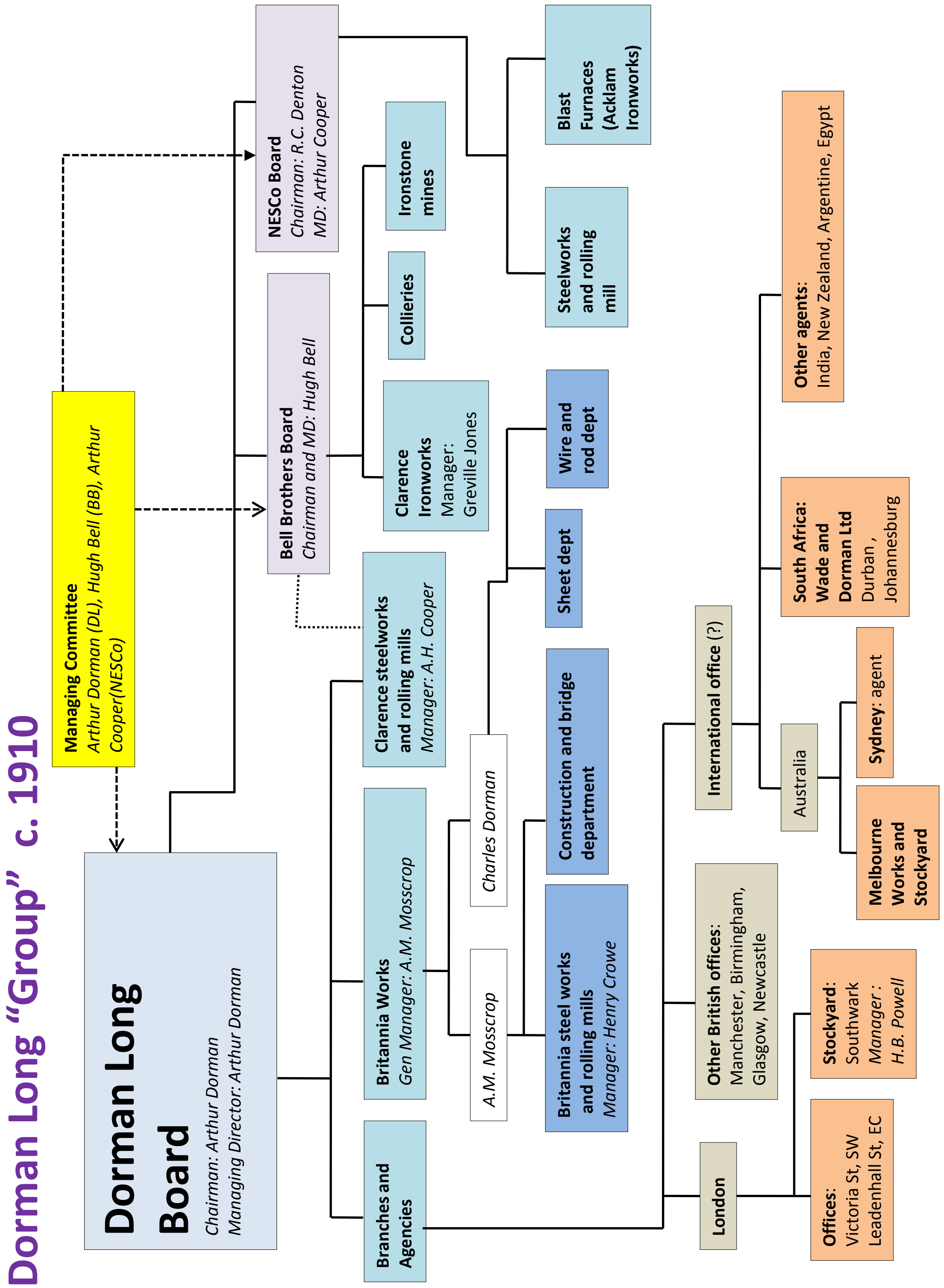
This section has presented evidence that at the time of Dorman Long's rapid expansion steps were taken to create a management structure that enabled control to be exercised over an increasingly diverse business. It arose in a somewhat piecemeal fashion, developing in response to the demands of a growing company and the need to coordinate the different departments and subsidiaries. There appears to be a sense that the constituent companies were all part of one

[577] Elbaum, 'Steel industry', p.67.
[578] DLDM vol. 2, 6 April 1904, pp. 230-1; 4 May 1904, pp. 232-5.

group and that this was ultimately under the control of the Dorman Long board. Dorman Long directors monitored not only their own departments at the Britannia and West Marsh works, but increasingly the performance of the subsidiary firms. Operations and strategy could be coordinated through the extensive degree of overlap in board membership and by the special management committee, the latter especially after 1904. It is not suggested that the extent of corporate organisation in any way matched that achieved later in companies such as DuPont, Siemens or ICI.[579] Nevertheless, Dorman Long's organisational development does show an understanding both of the need for information to monitor performance and also that this was crucial to the coordination and control of the group's activities. It provided incentives to and a check on those in day-to-day control of the businesses. Furthermore, to implement effective decision making required changes in management structure in a way that linked the different parts of the business. The constituent firms may outwardly have kept their identities and apparent independence, but behind the scenes there was a far greater degree of cohesion as well as indications of a common strategy. It would be wrong therefore to see the three companies as separate businesses operating independently from each other, even though they kept their names and had separate boards. Of course, organisational structure and information are not substitutes for good management, but they do provide a framework for, and a flow of intelligence on which, sound decisions can be taken, policies implemented and effective control exerted. Figure 7.2 presents an organisational chart for the firm circa 1910, with the three main companies constituting three departments of the Dorman Long group. The chart also shows the marketing and distribution sections of the business, which by this time had become fairly extensive.

[579] Chandler, *Scale and Scope*, pp. 181-7, 463-74.

Figure 7.2: The Dorman Long Group, *c*1910



Sources: Dorman Long, *Works*; Dorman Long, *Pocket Companion*; DLDM 1889-1914; DLDM 1890-1914; BBDM 1899-1914; NESDM 1903-1914.

7.4 Products, Distribution and Marketing

Building up an extensive distribution network was a central feature of Dorman Long's growth after incorporation. What is interesting about this network is that it was not just through the use of agents, which had been the traditional channel and for which British companies have been much criticised, that it distributed its products.[580] Dorman Long had its own stockyards and branch offices in some of the major consuming markets both in Britain and across the world. Indeed, it is evident from the way the company set about developing its distribution system that it was keen not only to find new outlets for its products but also to exert control over their sale and marketing. Chandler emphasised the importance of distribution as the key to achieving sales volume, thus supporting expanding productive capacity and securing the benefits of scale economies.[581] To some extent this is evident in Dorman Long's distribution and marketing policy from 1890, and possibly before. But its expansion was based on much more than increasing the total volume of output – or 'throughput" to use Chandler's terminology: it involved an increasing diversity of products, pushing into markets – product and geographical – where there was potential to expand.

Overall, in their approach to product development and marketing there appear to be four interrelated strands. One was to expand the 'downstream' use of steel to provide an immediate outlet for its basic product, steel ingots. This was achieved by developing or acquiring specialist processing facilities such as for wire and rods, and galvanised and corrugated sheets. As well as using their own steel, this helped to increase the firm's presence in the more specialist, higher value end of the market – in modern parlance, increasing the firm's value added. Arthur Dorman's comments to the AGM in 1912 on buying the Bowesfield Steel Company are instructive here: the acquisition would secure orders for steel bars from the rest of the company, creating what he calls 'internal demand' hence 'continuing the policy which has guided [the directors] for many years... [to] extend their operations in a direction that will carry their manufactures to a more advanced stage.'[582] Second, and closely related to the first, was the greater variety of output, which, as well as being part of the extension into higher value products, was also a way of spreading risks. Arthur Dorman in his 1906 chairman's statement emphasised the importance of not being dependent on one product, but of having a range so that

[580] For example, see Wilson and Thomson comment on the 1870 to 1914 period thus: 'This was a period when production was dominant and distribution secondary in the staple industries, with a continuation for the most part of the merchanting and agency system.' J.F. Wilson and A.W. Thomson, *The Making of Modern Management: British Management in Historical Perspective* (Oxford, 2006), p. 220. See also S. Nicholas, 'The overseas marketing performance of British industry, 1870-1914' *EcHR*, 38 (1984), pp. 489-506.
[581] Chandler, *Scale and Scope*, p. 28-31.
[582] DLAR 1912, p. 13.

‘if one trade is bad, we can fall back on another.’[583] Third, this process of diversification involved the exploitation of complementarities between goods. By producing and stocking products that customers were likely to buy together and which agents were willing to hold, the firm was able to achieve both greater sales and some degree of economies of scope. Again, Arthur Dorman’s comments to shareholders reveal this line of thought. In 1898, after the company had bought the sheet and wire businesses, the purchases were explained to shareholders thus: ‘wherever they sold joists the same people would only be too glad to handle sheets and wires.’[584] Fourth, the company developed a speciality in constructional steel – joists and girders – that enabled it to carve out a niche in an expanding market, and one which ensured that it avoided head-on competition with the other bulk steel producers on Teesside and in the north east – Bolckow Vaughan, Consett, and later Cargo Fleet-South Durham – with their concentration on ship-plates and rails. The company was already producing joists and girders and other building materials before 1890; it appears to have begun to move into this market as early as 1883, and over time this aspect of Dorman Long’s operations was to become increasingly important.[585]

There is no precise data on the proportion of output, sales, or contribution to profit from constructional steel work, but an impression of its significance can be gained from the product range included in the company’s *Pocket Companion* of 1910. This contains detailed specifications of their steel products ‘for the use of engineers, architects and builders.’[586] Of the 184 pages of steel products, 123 pages, approximately two-thirds, are devoted to the output of the constructional and bridge shops. Part of this is accounted for by the inclusion of diagrams and additional notes, but the emphasis on construction products does show the specialisation of the firm in this area (see Figure 7.3).

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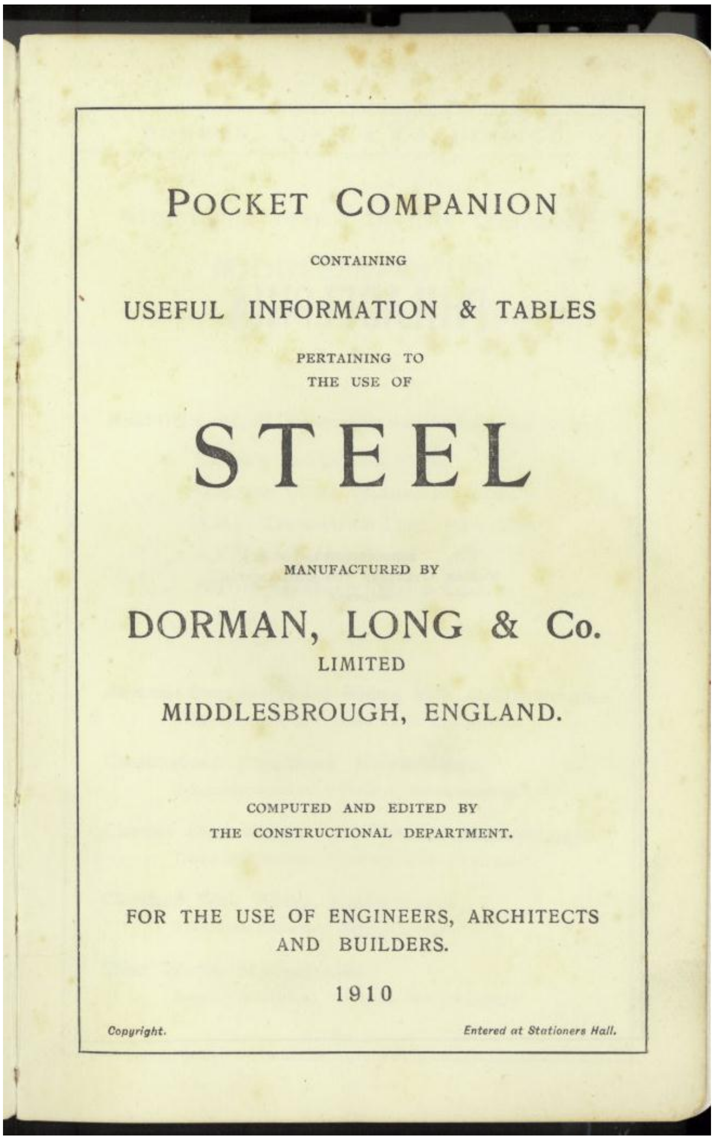
[583] DLAR 1906, p. 14.
[584] DLAR 1898.
[585] Dorman Long, W*orks,* p.12.
[586] Dorman Long, *Pocket Companion containing useful information & tables pertaining to the use of steel* (Middlesbrough, 1910). In fact Dorman Long was one of the first companies to produce a set of detailed specifications of its steel girders and safe load tables for engineers in 1887, before the introduction of *British Standards* (1906). W. Bates, *Historical Structural Steelwork Handbook* (London, 1984), pp. 8-9, 15-19.

Figure 7.3: Extracts from Dorman Long *Pocket Companion*, 1910

a) Title page



POCKET COMPANION

CONTAINING

USEFUL INFORMATION & TABLES

PERTAINING TO

THE USE OF

STEEL

MANUFACTURED BY

DORMAN, LONG & Co.

LIMITED

MIDDLESBROUGH, ENGLAND.

COMPUTED AND EDITED BY

THE CONSTRUCTIONAL DEPARTMENT.

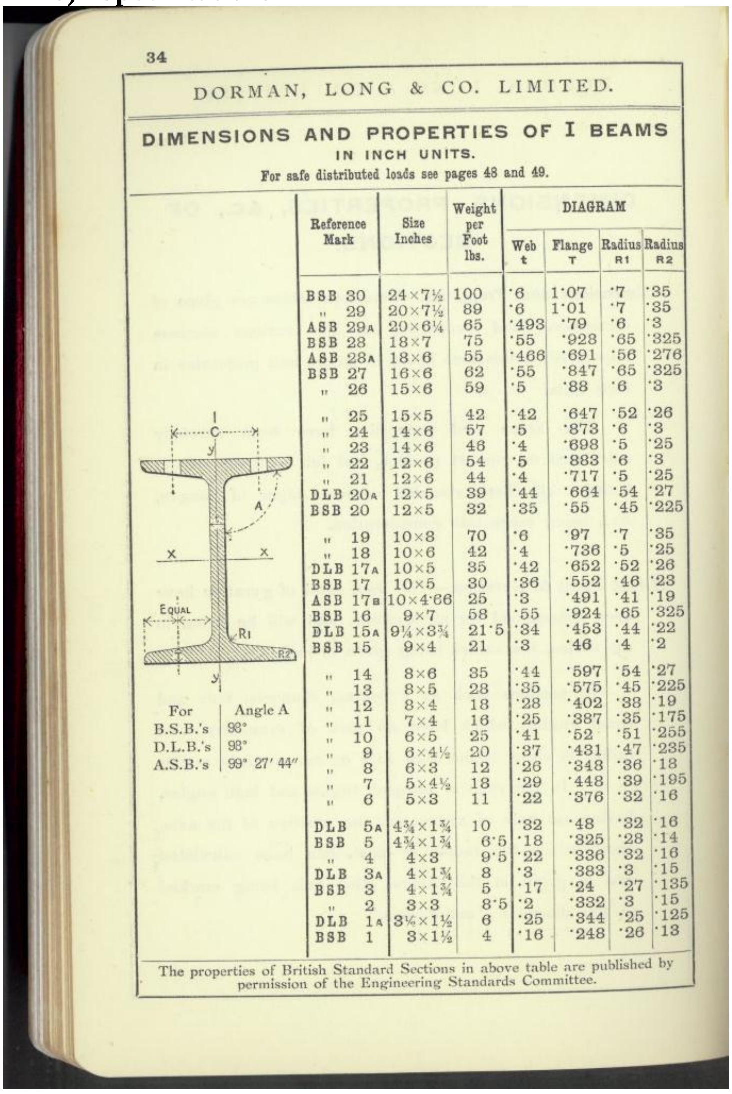
FOR THE USE OF ENGINEERS, ARCHITECTS

AND BUILDERS.

1910

Copyright. *Entered at Stationers Hall.*

b) Specifications



DORMAN, LONG & CO. LIMITED.

DIMENSIONS AND PROPERTIES OF I BEAMS IN INCH UNITS.

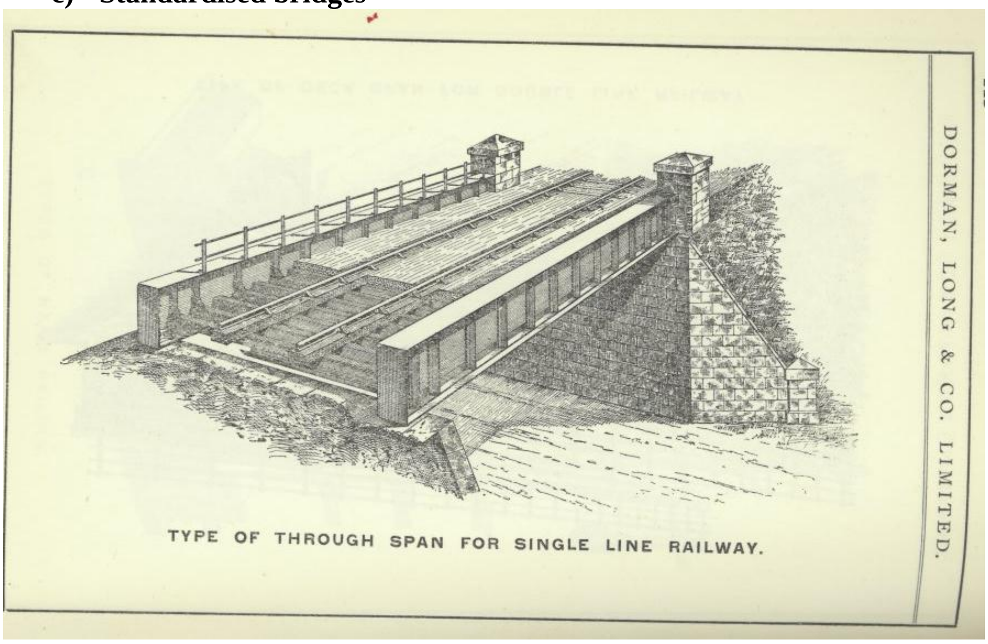
For safe distributed loads see pages 48 and 49.

Reference Mark	Size Inches	Weight per Foot lbs.	DIAGRAM Web t	Flange T	Radius R1	Radius R2
BSB 30	24×7½	100	·6	1·07	·7	·35
" 29	20×7½	89	·6	1·01	·7	·35
ASB 29A	20×6¼	65	·493	·79	·6	·3
BSB 28	18×7	75	·55	·928	·65	·325
ASB 28A	18×6	55	·466	·691	·56	·276
BSB 27	16×6	62	·55	·847	·65	·325
" 26	15×6	59	·5	·88	·6	·3
" 25	15×5	42	·42	·647	·52	·26
" 24	14×6	57	·5	·873	·6	·3
" 23	14×6	46	·4	·698	·5	·25
" 22	12×6	54	·5	·883	·6	·3
" 21	12×6	44	·4	·717	·5	·25
DLB 20A	12×5	39	·44	·664	·54	·27
BSB 20	12×5	32	·35	·55	·45	·225
" 19	10×8	70	·6	·97	·7	·35
" 18	10×6	42	·4	·736	·5	·25
DLB 17A	10×5	35	·42	·652	·52	·26
BSB 17	10×5	30	·36	·552	·46	·23
ASB 17B	10×4·66	25	·3	·491	·41	·19
BSB 16	9×7	58	·55	·924	·65	·325
DLB 15A	9¼×3¾	21·5	·34	·453	·44	·22
BSB 15	9×4	21	·3	·46	·4	·2
" 14	8×6	35	·44	·597	·54	·27
" 13	8×5	28	·35	·575	·45	·225
" 12	8×4	18	·28	·402	·38	·19
" 11	7×4	16	·25	·387	·35	·175
" 10	6×5	25	·41	·52	·51	·255
" 9	6×4½	20	·37	·431	·47	·235
" 8	6×3	12	·26	·348	·36	·18
" 7	5×4½	18	·29	·448	·39	·195
" 6	5×3	11	·22	·376	·32	·16
DLB 5A	4¾×1¾	10	·32	·48	·32	·16
BSB 5	4¾×1¾	6·5	·18	·325	·28	·14
" 4	4×3	9·5	·22	·336	·32	·16
DLB 3A	4×1¾	8	·3	·383	·3	·15
BSB 3	4×1¾	5	·17	·24	·27	·135
" 2	3×3	8·5	·2	·332	·3	·15
DLB 1A	3¼×1½	6	·25	·344	·25	·125
BSB 1	3×1½	4	·16	·248	·26	·13

For	Angle A
B.S.B.'s	98°
D.L.B.'s	98°
A.S.B.'s	99° 27′ 44″

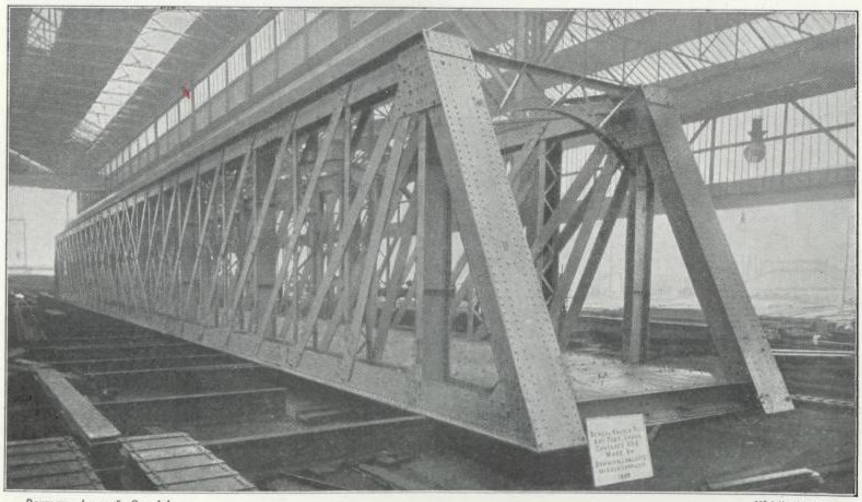
The properties of British Standard Sections in above table are published by permission of the Engineering Standards Committee.

c) Standardised bridges



TYPE OF THROUGH SPAN FOR SINGLE LINE RAILWAY.

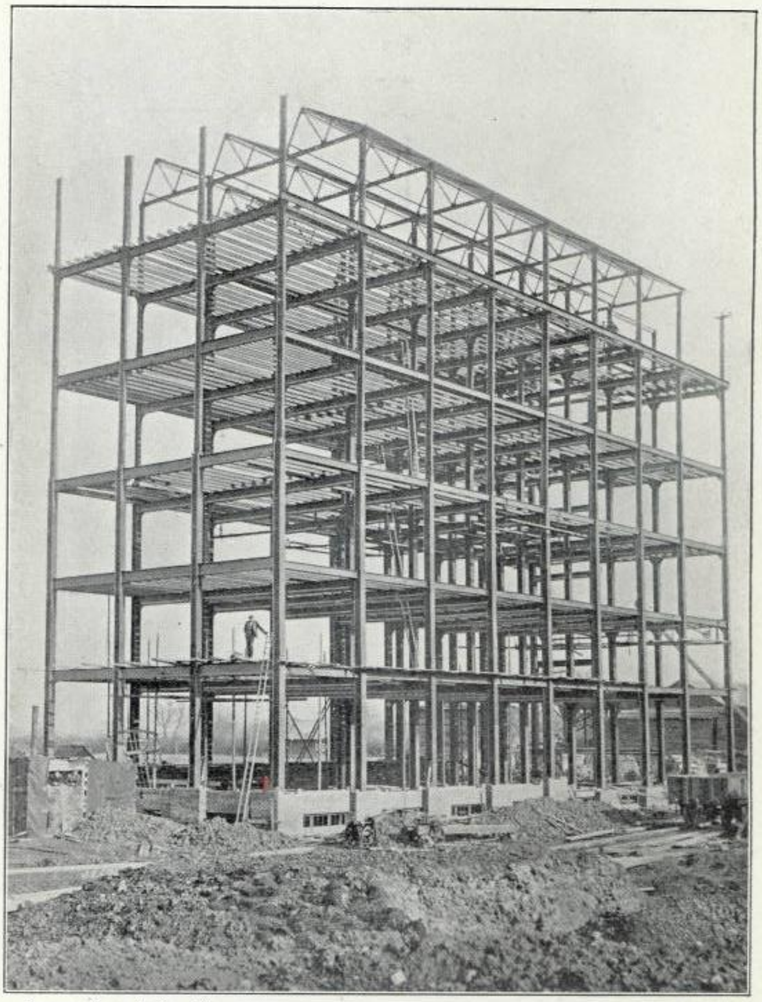
DORMAN, LONG & CO. LIMITED.



Dorman, Long & Co. Ld. — Middlesbrough.

BRIDGE OF 200 FEET SPAN.
BUILT BY D. L. & CO. LD.

d) Steel-framed building



Dorman, Long & Co. Ld. — Middlesbrough.

STEEL FRAME BUILDING.
SUPPLIED AND ERECTED BY D. L. & CO. LD.

The decision to specialise and expand the constructional steel side of the business coincided with a growth in the construction industry and changes in construction techniques. Larger buildings were possible with the use of the lighter steel compared to iron as a building product, and from the beginning of the twentieth century there was also the development of steel-framed buildings.[587] For example, the company supplied steel for a number of important early steel-framed buildings, including the British Westinghouse factory at Trafford Park, the Midland Hotel in Manchester (both 1900) and the Savoy Hotel extension in London (1903), reputed to be the first fully steel-framed construction in London.[588] As the *Pocket Companion* shows, by 1910 the company was not only offering steel frames but also standardised bridge designs as well as a wide range of other products with a variety of specifications (Figure 7.3). Whether this was a deliberate strategy planned in advance, or a fortuitous benefit is not clear, but Dorman Long did make the most of the changes by developing its bridge and constructional shops. W.H. Panton, the first general manager of the incorporated Dorman Long, spent some time expanding the construction department, which had first been established in 1890, the year before his arrival at the firm. In 1892, Panton put forward a proposal to improve the girder shop at a cost of just under £4,000, and over the following year he was instrumental in initiating the development of this side of the business. In the twelve years up to 1903 investment in construction amounted to a substantial £91,000, with the most significant being the decision in 1899 to build a new girder and bridge building shop at an estimated cost of £30,000.[589] In the event, actual capital expenditure overshot the planned amount and the limit was raised to £37,000. It was finally completed at the end of 1901 at a cost of £48,506.[590] By the turn of the century Dorman Long was producing over 30,000 tons of structural steel and employing 600 workers in these departments. For the time the works were extensive. There were four riveting shops (or bays), with the three largest (500 feet in length and spans of 60 to 70 feet) served by electrically driven equipment including cranes and gantries.[591] Arthur Dorman reported to shareholders at the AGM of 1901 that the output of the department had greatly increased and that following the investment the shops 'were fitted up with machines of the latest pattern and are up-to-date in every way.'[592] The importance of this development to the firm can also be gauged from the company booklet published in the same year, in which the girder trade and

[587] Naturally, iron and steel were used in many buildings before the end of the nineteenth century. The significance of steel-framed buildings is that it is the frame that bears the weight rather than the masonry walls and pillars as in earlier constructions. See A.A. Jackson, 'The development of steel framed buildings in Britain, 1880-1900', *Construction History*, 14 (1998), pp. 21-40; R. Thorne (ed.), *Structural Iron and Steel, 1850-1900* (Aldershot, 2000), pp. xiii-xxvi.
[588] DLDM vol. 2, 27 July 1900, pp. 13-4; 6 May 1903, pp. 173-5; A.A. Jackson, 'Steel framed buildings', pp. 18, 33.
[589] DLDM vol. 2, 14 July1899, pp. 272-5.
[590] DLDM vol. 2, 8 Jan. 1902, pp. 82-5
[591] Dorman Long, *Works*, p.24.
[592] DLAR 1901.

construction department receives some prominence. Dorman Long described itself as 'the most extensive producer of girders in the country... [with]...a large staff of men employed in drilling, cutting and riveting the girders up to the required length.'[593]

The appointment of Alfred Mosscrop as manager of the construction department in 1903, and later as general manager to replace Panton, also points to Dorman Long's intentions to consolidate and further expand its position as a leading supplier of constructional steel and a bridge builder. He was recruited by Charles Dorman on his visit to the United States in 1903.[594] An American, Mosscrop was a university-trained civil engineer with a degree from Cornell University (1885) who already had had significant experience in the industry, first at the Rochester Bridge and Iron Works (Rochester, New York) and then as vice president and manager of the Baltimore Bridge Company, Delaware.[595] Almost immediately after his appointment Mosscrop presented the board with plans for £11,500 of improvements, which were approved even before the cost estimates had been submitted.[596]

The total capital spending on developing this side of the business over the 15 years from 1890 amounted to over £100,000. And while some of this will have been replacement investment, a substantial proportion was a net expansion of capacity. Table 7.4 gives details of the main investments over the period. It was clearly a successful strategy with Arthur Dorman reporting to shareholders in 1912 that the department's performance was 'very remarkable'. However, investment in construction and bridge yards seems to have ceased in about 1904 and this may well have constrained the firm's expansion particularly during the upswings in trade. As Dorman also indicated at the same AGM, the firm had been unable to keep pace with demand: 'the demand on our powers of production is still larger than we can cope with.'[597]

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[593] Dorman Long, *Works*, pp.12-5.
[594] DLDM vol. 2, 8 July1903, pp. 184-8.
[595] *Cornell Alumni News*, vol. v, no. 10, 3 Dec. 1902, p. 81.
[596] DLDM vol. 2, 9 Sept. 1903, pp. 198-200; 7 Oct. 1903, pp. 203-8.
[597] DLAR 1912, p.13.

Table 7.4: Capital Spending on the Construction and Bridge Department, 1890-1905

Date agreed	Details	Voted (£)	Final Spending (£)*	Completion *
6/3/1890	New engineering shop at Britannia.	7,400		
Under W.H Panton				
9/8/1891	Improvements: boiler chimney, rods for straightening plate, shearing machine for beams.	900		
9/9/1891	Extension to girder shed.	3,000		
1/6/1892	Improvements to girder bank: overhead crane, gantry, straightening machine.	1,500		
19/7/1892	Further extension to girder bank.	4.000		
5/12/1894	Electric driving at girder shop.	2,500-3,000		
1/7/1896	Equip Cast Steel Foundry as girder shop.	1,000		
12/1/1898	Gantry extension.	3,500	3,545	30/4/1899
14/7/1899	New girder and bridge shop.	30,000	}	
10/10/1900	Office extension for construction department.	4,000	}48,406	30/11/1901
8/1/1902	Extra bay to girder shop, overhead crane and sidings.	6,500	}	
12/3/1902	New girder stockyard.	5,500	}18,350	30/11/1902
Under Arthur M. Mosscrop				
7/10/1903	Improvements to department: No. 4 Bay; air plant; machine shop; No.3 Bay; and other items.	11,500	11,507	31/1/1905
3/8/1904	New overhead crane.	1,200	1,181	7/3/1905
7/9/1904	Welding plant for beam bank.	450	532	30/4/1905
Total		**83,450**	**104,421**	

*Final spending and the completion dates are not recorded before 1898.
Sources: DLDM, vols. 1-3, 1889-1914.

In parallel with increasing its product range and productive capacity Dorman Long also put considerable effort into the distribution of its output. The company shows an early recognition of the importance of having a direct link to customers, especially for the specialised, more specific and highly processed products. For the girder trade there was an additional factor; it was having a range of stock available close to the market so that customers had ready access to the products. As Dorman emphasised at the AGM of 1892, to compete in the joist and girder market required holding a large stock and being able to deliver promptly. The decision to establish a stockyard in London was therefore highly significant. Not only was it a centre of international trade and hence export orders, it also provided a base from which the growing construction sector in and around the capital could be supplied – in Dorman's words: 'London is a great outlet for rolled joists'. Dorman also makes clear that the company had other reasons for embarking on a policy of distributing from its own yards; it was that by cutting out the merchants, not only could they secure the merchants' share of the profits, but it would also make the company more competitive.[598]

Dorman Long had already established a presence in London by 1890, with offices in Victoria Street, Westminster. As there is no record of an earlier date and it seems likely that setting up the office coincided with the incorporation of the company.[599] But even before this became the London office of the company, the board had already decided to establish a London yard for the girder trade. The suggestion came from Dorman at a directors' meeting in March 1890, and H.B. Powell was assigned the task of looking for a suitable location. It did take some time to set up the yard, which eventually opened in late 1892 or early 1893, with the board initially debating the merits of buying an existing business or setting up their own, new premises. They finally settled on the latter.[600] In fact concern was expressed by some of the directors during 1892 that delays in opening the yard were having an adverse effect on the business.[601] A riverside site that offered 100 feet of river frontage at Nine Elms Lane, Vauxhall in south west London was secured, and at first it was leased (£425 p.a.), with an option to buy (within four years at a price of £9,000). From the outset the arrangements appear to be well thought out; Powell was appointed manager of the yard as well as manager of the London office, with the power to hire and dismiss workers, and the two London sites were linked by a private telephone line.[602] On its opening, much was made of the fact that that the yard was well stocked during a period low prices, thus keeping production going at the Middlesbrough plants when there was sluggish demand, as well as ensuring that the company was in a position to take advantage of the revival of trade and prices when it came. It is also interesting to note that Dorman Long decided to set up the yard during a period of low profits and difficult trading conditions. This decision to press ahead is an indication that the company was looking beyond short-term returns

[598] DLAR 1892.
[599] Early meetings of the board in 1889 and 1890 were held at the London offices of its auditors, R. Mackay and Co (3, Lothbury) and at Cannon Street Hotel. The first recorded meeting at the Victoria office was in 1890. DLDM vol. 1, pp. 34-5.
[600] DLDM vol. 1, 12 Feb. 1890, p. 31; 2 Dec. 1890, pp. 53-4.
[601] DLAR 1892 and 1893; DLDM vol. 1, 19 July 1892.
[602] DLDM vol. 1, 6 April 1892, pp. 89-91; 8 Feb. 1893, pp. 110-2.

and to its long term position in the girder and construction market, and significantly this was not the only project they remained committed to despite the poor immediate outlook.

The importance of the yard at Nine Elms Lane was that it offered a means of direct contact between Dorman Long and its customers. In fact Dorman at one stage referred to it as ‘our retail trade…offering prompt delivery of [an] increasing number of daily orders.’ For construction and the building trade where demand was varied and quick supply essential, this clearly gave Dorman an advantage over its competitors who would have to deliver from distant plants.[603] The yard was not regarded as a sound investment throughout the period, however; for example in 1904 concern was raised over the size of the business (i.e. sales) relative to the stock and capital invested.[604] Nevertheless, the firm maintained their commitment and the yard was expanded several times over the twenty years between 1893 and 1913. Investment in equipment amounted to almost £10,000, including tools and machinery, gantries, cranes and even a steam vehicle (1902). The site was also extended on at least seven occasions with the company renting or buying additional land as the opportunity and need arose. In 1901 for example there was some concern raised at the board that the yard was too small and inefficient as customers had complained about delays in delivery.[605] The response was to acquire extra land so that by 1905 the yard comprised 11,560 square yards of freehold property, additional land on lease, and a freehold construction yard and shop. The value of the freehold property was put at £35,000. In mid-1914 a further £25,000 of investment was proposed (by Lawrence Ennis), although the director’s minutes are not explicit about this next stage of expansion.[606]

The development of the London yard was a central plank in the company’s distribution policy, and although it is not possible to measure its direct contribution to the profitability of the firm, it is possible to infer from the regular investment that it was regarded as a crucial element in the company’s successful expansion in the construction market. The very presence of stocks in London as well as an office in the city gave Dorman Long a higher profile than it would have had it remained a Middlesbrough-based business. The company offices in London were also expanded. Additional space was rented at Victoria Street (1898 and 1910) and the firm eventually moved to larger premises in Central Buildings, also in Westminster. An office was also opened in the City of London sometime before 1910 to deal specifically with orders for the sheet and wire departments. Locating this at 23, Leadenhall Street among the iron and steel merchants and agents and close to the London metal exchange is another example of the way in

[603] DLAR 1901.
[604] DLDM vol. 2, 5 Oct. 1904, pp. 254-6.
[605] DLDM various; DLAR 1902.
[606] DLAR 1905; DLDM, vol. 3, pp. 280-3.

which the company's distribution policy was designed to obtain direct access to customers and to bypass the traditional agent-based distribution route.[607]

London was neither the only market that Dorman Long targeted nor the sole key to the success of its sales strategy. There was a concerted effort to create and then expand the distribution network in the main consuming centres in Britain and to establish presence abroad, especially in the colonial markets. The first branch office outside London was opened in Birmingham in early 1894.[608] In other cities at first the agent channel was used for promotion and distribution, with agency offices in Manchester, Glasgow and Newcastle, although the Newcastle agent is probably best thought of as a branch as the firm was owned by the Dorman Long director Henry Echalaz.[609] By 1910 these had all been replaced by branch offices staffed by the company's own employees.[610] Dorman Long at various times also considered opening up stockyards in a number of provincial cities, notably Manchester and Cardiff. A Manchester yard on the new and Trafford Park Estate was first mooted in 1899 and the firm was on the point of leasing a 7,000 square foot plot. The negotiations were left to Arthur Dorman, but do not seem to have been successful. The question of stockyards in Manchester and Cardiff was also considered by the board in 1911 at the suggestion of Dorman, but the concentration of the home distribution effort was on the development of the London yard and there were no further discussions of the proposals at board level before the war. [611]

Apart from the London venture, there was greater discussion of, and possibly more emphasis placed on, expansion overseas than in Britain. From the early 1890s the firm demonstrated an understanding of the need to develop export markets. Dorman explained to shareholders in his 1897 statement: 'It is quite as important to find new markets and approved methods of distribution as to manufacture cheaply'. Moreover, the company recognised the need for a visible presence in the markets by having a stock of goods immediately available as well as by having sales representatives.[612] A number of early steps were taken to promote the firm abroad, including, at the suggestion of Dorman in 1891, sending a few small consignments of girders 'to foreign countries as an advertisement'.[613] Later, in December 1894, the board agreed to appoint Bernard Dean on a salary of £300 and with a budget of £1,000, as an 'international traveller'.

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[607] For examples of the agents and London offices of iron and steel companies see *Business Directory of London Part 2: Classified Section and Foreign and Commonwealth Register* (22nd edition, London, 1884), pp. 400-3.
[608] DLDM vol. 1, 6 Feb. 1894, pp. 135-7.
[609] The Manchester agent in1897 was M. Cooper (DLDM vol. 1, 10 Feb. 1897, pp. 194-5; and the Glasgow agent was P and W. MacLennan, (DLDM vol.1, 3 Feb. 1897, pp. xx).
[610] Dorman Long, *Pocket Companion*, p. iv.
[611] DLDM vol. 2, 7 Feb 1900, pp. 290-2 and 6 Mar. 1900, pp. 294-5.
[612] DLAR 1897
[613] DLDM vol. 1, 9 Sept. 1891, pp. 72-4.

Again, this was the suggestion of Dorman, who saw Dean's role as one of raising the profile of the company with foreign buyers. As the directors' minutes note: 'The chairman…called attention to the desirability of the company's manufacturers being brought before the notice of government officials, engineers and others who design constructional work in India, Africa and other countries.'[614] The board also discussed the possibility of setting up an export department to coordinate overseas sales. This was at the suggestion of Henry Echalaz a merchant by profession and therefore well versed in the importance of marketing products. It is not clear whether such a department was established at this time. These arrangements and discussions supplemented and prepared the way for the principal approach to promoting overseas sales, by securing agreements with agents, some of which were to supply Dorman Long products exclusively, and setting up their own branches and stockyards. By 1910, as Table 6.6 indicates, Dorman Long had branches and agency agreements in six countries and this continued to be extended up to 1914, by which time the network comprised distributors in nine countries, with three company branches and stockyards, two agents with stockyards and six agents. The details of the development are shown in outline in Table 7.6.

Table 7.5: Dorman Long Branches and Agencies in 1910

Location	Arrangement
London	Branch office and yard
Manchester	Branch office
Newcastle	Branch office
Glasgow	Branch office
Birmingham	Branch office
Australia (Melbourne and Sydney)	Branch office and yard
India	Agent
South Africa (Durban and Johannesburg)	Branch office and yard
Argentine Republic	Agent
Egypt	Agent

Source: Dorman Long, *Pocket companion*, p. iv.

614 DLDM vol. 1, 5 Dec. 1894, pp. 152-3.

Table 7.6: Overseas Branches, Agencies and Yards, 1892-1913

Year	Location	Nature of distribution arrangement	Agent and other details
1892	Melbourne	Agent and stock holder.	Austral Otis Elevator and Engineering. (£7,500 credit).
	Sydney	Agent and stock holder.	R.L. Scrutton and Co Ltd (£7,500 credit).
1896	Calcutta	Agent and representative.	Jessop and Co.
	Japan	Agent.	G.J. and H.J. Brindley. No details.
1898	Australia	Own branch and stockyard.	
	Port Elizabeth, South Africa	Agent on salary and commission.	F. Searle and Co.
1899	Cairo	Agent.	F.C. Bevan. No details.
1903	Cape Town, Johannesburg and one other city	Own branches.	Manager: Ernest Petersen.
1905	Straits Settlement and Malay Peninsular	Agent.	Messrs Huttenbach and Co. No details.
1906	Cape Town Johannesburg and one other city	Own branches.	Dorman Long (South Africa) Co Ltd.
1908	Buenos Aires	Agent.	Stanley W. Lewis. No details.
1909	Durban and Johannesburg	Branches and stockyards in a joint venture with C. Wade and Co.	Wade and Dorman and Co Ltd. Manager: H. Wade.
1910	Buenos Aires	Own branch and stockyard.	£6,000 to be invested. Outcome not known.
1912	British Columbia	Agent.	No details.
1913	China	Agent.	Part of *Representative on British Manufacturers China Agency*.

Sources: DLDM, vols. 1-3, 1889-1914; Dorman Long, *Pocket companion*, p. iv.

The list in Table 7.6 shows that the emphasis of the export effort was very much on colonial markets, although not exclusively – there were ventures in Japan and South America (The

Argentine). Aware of the growing competition from the US and German steel industries and the difficulties of penetrating the heavily protected continental markets of America and mainland Europe (see for example Arthur Dorman's comments in the Annual Reports of 1892, 1897 and 1900), it is not surprising that the firm was Empire orientated. These, after all, would be the most accessible markets, with colonial customers often British themselves being predisposed to British firms. This is not to say that there was an absence of competition; this came from other British firms and, as Dorman was only too well aware, from Germany and America. His view expressed at the shareholders' meeting in 1897 was that 'there is a very good opening [in the colonial markets], and unless we take immediate advantage of it, others will, and we will be ousted from these markets.'[615] This comment was aimed particularly at the firm's developing interests in Australia and South Africa, where Dorman Long, saw the greatest potential for establishing profitable outlets, and to where most of its overseas efforts were directed.

Australia received the most attention. Arthur Dorman himself visited for the first time in 1891, in part to assess the potential of the Australian market. During his tour he opened negotiations with Austral Otis Elevator and Engineering, the Melbourne-based subsidiary of the pioneering American elevator company Otis, to act as Dorman Long's agent. He also entered discussions with the Sydney iron and steel merchant R.L. Scrutton. These were concluded in early 1892, with agreements that Austral Otis would stock and supply joists and girders to Victoria and South Australia, and Scrutton would provide the same for New South Wales.[616] The trade appeared to prosper at first ('trade in Australia has developed in a very satisfactory manner', *Annual Report* 1892), but following the 1893 Australian banking crisis and subsequent recession, the business suffered considerably for some years. Arthur Dorman returned to Australia in 1897 to review and restructure the operations there – it was part of a longer tour and business trip that took in South Africa – and the board gave him the freedom to take action 'as he may consider desirable.'[617] The board minutes do not record the details of the report he gave on his return, but the upshot of the his visit was that the company ended the arrangement with Austral Otis and decided to set up its own yard in Melbourne to supply South Australia and Tasmania. Land was leased from Austral Otis, a Mr Timmins was appointed to manage the yard and given a budget of £1,000 for improvements to the equipment. The agreement with the Sydney agents (Scrutton) was renewed.[618]

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[615] DLAR 1897.
[616] DLDM vol. 1, 1 July 1891, pp. 67-8; 6 April 1892, pp. 89-91; 6 May 1892, pp. 92-3; DLAR 1892.
[617] DLDM vol. 1 10 Nov. 1897, pp. 210-13.
[618] DLDM vol. 1, 26 July 1898, pp. 232-4; 30 Aug. 1898, pp. 255-8.

Over the next few years the Melbourne stockyard was extended; additional land was leased from Austral Otis in 1900, and there was a further investment of £2,100 in capital equipment. However, by the following year the business was again in trouble as result of a further recession in the Australian economy. The board discussed disposing of the yard, but in the end decided to dispatch J.H. Wright, who was later to become assistant secretary to the company, to Melbourne to report on ‘the position and prospects of the business in Australia.’[619] Wright’s report must have been very optimistic since later in 1902 more land was leased at the Melbourne site and the services offered to customers were extended, including the addition of a bridge shop so that the company could offer not only joists and girders but also constructional services. The short-term outlook, however, remained poor, with the annual reports of 1903, 1904 and 1905 all reporting that the Australian business was either making a loss or ‘not prospering’. This time the recession was explained by the effects of a severe drought. But in spite of these short-term setbacks, Dorman Long persisted with their Australian operations and by 1906 the Melbourne yard was reported to be ‘paying its way’ and both the Australian and South African businesses were ‘sending good orders home.’[620]

As well as demonstrating long-term commitment to its investments, and even expanding them in difficult times, Dorman Long also responded to the effects of the recession in the traditional short-term way by seeking to limit competition and stabilise prices. At the board meeting of January 1905 the directors discussed the Melbourne business, with Arthur Dorman explaining the nature of the competitive pressures on the firm.[621] The outcome was that Timmins, the Melbourne manager, was instructed to open negotiations with Johns and Waygood, a competing local supplier, to fix prices and divide orders.[622] There are no details of the nature of this agreement, how long it lasted, or whether it was ever implemented. Furthermore, it is not possible to tell whether the return to profit at the branch the following year was the result of a general economic recovery or the supply restraint. But the Australian operations did remain satisfactory, if not especially profitable for the remainder of the period before the War. One of the few references in the directors’ minutes to the return on the Australian business was for 1911-12. The reported profit was just £3,998, which out of a total for the company of £233,016. Nevertheless, the total profit is not the sole criterion by which to judge the contribution of the Australian yards; total sales, which maintained production in Middlesbrough, and thus kept unit

[619] DLDM vol. 2, 10 Oct. 1901, pp. 21-3; 30 Oct.1901, pp. 24-2; 9 Oct. 1901, pp. 70-2; 8 Jan. 1902, pp. 82-5.
[620] DLAR 1906.
[621] DLDM vol. 2, 11 Jan. 1905, pp. 266-8.
[622] DLDM vol. 2, 9 May 1905, pp. 278-80; 11 July 1905, pp. 284-7. Dorman Long faced considerable competition from Johns and Waygood, which acted as the Australian agent for Carnegie (see G. Blainey, *Johns and Waygood Limited: One Hundred Years, 1856-1956* (Melbourne, 1956), pp. 43-7. Although more accessible to British firms, the colonial markets were still competitive.

costs lower, was also important as was the company's very presence in the market. It helped promote the firm's profile and its sales elsewhere. Economically, as long as profits are made at the margin, then the activity makes a positive contribution to the overall enterprise. That the firm was satisfied with the performance is indicated by the fact that there were no further special discussions of the Melbourne yard or the Sydney agents by the board, except for periodic reports from the colonial businesses, until 1912 to 1913. By this time trade had expanded and once again there were plans to enlarge and improve the site at Melbourne. The planned expansion was significant, with the lease of more land, the purchase of an existing lease for £25,000 and £20,000 of capital investment in new buildings and plant and equipment.[623]

South Africa was the other main market that Dorman Long set out to develop and to which it devoted considerable time, effort and resources. And once again it was Arthur Dorman who played a central role, initiating the links and guiding the development. Interestingly, however, the first approach came from a South African based businessman, D.M. Kisch, who contacted the company with a proposal to act as an agent and stockist for steel joists and small rails in Johannesburg. Dorman met and negotiated with Kisch during 1896, presumably in London, but the decision was put off until the end of the following year when it was agreed that Dorman should travel to South Africa to make the necessary arrangements for a stockyard.[624] His trip in the first half of 1898 did not result in the appointment of Kisch but of E. Searle and Co in Port Elizabeth. This firm was to act as agent for the whole of South Africa, except the Cape and Western Province. The distributor for these other areas is not known.[625]

War interrupted expansion in South Africa and in 1899 the company reported that there were no stocks held in the country. However, by 1902 there were again prospects for developing the trade. This time plans were made to extend the company's 'direct business' rather than supply through agents, and it was decided to send one or more staff 'with a view to taking initiatory measures'. J.H. Wright, who had previously been sent to Australia to improve the Melbourne yard, went in September 1902 to compile a report for the board, and was followed by Arthur Dorman the next month, empowered to make whatever arrangements were in the firm's interests.[626] By January 1903 a new organisation had been set up, this time in Cape Town, and a general manager, Ernest Petersen appointed.[627] He also acted as chief engineer and contracting

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623 DLDM vol. 3, 6 May 1913, pp. 239-41; 7 Oct. 1913, pp. 249-51.
624 DLDM vol. 1, 1 July 1896, pp. 179-81; 6 Aug. 1896, pp. 183-4; 11 Dec 1896, pp. 191-2; 8 Dec 1897, pp. 215-7.
625 DLDM vol. 1, 26 July 1898, pp. 232-4.
626 DLDM vol. 2, 5 Aug 1902, pp. 117-20.
627 Three branches may have established in South Africa at this time – in Cape Town, Johannesburg and one other. Source: telephone interview on 7 Feb. 2011 with W. Pearce, director of Wade Building Services, formerly Charles Wade and Co Ltd and the company journal, *Wade News*, Centenary Issue, 38

agent, and was later joined by John Shore, who was sent by the company to replace Wright.[628] These arrangements did not last long; in October Petersen was dismissed and replaced by Shore. At about the same time the company began to consider a working relationship in Natal with a Birmingham-based construction company, Charles Wade and Co, which already had a base in Johannesburg and was supplying Dorman Long steel in competition with the Dorman Long branch. The negotiations continued through until 1905, with details left as usual to Arthur Dorman, but short of noting that the companies had a 'working arrangement' they are not recorded in the board minutes. Whatever they were, Dorman Long continued to develop its South African business, setting up a subsidiary company – Dorman Long and Co (South Africa) Limited – to replace the branch in 1906 and then investigating, under Dorman's direction, the potential for a stockyard in 1908.[629] Ever the inventive businessman with an eye for cost savings and reducing competition, rather than buy their own premises, Dorman decided to form a closer link with Wade to form a joint venture. A new company of Wade, Dorman and Co was formed in early 1909 to take over Wade's Durban business and stockyard and the Johannesburg branch, with ownership shared equally between the two companies.[630] It clearly took some time for Dorman Long to find a formula for developing the South Africa market, but as with Australia, the firm persisted, eventually finding a satisfactory way of organising its interests there. Early reports to the board record that Herbert Wade, the South Africa manager was sending back 'good export orders.'[631]

7.5 The Rudiments of a Strategy

It is tempting to see Dorman Long's growth as part of the late-nineteenth merger wave that marked the beginnings of large corporations in Britain.[632] But as Payne points out, apart from the amalgamation of some steel firms with armaments businesses (Vickers and Maxim, Armstrong and Whitworth, and John Brown, Cammell and Laird), there were relatively few steel-only mergers of any size in the industry.[633] A notable exception was Guest, Keen and Nettlefold. Dorman Long's expansion was not, therefore, part of a sector-wide movement

(1971) p. 3. Wade was already a major user and distributor for Dorman Long construction products in the Birmingham area.

628 DLDM vol. 2, 7 Jan. 1903, pp. 153-7; 4 Feb, 1903, pp. 160-2. Wright returned to Middlesbrough take up his position as the assistant secretary to the company.

629 DLDM vol. 2, 5 Oct. 1904, pp. 254-6; 11 July 1905, pp. 284-7; 8 Aug. 1905, p. 292; vol. 3, 7 Aug. 1906, pp. 22-4; 11 Sept. 1906, pp. 25-7; 18 Nov. 1906, pp. 31-5.

630 DLDL vol. 3, 17 Jan. 1908, pp. 103-4; 12 Jan. 1909, pp. 112-4; 9 Feb. 1909, pp. 115-7; 8 June 1909, pp.126-7; 12 July 1909, pp.160-2.

631 DLDM vol. 3, 12 July 1910, pp. 160-2.

632 See Payne, 'Large scale companies', pp. 527-32; Macrosty, *Trusts*, pp. 6-23; L. Hannah, *The Rise of the Corporate Economy* (London, 1976), pp. 21-6 and Appendix 1.

633 Payne, 'Large-scale companies', p. 53.

towards the creation of giant businesses, as occurred in textiles and brewing, but was much more specific to the region and the firm. For Boswell, the explanation lies mainly in the personal influence of Arthur Dorman, whom he regards as a risk-taker and an optimist, 'a formidable embodiment of late-Victorian and Edwardian enterprise', all attributes that explain Dorman's 'growthmanship'.[634] But the firm's expansion was more than growth for growth's sake, and although at times it appears piecemeal, with the firm (and Dorman) taking advantage of opportunities as they arose, it is possible to identify an underlying logic and to discern the rudiments of a strategy. There were five elements to this. The main aim was to increase the size of the business, but this was in conjunction with other closely related moves that supported expansion: vertically integrating operations; diversifying production; investing in new plant and technological developments; and creating organisational and marketing structures to manage a large scale business.

There can be little doubt that the acquisitions of the 1898 to 1904 period set Dorman Long on its growth path. But in fact the plan was even more expansionary than the takeover of Bell Brothers, NESCo and some smaller companies might suggest. The intention seems to have been to absorb into ownership, and thus gain control of, a substantial proportion of the Cleveland industry. Two failed large takeover attempts, in addition to the two successful ones, indicate the extent of the company's expansionist ambitions.

The first failed bid was in 1899 for Samuelson's, which operated a large blast furnace plant, the Newport ironworks, adjacent to the Britannia works. There are no indications of this bid in the directors' minutes of either company, but a Barclays Bank Directors' Committee discussed a possible application by Arthur Dorman for a loan of £300,000 for 18 months (at the Bank Rate) to finance the takeover. The initial approach came through the bank's Darlington branch and the decision was left to 'the Lombard Street directors with Mr Backhouse (the Darlington director) to settle', with the condition that the loan should be granted only if the security offered was satisfactory.[635] As there are no further references to Dorman's loan application or the takeover, it is not certain whether the failure to acquire the firm at this stage was the result of the loan being turned down or a decision by Samuelson's, a family-owned firm and effectively a private limited company, to reject Dorman's advances. It was a merger that would have benefitted both firms and should be regarded as something of a missed opportunity.

[634] J.S. Boswell, *Business Policies in the Making: Three Steel Companies Compared* (London, 1983), p. 36.

[635] Committee Book No. 1, Jan. 5, 1899, p. 178, BBA 38/593. The Darlington branch was the Northern regional office of Barclays after the 1896 amalgamations and had been the main office of the Darlington-based private bank J. Backhouse and Co. Backhouse had been Dorman Long's bank at least since incorporation in 1889.

A second, more adventurous, takeover proposal was for Bolckow Vaughan. This was a considerably larger company, with total assets valued at £4.1 million compared to Dorman Long's £1.2 million.[636] Once again, there is no indication of the plan in the board minutes, but a letter from Barclay's Darlington director, Jonathan E. Backhouse, to the chairman, Francis Bevan, in November 1901 provides some of the basic details.[637] Backhouse noted that the plan was to unite four companies – Dorman Long, Bell Brothers, NESCo and Bolckow Vaughan – with Arthur Dorman and Hugh Bell leading the group. Dorman and Bell had already built up a significant shareholding in Bolckow Vaughan and between them were proposing to buy £½ million additional shares with their own funds. To gain a controlling interest, however, they needed a further £½ million of shares which they proposed to finance by borrowing from Barclays – a six- to 12-month loan at ½ per cent above the Bank Rate, with a 4 per cent minimum. This had clearly been discussed with Backhouse, who forwarded the proposal to London with his enthusiastic support: 'I strongly recommend this ask to the favourable decision of the Board, great interest is…involved, and the Syndicate is of tremendous influence and…represents the most money and the best talent in the Iron Trade'. As in the bid for Samuelson's, it is not clear why this one failed. It was certainly unsolicited and from Bolckow Vaughan's point of view, a hostile one. As Backhouse put in his letter to Bevan, to avoid local publicity the £1 million of additional shares that were to be bought would be registered in London names. It may have been that Bolckow and Vaughan's directors were able to put up some kind of defence against the bid or to deter Dorman and Bell in some way. But the most likely explanation is that Barclays was unwilling to supply the funds. This is indicated by the secrecy surrounding the bid and especially by Barclay's unwillingness to accept Bolckow Vaughan's shares as security, even when the value of the shares offered was twice that of the loan. As the Barclay's committee minutes record: 'We should not in any case wish shares in Bolckow Vaughan & Co to be placed in our names and that we should wish to know the names of the persons who would be liable for the amount.'[638]

Arthur Dorman's ambitions may have provided the impetus behind these bids, and the company's expansion in general, but the involvement of Hugh Bell and comments by Backhouse in his letter to Bevan indicate that company amalgamations were clearly under discussion in the Cleveland industry at the time. As Backhouse stated at the opening of his letter, 'concentration and combination ideas in the Cleveland district are brought to the fore by a wealthy syndicate, headed by Arthur Dorman… one of our most important and wealthiest clients.' However, in addition to whatever concerns there were in the industry as a whole, there

636 BVAR 1901, DLAR 1901.
637 Copy of a letter from J.E.Backhouse to Bevan, 21 Nov. 1901, BS.DL/7/3/1/1.
638 Committee Book No. 2, Nov. 28 1901, pp. 157-8; Dec 5, 1901, p. 161-2, BBA 38/594.

are a number of possible underlying motives for Dorman Long's takeover bids. One is that they were defensive moves in reaction to the creation of South Durham Steel from four smaller iron and steel firms by Christopher Furness in order to supply his Hartlepool-based shipyards. Another is that the mergers were attempts to control production and hence reduce competition in an industry where long-term agreements to restrict supply and stabilise prices had proved to be unsustainable. This interpretation contrasts with Payne's contention that because of the 'absence of statutory provisions for dealing with monopoly problems', as existed in the US, there was little incentive for British iron and steel firms to amalgamate. They could rely on widespread inter-firm agreements and temporary cooperation to achieve the same end. But as Wengenroth points out, these cartel-type agreements frequently collapsed, and this instability may have been another prompt to mergers in Cleveland as firms sought a surer way of limiting competition.[639] Perhaps most of all, Dorman's expansionist tendencies demonstrated that he was acutely aware of the challenges from American and German competitors. As he stated in the 1900 annual report, although the order books were full that year, 'any fresh business, owing to American competition, will have to be taken at very much lower prices'.[640] Dorman Long's growth therefore was more than just increasing the scale of the business and dominating as much of the Cleveland industry as possible through a series of apparently haphazard takeovers. It was an expansion designed to reduce costs and maintain the firm's market position. This was the logic underlying the second strand of the firm's growth strategy, vertically integrating production by acquiring iron smelting firms that also had substantial iron ore and coal interests.

It is clear that Bell Brothers fits this explanation as does the attempt to takeover Samuelson's. Indeed, Samuelson's made more sense than Bell's; the Newport works were next door to the Britannia steelworks, thus making the supply of molten iron feasible, and the company produced both hematite and Cleveland pig which Dorman Long could use in acid and basic open hearth furnaces respectively. In the event, despite the failure of the initial bid, over time the interests of the two works and firms became more closely intertwined, first with short-term and then long-term agreements, for supplying iron. Later, in 1912, Francis Samuleson, Samuelson's chairman and managing director, joined the Dorman Long board, and eventually there was a full takeover in 1917.[641] Bell Brothers works was less well placed, being on the opposite side of the Tees. But with the development of the Clarence steelworks, leased and managed by Dorman Long, Bell's effectively operated as the steelmaker's iron-producing department. To some extent even the attempted Bolckow Vaughan acquisition can be seen as

[639] Wengenroth, *Enterprise*, p. 271; Hargrave, Thesis.
[640] DLAR 1900, pp. 6-7.
[641] DLAR 1911, p. 7; DLDM, vol. 3, 3 Mar. 1912, p. 206.

part of the same strategy; it offered considerable iron ore and coal resources and an enormous blast furnace capacity.

For Dorman Long, a specialist steel producer that relied on buying-in its iron and coal supplies, this backward vertical integration was important on two grounds. First it gave the security of supply for the main inputs, insulating it from market fluctuations and reducing the transaction costs of negotiating supply agreements. Second, as Dorman Long shifted towards producing basic open hearth steel at both the Britannia and Clarence sites, substantial cost reductions could be obtained by supplying molten iron directly from the blast furnaces to the mixers and subsequently to the steel furnaces. Acquiring blast furnace plant was one way of ensuring and coordinating this supply.

The company's vertical integration also took the form of a movement into downstream intermediate and final products. This is probably best seen as part of the diversification process, and makes up the third strand of Dorman Long's strategy. It extended the product range beyond the staples of ship plate, angles and girders into wire, iron and steel sheets and the development of a wide ranging collection of construction and bridge building services. Expansion in this direction was not entirely by acquisitions; it was more the result of internal growth through capital investment, especially on the construction side. The aims were: to enabled the spreading of risks by creating a diversified iron and steel company; to make use of the basic output of the firm – bulk steel; and to exploit the complementarities between the products. The last was most evident in the construction business, where the objective was to offer customers a broad product range, reducing the need to source different products from different suppliers. In short, there was an understanding, though not explicitly stated, of the benefits of economies of scope.

The Bell Brothers merger can also be seen as making a contribution to diversification. Not all iron producing capacity of the Port Clarence blast furnaces was, or could be, used to supply the steel plant. A substantial proportion was forge and foundry iron that could be produced very competitively in Cleveland and had a ready market both at home and as exports. Bell Brothers' coal interests also served a similar dual purpose, not only supplying the Dorman Long companies' iron and steel production, but also acting as a separate business that was profitable in its own right. Indeed, in the period from 1896 to 1902 most of Bell Brothers' profits came from their coal sales rather than from iron production.[642] Even the NESCo takeover contributed to process of diversification, although it is more difficult to place in the Dorman Long strategy.

[642] Of the £1.08 million cumulative profits between 1896 and 1902, 25 per cent came from pig iron (author's calculations from BBA and BBAR, 1896-1902).

The company provided Dorman Long with a basic Bessemer plant to complement its basic open hearth production, and gave it a way into the rail market.

The fourth element of the strategy was technological. First and foremost Dorman Long's expansion would not have been possible without an ability to produce good quality steel in bulk. Central to this was the switch from iron to acid open hearth steel for the expanding ship plate market in the mid-1880s followed by the experimentation with, and adoption of, the basic open hearth process.[643] This latter move broke Cleveland's dependence on imported ore for the manufacture of mild steel by releasing the constraint on the use of Cleveland pig in steel production. Up to that time Cleveland pig had been confined to the basic Bessemer process and had a fairly limited market, mainly for rails. The effect was to enable exploitation of the district's natural advantages of low quality, but cheaply produced, basic pig iron to be used to manufacture steel that was suitable for most markets. That this was a deliberate long-term strategy is shown by the company's persistence with trials in the basic open hearth process from the first experiments in 1891 to successful production in 1905-6 when the technical problems had been finally resolved. For the latter part of the period this involved some sacrifice of profits, especially in 1904 and 1905 when the plant was not fully operational. The link with Bell Brothers can also be seen as a way of buying-in expertise in basic open hearth methods, and of acquiring the necessary plant. Initially, this was to allow experimental and developmental work on the process to be carried out at the Clarence steelworks while the Britannia furnaces maintained their profitable production of acid steel. Later, after the new steelworks had been built at Clarence, the Britannia works could be changed over to the new process and the company's steel production maintained.[644]

The commitment to introducing new technology went beyond the basic process, and in a number of other areas Dorman Long was comparatively early to adopt new equipment and machinery, often following advances on the continent and in America. Much of the influence may have been due to Arthur Dorman, whom Boswell describes as an 'enthusiast for technological progress'.[645] On numerous occasions, Dorman justified to shareholders investment in new technology, such as in 1900 when he stated in the annual report: 'It is necessary constantly to discard old machinery in favour of more modern appliances, what is new today is often obsolete and out of date tomorrow… our eyes are open to the superior mechanical contrivances of other countries, it only remains for our engineers and managers to

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[643] See Chapter 6, section 6.4.
[644] Teething problems actually meant that both works were not fully operational until 1906, see Chapter 6.
[645] Boswell, *Business Policies*, p. 42.

apply them.'[646] One example, electrification, is sufficient to illustrate the firm's interest in new technology.

In a series of four papers in the *JISI* between 1894 and 1910, Selby-Bigge, an electrical engineer from Newcastle, was repeatedly critical of the slow adoption of electrical plant by British iron and steel manufacturers.[647] Writing in 1907 he commented that 'with few exceptions, far greater attention has been given to this subject (electrification) on the Continent than in this country, and it is undoubtedly high time that engineers in Great Britain fully realised this fact, and having studied the subject more closely, acted on the results of their investigation.'[648] He does note, however, that there were some exceptions and 'pioneers'; the two he identified were Dorman Long and Bell Brothers. The first electrical installations at Dorman Long were in the Britannia works' girder shops in 1894 where electric motors replaced steam, hydraulic or pneumatic drives for machinery such as saws, straighteners, punching machines and overhead travellers.[649] The electricity was generated by the firm's own power station. Selby-Bigge, who given his contacts with Dorman Long, may well have had a significant influence on the electrification of the works, estimated a cost saving of this early equipment of 30 tons of coal per week.[650] Over the next few years the use of electrical appliances was extended across the plant to include cranes, lifting gear and live rollers used to transport steel between the different rolling mills. Bell Brothers also introduced electrical equipment in the late 1890s, again including live rollers for the mills.

The use of electric motors to drive rolling mills was introduced in the industry at a rather later date. Even in Germany, as Daelen reported in 1902, electricity was used mainly for the ancillary machinery.[651] It was employed first in light rolling such as in wire-drawing, and Dorman Long operated one of the earliest electrical mills in Britain at the Cleveland Wireworks. This plant had been built between 1894 and 1895 by the Bedson Wire Company but taken over by Arthur Dorman in1896 (as R.P. Dorman and Co) and two years later became part of the

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646 DLAR 1900. See also DLAR 1907: 'A company such as ours to keep in the front rank must always be spending money, must go ahead, and must have the latest and most up-to-date machinery and appliances, so as to be able to make profits in good times and bad times…' (p. 12).

647 D. Selby-Bigge, 'Electricity as a motive power in the iron and steel industries', *JISI*, 25 (1894), pp. 252-73; 'The application of electric power in the iron and steel industries', *JISI*, 33 (1902), pp. 220-48; 'The development of electricity in the iron and steel industries', *JISI*, 38 (1907), pp. 57-81; 'Development in the production of electric power', *JISI*, 41 (1910), pp. 60-102.

648 Selby-Bigge, 'Development of electricity', pp. 61-2.

649 DLDM vol. 1, 5 Dec. 1894, 152-3; DLAR 1894; Selby-Bigge, 'Motive power', pp. 256, 272; *JISI* 32 (1901), p. 475.

650 Selby-Bigge, 'Electricity as a motive power' p 256. Selby-Bigge worked closely with Dorman Long and used research at the company for his 1894 and 1902 papers.

651 Daelen, R.M. 'Progress in steelworks in Germany since 1880', *JISI*, 33 (1902), p. 55.

Dorman Long.[652] For heavy duty primary rolling in reversing mills (cogging mills and roughing mills) it was not until 1906-7 that a satisfactory electric motor (based on the Ilgner system) had been developed in Austria.[653] Once again Dorman Long was early to install the new technology, first converting two mills at the West Marsh site and later installing two new ones at Britannia. By 1912, after some initial problems, the firm had four electric mills in operation, one reversible cogging mill, one roughing mill and two finishing mills.[654] This is not to say that other Cleveland firms, or iron and steel firms elsewhere, did not electrify their works. In fact, by 1900 many of the larger works on Teesside had their own plant powered by waste steam from blast furnaces or gas from steel furnaces to generate electricity for lighting and to power other equipment. For example, by 1908 Bolckow Vaughan generated its own electricity, and rather earlier, in 1902, Selby-Bigge reported that two engineering companies, Richardson Westgarth (Hartlepool) and Head Wrightson (Stockton) had installed electric motors to replace steam engines. And following the successful use of electric motors in reversible mills, Henry Crowe commented at an *ISI* discussion that there was considerable interest in Cleveland, with the new steelworks being built at Skinningrove considering an electric mill.[655] However, it remains the case that Dorman Long was among the earliest of the British firms to introduce electrical equipment, and this was despite an unsettled dispute in the industry over the reliability and cost advantages of electric mills over their steam driven counterparts. The influential rolling mill engineer and designer, Lamberton, was sceptical, and in 1911 there were even reports that some German mills were reverting to steam.[656] A measure of British steelmasters' scepticism, or as Selby-Bigge put it 'apathy…and lack of enterprise', is shown by a comparison of the electric rolling mill capacity installed in Britain and on the Continent between 1907 and 1910. Citing figures from two of the main electrical manufacturers, Selby-Bigge states that while 605,000 bhp was installed on the continent, just 20,000 bhp in Britain, just one-thirtieth of the capacity.[657] In its attitude to technological strategy, therefore, it appears that Dorman Long was closer to its European and American competitors than some of its British ones.

Lastly, in the fifth strand of the strategy, developing the managerial and sales aspects of the organisation, the company was also making changes along the American lines, although there is no evidence of any direct influence. In comparison with later advances management organisation, Dorman Long's were very basic, but they did demonstrate an understanding of the

[652] See above.
[653] This was at the Hildegarde Works near Teschen, Selby-Bigge, 'Development of electricity', pp. 86-7.
[654] *JISI* 39 (1908), p. 449; *JISI* 40 (1909), p. 443; *ICTR*, 2 Oct. 1908, p. 1454; *ICTR*, 29 Mar. 1912, pp. 483-4. There are also references to the problems in DLDM and DLAR.
[655] 'Visits to Works: Bolckow Vaughan' *JISI*, 39(1908), p. 444; Selby-Bigge, 'Application of electric power', pp. 228-31; Henry Crowe, *JISI* 39 (1908), pp. 130-1.
[656] Lamberton, *JISI*, 39 (1908), pp. 128-9; Carr and Taplin, *History of British Steel*, pp. 26-7.
[657] Selby-Bigge, 'Production of electric power', pp. 96-7.

importance of coordinating the different parts of the firm and having the information to do this. Thus the main Dorman Long board received regular reports from various parts of the firm and its subsidiaries to help monitoring and a management committee of the managing directors of the three constituent firms was set up. This was responsible for the overall coordination and strategy of the business and shows that while the companies maintained their independence in a nominal sense, they were effectively part of the Dorman Long 'Group'. On the sales and marketing side, there was an effort to exercise increasing control over distribution and move closer to customers. The firm established branches and stock yards both at home and abroad in order to reduce the dependence on the traditional mode of distribution through agents. It was a policy that was associated closely with the development of the firm as a supplier of constructional steel and construction services.

Taken together, these five features indicate a marked strategic element behind Dorman Long's expansion. This was not a strategy in the modern business sense of a precise vision of the position of the company at some time in the future that would be realised by the implementation of a carefully formulated plan. It was more a case of an identifiable general aim, not necessarily very clearly specified, and a discernible consistency in the steps taken to achieve it. Not all the steps were mapped out in advance – some may have developed in response to changing circumstances – but in retrospect they can be seen as complementary. For Dorman Long the broad objectives were to grow, remain competitive and profitable, and this was supported by acquisitions, investment in new plant and technology, and the marketing and organisational changes that the firm made to manage the growing size and scope of its business. It may be the business and economic historians' vice to see a strategy when what is actually being observed is a business success resulting from chance, when a firm's right (or wrong) past decisions later enable it to take advantage of favourable changes in external circumstances. There was an element of this for Dorman Long; for example the failure of the bid for Bolckow Vaughan may have had unanticipated beneficial effects. Had it been successful the company may have grown too quickly, and there must be some doubt as to whether the necessary managerial changes would have been made. Indeed, a possible outcome is that it would have remained a separate business operating along the lines of US Steel, where the parent company 'did little more that form an office to help set the price and production schedules for the many almost completely autonomous divisions.'[658]

Nevertheless, in spite of the qualifications, there were a sufficient number of deliberate policy decisions and long-term commitments to conclude that Dorman Long was managed with a

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[658] Chandler, *Strategy and Structure*, p. 40.

degree of strategic foresight. It was more than just chance, therefore, that the company was in a reasonably strong position to take advantage of a buoyant iron and steel market in the years immediately up to 1914, and to weather depressed periods without making losses, apart from during the obviously difficult years of 1903 to 1905. Profits rose for much of the period after incorporation, and from 1900 exceeded £100,000 in nine out of fifteen years. After talking account of the highly cyclical nature of the industry, profits on average increased fourfold compared to Bolckow Vaughan and Consett, whose profits doubled (Figure 7.4, Table 7.7). Much of this reflected the increasing size of the company and when measured by indicators of financial performance, Dorman Long's profitability was considerably more modest (Table 7.7, Figure 7.5). The 6.8 per cent return on capital employed was broadly in line with other firms on Teesside, e.g. 6.6 per cent for Bolckow Vaughan, and well below the 20.8 per cent for Consett, acknowledged to be one of the most profitable iron and steel companies at the time.[659] Consequently, Consett was able to pay a dividend for ordinary shareholders of 28.6 per cent. By contrast, Dorman Long's shareholders received a dividend rate of 6.1 per cent on average, which was marginally higher than that for Bolckow Vaughan (5.6 per cent) but barely above the rate on debentures (4 to 6 per cent). With a coefficient of variation for the dividend payments of 63 per cent and two years without any (1904 and 1905), the returns were clearly inadequate compensation for the additional risks to share- over bond holders. It is not surprising that the firm relied on issues of debt to finance its expansion rather than new issues of shares.[660] On the other hand, the difference in the dividend yield was far less marked, suggesting that stock markets were pricing the shares reasonably efficiently.

[659] Richardson and Bass, 'Profitability of Consett'.

[660] The increase in shares issued in 1902 and 1903 were to pay for the acquisition of Bell Brothers and NESCo. See Chapter 5.

Table 7.7: Comparative Financial Performance, 1890-1914

Profit (after interest) £	Dorman Long	Bolckow Vaughan	Consett
1890-4	38,403	140,067	207,096
1895-9	45,238	109,744	250,182
1900-4	63,025	255,130	405,812
1905-9	103,116	341,334	332,814
1910-4	169,289	279,315	395,369
Mean	83,814	225,118	318,255

Return on Capital Employed (per cent)[a]	Dorman Long	Bolckow Vaughan	Consett
1890-4	7.4	3.7	19.5
1895-9	7.4	7.2	21.9
1900-4	5.7	7.5	22.2
1905-9	5.2	8.0	18.5
1910-4	8.5	6.4	21.9
Mean	6.8	6.6	20.8

Dividend Rate on Ordinary Shares (per cent)	Dorman Long	Bolckow Vaughan	Consett
1890-4	6.6	3.2	20.3
1895-9	5.8	5.2	19.1
1900-4	6.7	6.5	36.0
1905-9	4.6	6.4	29.2
1910-4	6.9	6.6	38.2
Mean	6.1	5.6	28.6
Coefficient of variation[b]	63%	38%	45%

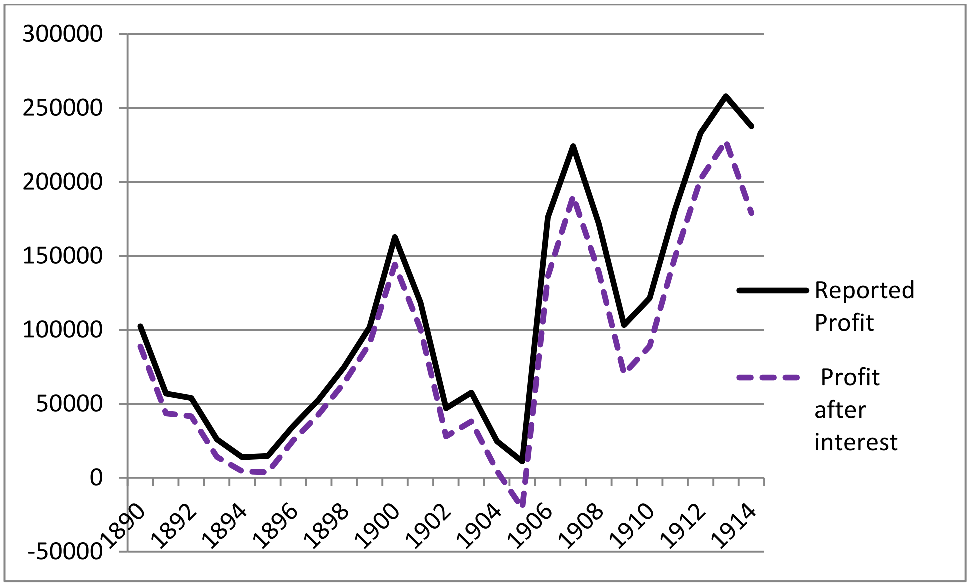
Dividend yield (per cent)	Dorman Long	Bolckow Vaughan	Consett
1890-4	--	4.9	5.8
1895-9	--	5.9	5.2
1900-4	3.2	5.8	8.0
1905-9	5.2	6.0	6.3
1910-4	7.3	6.5	8.2
Mean	5.2	5.8	6.7

Notes:
a:capital employed is defined as shareholders' funds plus total long-term liabilities. b: the coefficient of variation is the ratio of the standard deviation to the mean.

Sources:

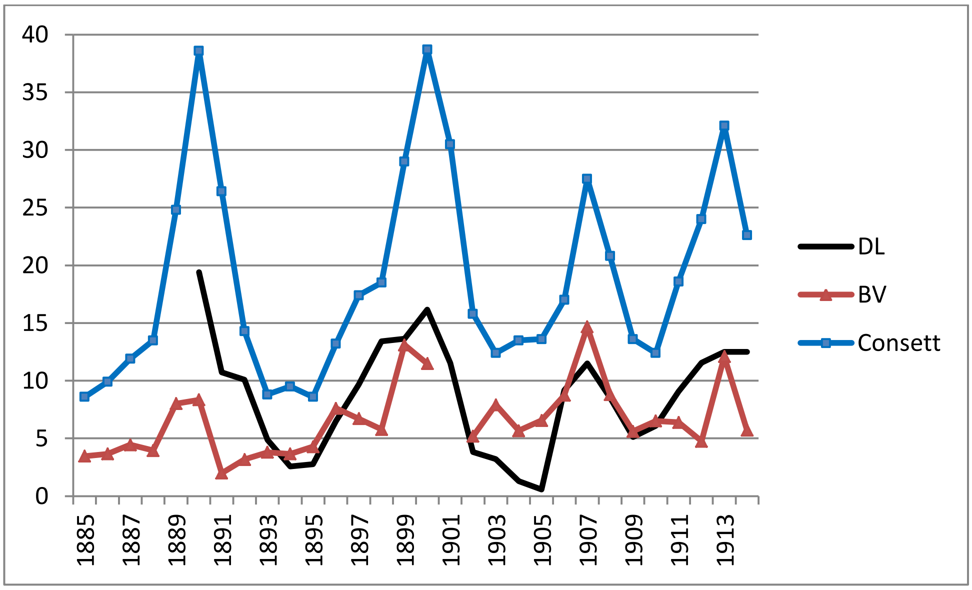
1. Data for Dorman Long and Bolckow Vaughan are derived from the companies' annual reports and directors' minutes - DLAR, 1890-1914, DLDM, 1890-1914; BVAR, 1890-1914, BVDM, 1890-1914.
2. Dividend yields are calculated on the share price at the time of the dividend announcement and publication of the annual report. Share prices for Dorman Long are recorded in the directors' minutes; they were not listed on the London Stock Exchange before 1900. For Bolckow Vaughan, the share price is taken from *The Investors Monthly Manual*, (1890-1914) available at: http://icf.som.yale.edu/imm/index.shtml
3. Consett data are taken from Richardson and Bass, 'Profitability of Consett', pp. 91-2.

Figure 7.4: Dorman Long Profits, 1890-1914 (£)



Sources: DLAR, 1890-1914.

Figure 7.5: Return on Capital Employed, 1885-1914 (per cent p.a.)



Sources: Dorman Long – DLAR, 1890-1914; Bolckow Vaughan – BVAR 1885-1914; Consett – Richardson and Bass, 'Profitability of Consett', pp. 91-2.

7.6 Conclusion

This close examination of Dorman Long has shown that there was a degree of strategic design behind the firm's expansion. The conclusion that British firms at the end of the nineteenth century lacked a strategic outlook or failed to adapt to technical or organisational changes is not the case for all firms. Dorman Long successfully converted from a specialist puddling and iron rolling firm to a steelmaker and then to a vertically integrated and diversified steel company. This was achieved largely, though not exclusively, through a series of takeovers, which for a relatively late entrant to Teesside's industry was the most feasible route for growth. Since most of the critical resources – iron ore, coal and a riverside production site – were already under the ownership of existing firms, the almost exclusively internal growth path pursued by Bolckow Vaughan and Consett was not open. There was, nevertheless, an important internal growth element, with Dorman Long diversifying output, developing a distribution network and, perhaps most of all, adopting new technology as soon as practicable, notably acid open hearth in the 1880s and basic open hearth process in the 1900s. The firm also took some rudimentary steps to manage a large and diverse group of businesses, controlling them through the Dorman Long board and the management committee of the group's managing directors.

The process, however, was not fully carried through and this left a legacy of separate plants in different locations across Teesside. While potential problems were disguised for a time by the War and the boom immediately afterwards, the failure to integrate and modernise its production, or to develop further the managerial and organisational structures, meant that Dorman Long found it difficult to deal with the deteriorating economic conditions during the 1920s.[661] In short, the company made a promising start to the transition to a large corporation, but failed to capitalise on this early advantage.

[661] Tolliday, *Business, Banking and Politics*, pp. 52-64.

Chapter 8: Conclusions

This study had two broad aims. The first was to examine and assess the contribution of business networks to the initial development and early growth of the iron and steel industry in Cleveland. The second was to investigate the transition of the industry from the 1870s to determine how effectively the district's firms responded to significant changes in technology, international competition, corporate legislation and financial markets. Thus it was intended that the thesis would add to an understanding of the growth of an industry and industrial district, and also of the way in which prosperity can be sustained in the face of changing circumstances. In addition, by looking at a crucial sector of Britain's economy at a critical time the study would provide if not a new perspective, then more evidence in the debate over Britain's industrial decline that has been seen by many historians as rooted in the late Victorian and Edwardian period.[662]

The conclusions can be summarised as follows. Firstly, the operation of business networks was important for the early development of the Cleveland iron cluster, providing the means of marshalling resources and stimulating the entry or formation of new businesses in the industry. Secondly, the district made the transition from iron to steel successfully despite difficult domestic resource and market conditions, and an international environment in which trade protection by, and the rate of expansion in, the US and Germany put British producers at a considerable disadvantage. Thirdly, in the process of adaptation, Cleveland firms made use of developments in financial markets and changes in corporate legislation to finance and expand successful businesses. Fourthly, the evidence from some of Cleveland's largest firms shows that far from being technologically backward, slow to look to new markets or to introduce organisational changes, they made both rational and entrepreneurial decisions as and when conditions permitted.

In Part 1, analysis both from theoretical (Chapter 2) and empirical (Chapter 3) perspectives show that business networks do play a role in the growth and industrial clustering process. Research on the origins and connections between firms entering Cleveland from 1850 reveal, unsurprisingly, that many were already linked to the industry, either regionally or nationally. Many of the other, later entrants also had pre-existing connections to the developing industrial district. The main finding, however, is that at the beginnings of the industry a disproportionate number of firms and entrepreneurs were connected to the Quaker family and business network centred on the Darlington-based Pease and Backhouse interests. Moreover, these firms were

[662] N.F.R. Crafts 'Victorian Britain did fail' *EcHR*, 32 (1979), pp. 533-7.

more likely to survive for a longer period. Consequently, this group made a significant contribution to the growth of the industry in its first ten to twenty years.[663]

It is not suggested that the impact of the Quaker network and the high proportion of Quaker-linked firms was due directly to the application of Quaker attributes or outlook to the conduct of business.[664] The reasons for its influence are twofold. First, as Kirby, Orde and Cookson have all noted in connection with the S&DR, the family networks were extensive, close and cohesive.[665] The nature of the group was such that Quaker families were not only keen to find Quaker husbands and wives for their daughters and sons, but to set up the sons in occupations or business, and where possible supply the finance.[666] The developing Cleveland iron industry provided opportunities for those with business and engineering talent and as a result there were a significant number of ironmasters with Quaker origins – Isaac Wilson, William and Thomas Whitwell, Edgar Gilkes, William Leatham, Jeremiah and Charles Head, J.B. Pease and Edward Crewdson were all partners in iron firms. However, the family-cum-religious links between firms is not a full explanation.

There is a more convincing reason: there had to be an incentive for the Pease-Backhouse interests to encourage inward investment and the development of the district. This arose from their own investments in existing local businesses, notably the transport system, mines, property in Middlesbrough and banking services. All of these stood to gain from the development of an iron industry. It was then by using the family and religious connections that this Quaker network successfully attracted and supported the entry of firms into the industry. Moreover, new entrants did not just replicate plant at the same stage of production; they added to the development of the district by downstream processing of pig iron and diversification into closely related activities.

At a more general level, the Cleveland example suggests there are a number of conditions that have to be met at the beginning of the growth and clustering process. First, there has to be some locational advantages to start development. Second, there needs to be a means through which

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[663] This is reminiscent of the Quaker dominance of the iron industry in the eighteenth century when most of the iron works were 'interconnected by a complex series of partnerships and marriages.' C.K. Hyde, *Technological Change and the British iron Industry, 1700-1870* (Princeton, 1977), p. 16.
[664] For a discussion of Quaker business qualities see J. Walvin, *The Quakers: Money and Morals* (London, 1997), pp. 207-10.
[665] Kirby notes with reference to the Quakers network and the S&DR, 'its unusual cohesion and extensive family linkages, well-illustrated in the case of the Backhouses and Peases, render it the most impressive of external networks conducive to the formation and subsequent growth of the firm'. Kirby, *Origins*, 1993, p. 53.
[666] Walvin comments on Joseph Crosfield's soap business: 'Business was a preoccupation secured by, among other things, fruitful family links from one generation to another.' Walvin, *Quakers*, pp. 114-5.

new firms are attracted to the industry in order to generate expansion. This is provided by business networks, the connections between entrepreneurs that transmit information about potentially profitable investments, and which also coordinate and supply the necessary resources. The third condition is for the presence of an incentive to localise industry and thus concentrate development in the district. One possible explanation arises from the ownership of the local infrastructure. For physical capital such as railways and ports, there is a powerful incentive for investors in these assets to stimulate increased usage – with high fixed costs, unit costs fall and profits rise as they are used more intensively. For other services such as banking and shipping, increased development raises demand, creating opportunities for business expansion. The effects are also cumulative, resulting not only from the benefits of clustering that stem from agglomeration economies, an expanding network and a growing institutional infrastructure (see Figure 2.3) ; there are also incentives to improve the physical infrastructure (e.g. railways), thus further adding to the advantages of the district.

This interpretation lends support to the 'history matters' view of regional economic development. Arthur, David and Rosenbloom, and Krugman have all shown that historical events, even small ones, can have major and lasting impacts on the location of firms and the development industrial districts.[667] A small accident of history that places the initial site of an industry in a particular town may over time have a cumulative effect leading to the town becoming a centre of a specialist industrial cluster. It may be that originally the location was almost a random event, perhaps one of several equally appropriate places, the product of the preferences of workers, or of entrepreneurs over where to set up in business. As industry develops in this location, it acquires the benefits of agglomeration, advantages that grow as the industry grows. What this suggests is that even at the outset the development of an industry is not necessarily determined by 'natural' geographical or geological factors. The incentives facing, and choices made by, entrepreneurs setting up the first businesses in the industry are crucial, and subsequent expansion is influenced by the networks to which they are connected. Cleveland is perhaps an example of this process, though at first sight not an obvious one.

The emphasis that has been placed on networks contrasts with the impersonal market mechanism view of standard economic theory in which economic agents react to price signals. But it can be argued that the two approaches are complementary. Markets work in a social context, decisions have to be taken by, and actions co-ordinated between, people. Recognising networks as the channel through which signals are sent, especially where organised and well-

[667] B. Arthur, 'Competing technologies, increasing returns, and lock-in by historical events', *Economic Journal*, 99 (1989), pp. 167-83; P.A. David and J.L. Rosenbloom, 'Marshallian factor market externalities', pp. 349-370; P. Krugman, *Geography*.

developed markets do not exist, adds detail and richness to the analysis, and helps to uncover causal links that may not otherwise be identified. On the other hand, the contribution of networks should not be overstated. The setting in which they have been used in this study is one of industrial expansion. They provided the means through which expansion could occur, but without underlying incentives – an underutilised infrastructure and a strong demand for the product – there would have been no development. In general the findings and interpretation in this study are largely consistent with the results of the cases in Wilson and Popp's *Industrial Clusters*. These studies stressed the importance of networks to the initial development of industrial clusters, especially in underdeveloped regions, as Teesside was in the 1850s, with religion and family ties providing 'supportive social structures to the creating of effective business structures'.[668] Wilson and Popp, following Casson, also suggest that leadership is crucial, and in Cleveland's case this was provided by Joseph Pease from the Quaker side, and by industrialists such as Lowthian Bell, Henry Bolckow and Isaac Wilson.[669]

While the absence of networks may hamper development, their presence does not guarantee good business or economic performance. Entrepreneurs also have to take advantage of, or indeed make, opportunities. It may be that in new industries or industrialising districts this is more likely than in established ones, where networks may become sclerotic and used to defend the interests of existing businesses, e.g. by enforcing cartel agreements or other anti-competitive practices, rather than as means for economic growth or renewal. An example is the Manchester cotton industry in the early part of the twentieth century.[670] Overall, therefore, the existence of a business network is a necessary condition for economic growth, but it is not in itself sufficient; there is no substitute for the quality of enterprise. Networks may function well, but entrepreneurs still have to respond to the signals.

The second part of the thesis suggests that Cleveland's iron- and steel-masters did respond appropriately, at least in a number of important cases, when there were signs by the mid-1870s that the district's iron-based prosperity was flagging and at risk of petering out. Yasumoto has recently argued that 'it [Middlesbrough] experienced the full life cycle of an industrial district over these years [1850 to 1880]'.[671] But the evidence indicates that by adapting to the shifting external conditions, in the time up to 1914 Cleveland was able to maintain its position as one of Britain's principal iron and steel producing districts.

[668] Wilson and Popp, *Industrial Clusters*, p. 277; see also in the same volume Cookson, 'Quaker networks', and S. Caunce, 'Banks, communities and manufacturing in West Yorkshire Textiles, c. 1800-1830' in Wilson and Popp, *Industrial Clusters*, pp. 112-29; and Prior and Kirby, 'The Society of Friends'.
[669] Wilson and Popp, *Industrial Clusters*, p. 278; Casson, 'Regional business networks', pp. 31-2.
[670] J.F. Wilson and J. Singleton, 'The Manchester industrial district, 1750-1939: clustering, networking and performance', in Wilson and Popp (eds.), *Industrial Clusters*, pp. 60-5.
[671] Yasumoto, *Victorian Ironopolis*, p. 188.

The key to the industry's continued prosperity was for the manufactured iron producers to make a transition to steel by adopting the new developments in bulk steel production technology. A number of Teesside firms, though by no means all, did respond, and even though the spectacular growth of the early years was not repeated, something that would have been highly unlikely in a mature industry, the changeover prevented the industry entering an inexorable and terminal decline, or at the very least contracting to settle at a lower level.

If, as has been claimed, there was a relatively slow take up of new steel technology compared to the US and Germany, then there were often sound market and technical reasons. First, a boom in demand for iron ship-plate as the iron rail market declined did delay the introduction of the acid open hearth process, but the switchover was rapid once it became apparent in the mid-1880s that shipbuilders preferred steel. Second, Bessemer steel was never accepted in the high quality (mild) steel market that became so important to British producers. Third, although two Cleveland firms pioneered the basic Bessemer process, the technical problems of using Cleveland pig left them at a cost disadvantage and prevented the spread of the technology both in Cleveland and Britain. Fourth, market resistance to basic steel of any description, the success of acid open hearth steel, and the technical problems of using Cleveland's moderately high phosphorus pig iron in the basic open hearth furnace may also have slowed the introduction of the process that eventually came to dominate the industry – the basic open hearth. Nevertheless, there is ample evidence of widespread interest in the method across the British industry. Trials started in the early 1880s and technical information was exchanged between firms through the meetings and publications of the industry's technical institutions and in the trade's newspaper (*ICTR*). There were personal contacts with and visits to producers in the US and continental Europe, and some exchange of technical staff. In Cleveland experiments using the basic open hearth started from the late 1880s and the process was adopted from 1900, both clear signs that at least some producers were aware of its potential and understood the implications for the district. One, Dorman Long, stands out as willing to take the risk of making an early commitment. On the evidence it would be difficult to conclude that Cleveland's firms, and perhaps Britain's industry, were neglectful of basic open hearth steel. It has not been possible to judge whether the optimum technological choices were made, but as a general point, comparisons with US and German industry on which previous assessments of relative performance were based have not always taken account of local circumstances.[672] Firms in all three countries faced very different resource and market conditions that affected the selection of technology and the timing of its introduction.

[672] E.g. Abé, 'Technological strategy'. For an exception, see McCloskey, *Economic Maturity*, p. 125

A feature of this later period is the emergence of a more corporate-style economy in which large firms began to replace the family-firm based capitalism that characterised the early stages of development. The change was made possible by the free availability of corporate status, which Cleveland firms used flexibly and in a variety of ways. Large corporate businesses were slow to appear, however. For many the primary motivation for converting to a joint stock company was to obtain the protection of limited liability whilst at the same time enabling the original partners or their families to retain ownership and control. An important implication of the predominance of what were essentially private limited companies is that access to the capital market for investment funds was clearly not a prime motivation for conversion. Indeed, like incorporation, the capital markets were also used flexibly, as the examples of Bolckow Vaughan and Dorman Long indicate. In the case of Bolckow Vaughan the ability to issue equity and debt meant that the firm was able to balance three demands on the business: the desire of the original partners to capitalise their business assets with high dividend payments to shareholders, including themselves, and the need for funds to finance capital investment. In terms of the type of capital issued, the two detailed examples show that in line with national trends, there was an increasing use of debt securities. As well as reflecting investor preferences for stable returns, there were also benefits to the companies. It gave firms the ability to raise low costs funds, to manage liabilities through the retirement debt when profits were high and may also have reflected a desire not to dilute control or spread dividend payments more thinly. Moreover, the ease with which both Bolckow Vaughan and Dorman Long were able to raise finance through new issues indicates that investment does not appear to have been constrained by a general shortage of funds.

By about 1900 large incorporated enterprises began to dominate, and the industry in Cleveland became increasingly concentrated. Bolckow Vaughan, already a large vertically integrated company at the time of its incorporation in 1865, was joined by Dorman Long and the South Durham-Cargo Fleet group; but unlike Bolckow Vaughan, which grew internally, Dorman Long and South Durham expanded principally by a series of mergers and takeovers. It was developments in the securities markets that facilitated the increasing concentration in the sector, operating through mechanisms such as issuing debentures to raise cash to finance acquisitions, exchanging shares or issuing new shares to exchange for those of the acquired company. Thus the importance of financial market developments lay not just in whether they eased restrictions on the supply of finance for capital investment, but also in providing a means through which successful firms could expand. In short, they formed the basis for the growth of large corporations.

Running alongside the growth in corporate enterprise and finance, other features of Cleveland's industry that can be identified are the beginnings of corporate strategy and of a more managerial style of capitalism. This is demonstrated by the case study of Dorman Long. Outwardly, the firm was made up of three separate and independently managed companies linked only by ownership; but this is misleading. Although only nascent, the parent company established mechanisms to coordinate the management and strategy of the three firms. This operated through interlocking membership of the boards and by setting up a committee of managing directors to oversee operations and make crucial decisions. There was also the regular collection and monitoring of information on the three businesses by the Dorman Long board. And although founding families often dominated boards and held senior management positions, there was an increasing reliance on professional managers and technical experts brought in from outside or promoted through the firm (e.g. Panton and Mosscrop at Dorman Long and Benjamin Talbot at South Durham-Cargo Fleet). Along with the organisational changes, Dorman Long itself adopted identifiable strategies: towards marketing by controlling distribution and getting close to customers; by diversifying the product range; and through the acquisition of assets to support the shift from acid to basic open hearth steel. Although these developments were more rudimentary than contemporary moves in US business, and the later shifts Britain, they do mark the beginnings of the evolution of a more corporate form of business, and were perhaps more advanced than is sometimes assumed.[673]

Lastly, the moves towards a corporate economy brought changes to the nature of the networks operating in the industry. The connections that linked iron- and steel-masters who had interests in different businesses remained, but by the end of the nineteenth century they had evolved. This was partly the result of the decline in the relative importance of the Quaker business interests, but perhaps more important was the effect of incorporation, which shifted the linkages from a series of overlapping partnerships in a number of family-owned firms to interlocking directorships.[674] And as consolidation and concentration of the industry into fewer firms progressed, the external networks were eventually replaced by ones internal to companies, comprising departments, distribution branches and subsidiaries. The external networks that became increasingly important were the industry associations and, as suggested in Chapter 6, the professional organisations of technical experts through which advances in technology were transmitted. In terms of Toms and Filatotchev's general framework in which network characteristics and their effects on economic performance shift as the underlying resource base

[673] A.D. Chandler, 'The emergence of managerial capitalism', *BHR*, 58 (1984), pp. 473-503; T. Gourvish, 'British business and the transition to a corporate economy: entrepreneurship and management structures', *BH*, 29 (1987), pp. 18-45.
[674] For example, from the late 1880s Dorman Long, NESCo and Head Wrightson had interlocking boards.

and dependence of an industry changes, Cleveland at this time does not seem to fit the model especially well.[675] Or, at least, the match is not as close at that with the Lancashire cotton industry, where the growing self-reliance of firms and interlocking directorships resulted in opaque networks. The consequences were reduced accountability and thus weaker incentives to make the investments needed to ensure the longer-term health and survival of the industry.[676] The move to larger, integrated firms in Cleveland did reduce resource dependence, and with control often vested in family members, it would appear that there was limited transparency and accountability to external stakeholders, especially shareholders. Nevertheless, the industry made the transition to steel and a more corporate form of enterprise, and significantly, it was in the most successful firms where the family presence on the board was greatest – i.e. at Dorman Long and South Durham-Cargo Fleet.[677] The crucial element therefore seems to be the quality of the entrepreneurial decisions made, particularly by Arthur Dorman at Dorman Long and Christopher Furness and Benjamin Talbot at South Durham-Cargo Fleet. In short, performance and the ability to adapt to changing external circumstances may owe more to factors specific to an industry at a particular time than they do to the structure of ownership and control.

The Cleveland iron and steel industry and industrial district did not pass through the full life cycle in a single generation after 1850. The transition to steel was successfully completed in three main stages as the more forward-looking firms adopted new processes when technological and market conditions allowed. There is also evidence that entrepreneurial vitality persisted, with the most successful steelmasters building their businesses into large corporate enterprises. Consequently it is difficult to conclude that Cleveland's, and thus Britain's, iron and steel industry was backward as a whole and in decline before 1914, although there were underlying weaknesses that would be revealed in the 1920s after the post-war boom evaporated. The results, along with the approach, of this thesis complement those of McCloskey and Wengenroth, who similarly concluded that there was little indication of entrepreneurial failure. McCloskey inferred his claim that 'late nineteenth-century entrepreneurs in iron and steel did not fail…in fact they did very well indeed' from estimates of US and British productivity, to which this study adds direct and detailed evidence from the investigations into the development of the basic open hearth process and the decision-making in major Cleveland iron and steel

[675] Toms and Filatotchev, 'Networks', pp. 71-6; Toms and Filatotchev, 'Corporate governance', pp. 634-7.

[676] Toms and Filatotchev, 'Networks', pp. 76-89; Toms and Filatotchev, 'Corporate governance', pp. 637-46; Wilson and Popp, *Industrial Clusters*, pp. 279-80; S. Toms, 'Oldham capitalism and the rise of the Lancashire textile industry', The York Management School Working Paper No. 30, (York, 2007), pp. 20-6.

[677] This is not to say that family domination of the Dorman Long board did not impede later adjustments. See Tolliday, *Business, Banking and Politics*, pp. 52-64.

companies.[678] The work also extends Wengenroth's research into the development of the acid open hearth process, pioneered in Scotland in the 1880s, to the basic open hearth process that made such an impact in Cleveland from the 1890s.[679]

As for the industrial district on Teesside, other industries emerged out of iron and steel. These were in the closely-related engineering and shipbuilding sectors, but also included gas production, electricity generation and chemicals, all of which developed from the by-products of iron and steel firms. The study of the development of these industries would add a further dimension to an understanding of how the life cycle of industrial districts is maintained.

[678] McCloskey, *Economic Maturity*, pp. 73-4, 124-5, 127.
[679] Wengenroth, *Enterprise*.

Appendices

Appendix 1: Iron and Steel and Engineering Firms on Teesside

The firms in this appendix provide the data for Chapters 3 and 4.

<u>Abbreviations</u>
n.a.: information not available

<u>Sector (col. 2)</u>
IS: iron smelting (blast furnace plant).
IP: iron and steel processing (puddling and rolling mills).
IF: iron forge and foundry.
IM: manufactured iron products (e.g. fire grates, fish plates).
II: integrated or multi-product works (blast furnaces and processing).
NFM: non-ferrous metals.
I (n.a.): information not available.
E: engineering.
Sh: shipbuilding

<u>Outcome (col. 4)</u>
B: proprietor or partners bankrupt.
D: partnership dissolved.
M: merger.
N: nationalised.
L: liquidation.
S: works (or part of) sold.
T: takeover.

<u>Sources (col. 6)</u>
AWJ: Aberdeen Weekly Journal.
BDP: Birmingham Daily Post.
CITB: Teesside Archives' Card Index of Teesside Businesses.
CJSDA: Cleveland Journal and South Durham Advertiser.
ICTR: Iron and Coal Trades Review.
IME: Institution of Mechanical Engineers Proceedings.
JISI: Journal of the Iron and Steel Institute
LG: London Gazette.
LM: Leeds Mercury.
LpM: Liverpool Mercury.
MT: Manchester Times.
NC: Newcastle Courant.
NE: Northern Echo.
NEG: North-Eastern Daily Gazette.
TCCMJ: Teesside Chamber of Commerce Monthly Journal.
YH: York Herald.

Firm	Sector	Est. on Teesside	Date of closure, take-over or merger	Incorp-orated	BT 31 Reference and other sources
Acklam Iron Co Ltd.	I (n.a.)	1888	1893	1888	BT31/4215/27281. *YH*, 2 Jul. and 4 Oct. 1888; *NEG*, 7 Aug. 1888.
Allan and Co Ltd.	IF	1880	1936 M	1889	BT31/4314/28030; 112507/99524. CITB.
Anderston Foundry Co Ltd.	IM	1874	1962 L		BT31: n.a. Hargrave thesis.
Archer, John	I (n.a.)	c. 1880	1896		CITB.
Armstrong, William, and Co.	IF/NFM	c. 1880	1898		CITB.
Ashmore and White (Later Ashmore, Benson, Pease and Co Ltd.).	IP/E	1871	1885 T		TA: u/cc/4/6; Sowler, *Stockton*; *NE*, 31 Mar. 1885; CITB.
Ashmore, Benson, Pease and Co Ltd.	E	1885	1901 T	1885	TA: u/cc/4/6; Sowler, *Stockton*; *NE*, 31 Mar. 1885; LM, 27 April 1885; CITB.
Atlas Foundry Ltd.	IF	1904	1907	n.a.	CITB.
Avery, W. and T. Ltd.	I (n.a.)	1891	1906	1891	BT31/5022/33668. CITB.
Aydon, A.H.	n.a.	c. 1885	1939		CITB.

Bacon , William, and Co.	IP	By 1873	1876 B		Burdett and & Hood, *Directory 1873; NE*, 3 Feb. 1876.
Bagnall, C. and T. (Grosmont Ironworks Co Ltd.)	IS	1860	1891 L	1860	BT31/511/2033. *LM*, 15 Aug. 1864; *NE*, 1 Nov 1879; 20 Jul. 1891; Harrison, 'Pig iron', p. 67.
Barningham Brothers	IF	1850	1856 L		*Ward's Directory, 1851*; Jeans, *Pioneers*, pp. 178-90.
Bastow, Samuel	IF/E	1846	1867 L	1865	*The Examiner*, 17 June 1865; *Daily News*, 10 Aug. 1866; *Daily News*, 28 Aug. 1867; *Leeds Mercury*, 20 Aug. 1869; *Northern Echo*, 24 Mar. 1870; *Birmingham Daily Post*, 26 April 1871; CITB.
Bedford and Leach	IM	By 1873	n.a.		Burdett and & Hood, *Directory 1873*.
Bedson Wire Company Ltd.	IM	1892	c. 1896 T	1892	BT31/5389/37078. Dorman Long, *Works*, p. 12.
Bell Brothers.	IS	1844	1899 T	1873	BT31/1916/7855. Dorman Long, Works, pp. 39-61; *ICTR*, 2 Oct. 1908; BS.BB.
Blackett, Hutton and Co Ltd.	IF/E	1862	1947	n.a.	BT31: n.a. CITB
Blair and Co Ltd.	E	1865	1931 L	1865	BT31/1184/2603C. *Industries of Stockton, 1890*, p. 24; CITB.
Bland Bros. Ltd.	I (n.a.)	By 1896	n.a.	1902	BT31/9642/71669. CITB.
Bolckow Vaughan and Co Ltd.	II	1840	1928 T	1865	BT31/30734/1705C. Jeans, *Pioneers*, pp. 47-66, 67-83; BS.BV.
Bolsover Bros Ltd.	E	1903	1917	1903	BT31/16976/76454; CITB.

Bower, George	IF	1876	c. 1896	1876	CITB.
Bowesfield Iron Co Ltd.	IP	1870	c. 1890	1870 and 1871	BT31/1565/5088; 1643/5670. Burdett and & Hood, *Directory 1871*, *1873*; *Industries of Stockton, 1890*, pp. 34; Jeans, *Pioneers*, pp. 94-116; Harrison, 'Malleable iron', p. 136; *NE*, 9 Sept. 1890 .
Bowesfield Steel Co Ltd.	IP	1896	1912 T	1896	BT31/31448/48431. BS.BOW.
Britannia Iron Works Co Ltd.	IP	1870	1876 L	1870/1872	BT31/1551/4982; 1753/6529. *NE*, 15 Dec. 1870; *BDP*, 11 April 1871, 7 Dec 1872; Burdett and & Hood, *Directory 1873.*
British Chilled Roll and Engineering Co Ltd.	IP	1907	1937 T	1907	*TCCMJ*, July 1930; correspondence with Frances MacLennan, see note 135; CITB.
British Metal Expansion Co Ltd.	IP/E	1889	n.a.	1889	BT31/4527/29609. CITB.
Brown Bros.	E	c. 1884	1911-12		CITB.
Brown, Andrew, and Co. (Later James Brown and Sons Ltd.)	NFM	1860	After 1930	n.a	*White's Directory of the North Riding, 1867*; *Industries of Middlesbrough*, *1890*, p. 40; *TCCMJ*, July 1930; CITB.
Brown, Francis Ltd.	E	1903	Still open in 1976		CITB.
Brown, George and Brothers Ltd. (Originally Andrew Brown.)	IF/E	1800	1970	n.a.	*White's Directory* 1847; *Northern Echo*, 7 May 1879; *TCCMJ*, July 1930; CITB.
Brown, James and Sons Ltd.	NFM	1860	After 1930	n.a.	BT31: n.a. CITB.

Bulmer, W., later The Patent Brick Machine Company	E	1865	n.a.	1903	BT31/10434/78621. Burdett and & Hood, *Directory 1871*; *Industries of Middlesbrough, 1890*, pp. 22-3.
Burr, F	I (n.a.)	1908	c. 1912		CITB.
Cargo Fleet Iron Co Ltd.	IS	1883	1900 T	1883	BT31/42890/17822; 42891/17822. *White's Directory, 1885*-6; Willis, *South Durham*, p.4; CITB.
Cargo Fleet Iron Co Ltd.	IS	1901	1928 T	1900/1904	BT31/42890/17822; 42891/17822. Willis, *South Durham*, p.4; BS.CFI; CITB.
Carling and Son	E	c. 1884	1958		CITB.
Carlton Iron Co Ltd Also known as: North of England Industrial Iron and Coal Co Ltd.	IS	1870	1921 T	1870	BT31/1538/4891(1914: 32189/136855). *NE* 19 Jan. 1877; Tuffs, *Green Hill*; CITB.
Carr House Iron Co.	IF	c. 1880	1896		CITB.
Chapman, C.W.	E	1906	1933		CITB.
Clay Lane Iron Co Ltd.	IP	1882	1899 T	1882	BT31/2929/16285. *White's Directory, 1885*-6; *GH*, 31 Oct. 1899; *NEG*, 5 Jan. 1900; CITB.
Cleveland Nut and Bolt Co.	IM	By 1870.	1876 L		Burdett and & Hood, *Directory 1871*.
Cochrane and Co	IS	1854	1960 T	1902	G.D. Cochrane, 'Notes on company history', 1953 (BS.COC – 7/1/19); Hadfield thesis; CITB.
Cochrane, Grove and Co.	IF/E	1861	1902	1894	BT31/6052/42803.

			M		G.D. Cochrane, Notes on company history, 1953 (BS.COC – 7/1/19); Hadfield thesis; CIBT.
Copeland and Co.	E	1902	c. 1917		CITB.
Copley and Co Ltd. (I. Copley & Co.)	IF/E	1873 or 1874	c. 1892-93	1873	BT31: n.a. *Industries of Middlesbrough, 1890*, pp. 20-1; CITB.
Copley, Turner and Co Ltd.	E	1892	n.a.	21892	BT31/15223/36138. CITB.
Crewdson, Hardy and Co.	IM	1873	1930s	1899	BT31: n.a. TA: u/s/1785; correspondence with Frances MacLennan, see note 135.
Crossley, Ingham and Co.	E	1884	1933		CITB.
Crosthwaite, R.W.	IM	1879	After 1930	1902	BT31: n.a. *Industries of Stockton, 1890*, pp. 27; *TCCMJ*, July 1930; CITB.
Cuthbertson and Co.	E	1908	n.a.		CITB
Dabron, R.	E	1898	1909		CITB.
Davy and United Roll Foundry Ltd	IP/E	1912	Open	1909	CITB
Dorman Long and Co Ltd.	IP	1875	1967	1889	BS.DL; Dorman Long, *Works*.
Downey and Co.	IS	1871	1893 L		Burdett and & Hood, *Directory 1871*; CITB.
Downing, N. and Sons Ltd.	IF	1875	n.a.	n.a.	CITB.

Drysdale, Kirkpatrick and Co.	IF	By 1867	n.a.		*White's Directory, 1867*.
Dun Thompson and Co.	I (n.a.)	c. 1880	c. 1896		CITB.
Egglescliffe Iron Foundry Ltd. (originally Smith and Stoker).	IF	1878	1894 L	1893	BT31/5493/38036. Wardell, *History of Head Wrightson*, (TA: U/HW/8/1).
Elliott, R. and Sons	E	1906	1911		CITB.
Elwon, Malcolm and Co. (Clay Lane Iron Co.)	IS	1855	1867 D	n.a	Harrison, 'Pig iron', p. 59; *LG*, 14 Jul. 1868; Hadfield thesis; CITB.
Elwon, T.L.	IS	1853	1853		Harrison, 'Pig iron', p. 59.
Engineering and Repairing Co Ltd.	E	1906	1907		CITB.
Engineering Supply Company Ltd.	E/IP	1889	1897 L	1889	BT31/4398/28592. *Industries of Stockton, 1890*, pp. 37-9; Wardell, *History of Head Wrightson*, (TA: U/HW/8/1).
Erimus Iron Co Ltd.	IP	1873	1879 L	1872	BT31/1722/6294. Burdett and & Hood, *Directory 1873*;
Eston Grange Iron Co.	IS	1874	1876 B		*NE*, 23 Sept. 1874; 3 Feb. 1876; *AWJ*, 22 Sept 1879.
Evans, J.	E	1898	1906		CITB.
Ferryhill Iron Co (James Morrison) Later Rosedale and Ferryhill Coal and Iron Co Ltd.	IS	1859	1879 L	1864	BT31/968/1374. Jeans, *Pioneers* CITB.

Firth and Hodgson (Glaisdale Smelting Co. or South Cleveland Iron Co.)	IS	By 1863 at latest	By 1868 L		*White's Directory of the North Riding, 1867*; Harrison, 'Pig iron', pp. 67-8; CITB
Flintoft, A.N.	IF	By 1867	n.a.		*White's Directory, 1867*.
Fossick and Hackworth	E	1839	1865 T		*White's Directory, 1847*; CITB.
Fox, Head and Co	IP	1863	1888 D		Burdett and & Hood, *Directory 1871; Directory 1873*; Jeans, *Pioneers*, pp. 268-81; 'Obituary', *JISI*, (1899), pp. 263-4; CITB.
Gilkes, Wilson and Co.	E	1844	1865 M		Jeans, *Pioneers*, pp. 84-93, 117-27; Kirby, *Men of Business*; CITB.
Gilkes, Wilson, Leatham and Co	IS	1852	1879 L		Jeans, *Pioneers*, pp. 84-93, 117-27; Kirby, *Men of Business*; CITB.
Gilkes, Wilson, Pease and Co.	IS	1858	1881		Jeans, *Pioneers*, pp. 84-93, 117-27; Kirby, *Men of* Business; Industries *of Middlesbrough*, *1890*, pp. 14-15; CITB.
Gjers Mills and Co	IS	1870	1965	n.a.	BT31: n.a. *Industries of Middlesbrough*, *1890*, pp.14-15; Harrison, John K., *John Gjers* CITB.
Glaisdale Iron Co Ltd (also known as George Wilson and Co).	IS	1868	1871 L	1870	BT31:1708/4709.
Gray, Wm. and Co.	Sh/E	1883	n.a. M		Grace's Guide; CITB.
Hall, Robert	IF/E	By 1847	n.a.	n.a.	*White's Directory, 1847*; CITB.

Hanson, R.	E	1910	1921	n.a.	CITB
Hardy, J. and Son	E	c. 1884	n.a.		CITB.
Hardy, J.J. and Sons	E	By 1896	n.a.		CITB
Harker and Sons (Engineers) Ltd	E	1856	After 1976 T	n.a.	CITB.
Harker, Alfred	E	1898	By 1920		CITB.
Harker, Francis Todd	E	1878	c. 1932?		CITB.
Harris, Short and Co.		1867	1880?		CITB
Hartlepool Iron Co./Hartlepool Rolling Mill Co.	IP	1864	n.a		BT 31/932/1180c, 1276/3186. Richmond, *Local Records.*
Head Wrightson and Co Ltd.	IP/E	1866	1975 T	1890	BT31: n.a. Wardell, *History of Head Wrightson*, (TA:U/HW/8/1); *TCCMJ*, July 1930; CITB.
Head, Ashby and Co.	E	1859	1866		Wardell, *History of Head Wrightson*, (TA:U/HW/8/1); *TCCMJ*, July 1930; CITB.
Hill, J. and Co.	IP	By 1888	1910		*Industries of Middlesbrough, 1890*, pp. 24-5; CITB.
Hill, Richard, and Co Ltd. (originally Hill and Ward).	IM	1868	1955 T	1891	BT31/5208/35277. *Industries of Middlesbrough, 1890*, p. 25; CITB.
Hind, E. (South Bank) Ltd.		1897	n.a.	1912	BT31/20474/120289. CITB.

Hjerleid and Spence	IM/E	c. 1871	By 1881		Burdett and & Hood, *Directory 1871*; CITB.
Holdsworth, Bennington, Byers and Co Ltd.	IS	1856	1864	n.a.	Harrison, 'Pig iron', p. 63; Harrison, 'Malleable iron', pp. 131, 135, 136; CITB.
Holdsworth, J. and Co.	IP	1866	1882 T		*Engineer*, 19 Oct. 1866; Harrison, 'Malleable iron', pp. 131, 135, 136; CITB.
Holdsworth, John, and Co Ltd.	IP	1880	n.a.	n.a.	CITB.
Hopkins, Gilkes & Co.	IP/E	1861	1865 M		Lillie, *Middlesbrough* p. 99; Jeans, *Pioneers*, pp. 117-27, 149-63; Tighe, *Teesside Bridge*; CITB.
Hopkins, Gilkes and Co Ltd.	II/E	1865	1879 L	1865	BT31: n.a. *MT*, 21 Jan. 1865; *NE*, 15 May 1879, 19 Dec. 1879; Jeans, *Pioneers*, pp. 117-27, 149-63; *IME*, 1893, pp. 346-7; Tighe, *Teesside Bridge*; CITB.
Horne, C. and Co.	E	1910	c. 1980	n.a.	CITB.
Howcroft Carriage and Engineering Co.	E	1900	n.a.		CITB.
Imeson Finch and Co Ltd.	E	1908	n.a.	1908	BT31/12357/97639. CITB.
Irvine and Co Ltd.	E	1896	1898	1896	BT31/7047/49640 CITB.
Jackson, Gill and Co (Ltd.).	IM	1870	c. 1879	1872	BT31/1786/6633 Burdett and & Hood, *Directory 1871*; CITB.

James Butler (or Smithson and Butler)	IP	1879	1887 B		*LM*, 19 Jul. 1879; *NE*, 24 Oct. 1879.
James Ritchie	IM	c. 1880	After 1890		*Industries of Middlesbrough, 1890*, pp. 21.
Jaques, R. & Co Also referred to as R. Jaques and Son	IP	1871	1875 B		*JISI* (1872); *BDP*, 30 Dec 1872; *NE*, 20 Sept. 1875.
Jones Bros and Co Ltd.	IP	1870	1898 T	1874/ 1881	BT3/1977/8438; 2782/15189. Burdett and & Hood, *Directory 1871* , *1873*; CITB.
Jones, Dunning and Co	IS	1859	1890 T		Burdett and & Hood, *Directory 1871*; *White's Directory, 1885-6* CITB.
Joy and Co (David Joy)	IP/E	1862	n.a.		Armstrong, *Industrial Resources*, pp. 103, 113.
Lackenby Iron Co.	IS	1871	1876 T		Burdett and & Hood, *Directory* 1873; CITB.
Lee, J.	E	1902	1906		CITB.
Linthorpe-Dinsdale Smelting Co Ltd.	IS	c. 1900	1931 L	1903	BT31/16997/76930. Pallister, A., *Middleton St George*, p. 159.
Lishman & Leng	IM	1866	1872 T		*Industries of Stockton*, *1890*, pp. 37-9; Wardell, *History of Head Wrightson*, (TA: U/HW/8/1).
Livingston, John	NFM	By 1871	n.a.		Burdett and & Hood, *Directory 1871*; White's *Directory of Yorkshire, 1885-6*.
Lloyd and Co (sometimes known as Hopkins, Lloyd and Co.)	IS	1864	1879		*White's Directory of the North Riding, 1867;* Burdett and & Hood, *Directory 1871*; Harrison, 'Pig iron', pp. 84-5.

Loftus Iron Co Ltd.	IS	1872	1878 L	1872	BT31/1730/6354. Burdett and & Hood, *Directory 1873*; *NC*, 15 Nov. 1878; Willis, *South Durham Steel*.
Long Hill Foundry	IP/E	1902	1908		CITB.
Lumley Steel Co.	n.a.	1904	c. 1910		CITB.
Mainwaring, John and Co.	IM	By 1847	1879 T		*White's Directory, 1847*; John Wardell, *History of Head Wrightson*, (TA: U/HW/8/1); CITB.
Malthouse, William, later Robert Hunter Malthouse	IF/E	By 1847	n.a.		*White's Directory, 1847*; *Ward's Directory, 1851*.
McDonald and Bulman (later McDonald and Co).	IF	1870 at latest	1904		Burdett and & Hood, *Directory 1871*; *Porter's Directory, 1881; White's Directory, 1885*-6; CITB.
Meredith Bros Ltd.	IF	c. 1896	c. 1910		CITB.
Middlesbrough Galvanizing Co.	IM	1880	n.a.		CITB.
Middlesbrough Nut and Bolt Works (Watteau, E.)	IM	By 1873	n.a.		Burdett and & Hood, *Directory 1873*; *White's Directory, 1885*-6.
Middlesbrough Wrought Nail Co Ltd.	IM	1872	n.a.	1872	BT31/1720/6273. Burdett and & Hood, *Directory 1873*.
Milton Forge and Engineering Co Ltd.	IF/E	1898	By 1912	1899	BT31/8379/60098. CITB.
Moor Steel and Iron Co. (originally Shaw, Johnson and Reay).	IP	1885	1898 T	1885	BT31/3480/21116. *LpM*, 11 May 1885; Harrison, 'Malleable iron', p. 136;

Morrison, J.	E	1913	1922		CITB.
Mudd, P.A. and Co.	E	1906	1922		CITB.
Muir, J and Co Ltd.	IF	1896	c. 1900	1886	BT31/3886./22745. CITB.
Normanby Iron Works Co Ltd.	IS	1895/ 1900	c. 1912 L	1895	BT31/6432/45380; 16438/66673. *NE*, 23 Jul 1900.
Norrie, J.	IF/NFM	By 1867	After 1881		*White's Directory*, *1867*; *Porter's Directory, 1881*.
North Eastern Steel Co Ltd.	IP	1881	1923 T (1904)	1881	BT31/ 0960/15639. BS.NESC; CITB.
North Yorkshire Iron Co Ltd.	IP	1869	1873 L	1869	BT31/1470/4465. Jeans, *Pioneers*, p. 106; CITB.
Northern Engineering and Construction Co Ltd.	E	1907	1919		BT31/18623/95550. CITB.
Norton Iron Co Ltd.	IS	1865	After 1886	1865	BT31/1145/2382C. Burdett and & Hood, *Directory 1871*; *Middlesbrough Directory* (1885-6).
Norwegian Titanic Iron Company Limited	I	1869	1876 Norton works closed.	1863	BT31/831/686C. *NE*, 12 Jan. 1870; 18 Sept. 1870.
Pettigrew, G and Co Ltd.	E	1907	n.a.	1907	n.a.
Pickerings Ltd.	E	1854	Still open		Historical documents held by the company and interview with D. Fothergill (managing director, company, 30 Mar. 2009); CITB.

Pickersgill, R. and Sons Ltd	E	1860	n.a		CITB.
Pile, Spence and Co	IP/IF/Sh	1854	1866 L	1865	*BDP*, 11 Jan. 1865; *LM*, 11 Jan 1867; Harrison, 'Malleable iron', p. 129; North, *Economic Heritage*, p. 35; CITB.
Potter, Edwin	IF	By 1867	n.a.		*White's Directory, 1867*.
Richards, W. and Sons Ltd.	I	By 1871	After 1885		Burdett and & Hood, *Directory 1871*; CITB.
Richardson, Johnson and Co.	IP	1864	1868 T		Harrison, 'Malleable iron', p. 130-1; CITB.
Richardson, T. and Co	IS/IP	1866	1875 L		CITB
Richardson, Thomas, and Sons	IS/IP/E	1837	1875 (IS/IP)-S 1900 (E)-T		Armstrong, *Industrial Resources*, p. 307; Richmond, *Local Records*; CITB.
Richmond Iron and Steel Co.	IP	c. 1900	n.a.		CITB.
Richmond Ironworks Ltd	IP	1890	c. 1896 L		BT31/4688/30866. *LM*, 28 Feb. 1890; *BDP*, 3 Mar. 1890.
Richmond Rolling Mills Co Ltd.	IP	1896	n.a.	1896	BT31/7099/50052. *NE*, 20 Nov. 1896.
Ridley, T.D and Sons	E	1898	n.a.		CITB.
Riley Bros.	E	1865	n.a	1900	BT31/9007/66622. *Industries of Stockton, 1890*, p. 17.
Robert Punch	IM	c. 1877	After 1890		*Industries of Middlesbrough, 1890*, pp. 17.

Robert Sherwood and Henry Smith	E	1841	1844 T		TA: Box 04555 - Group (Cleveland RO), Location 19/4.
Robinson, Anderson and Co.	IF/E	1842	1920		Armstrong, *Industrial Resources*, pp. 112, 114; CITB.
Robinson, R,W.	E	1900	1906		CITB.
Robinson, Stephen	IF	By 1851	n.a.		*Ward's Directory, 1851*.
Robson, Maynard and Co.	IS	1873	1881 T		*CJSDA*, 25 Sept. 1873; Burdett and & Hood, *Directory 1873*; CITB.
Roger, Robert and Co.	I/E	1847 (1844?)	1927 L	1900	BT31/16388/65753. *White's Directory*, 1847; *Industries of Stockton 1890*, p. 27; CITB.
Ross, Willis and Co.	I(n.a.)	By 1873	n.a.		Burdett and & Hood, *Directory* 1873.
Scott, G and Sons	E	c. 1884?	1933		CITB.
Seaton Carew Iron Co Ltd.	IS	1881	1928	1882	BT31/14705/16711. CITB.
Shaw, Johnson and Reay (later Johnson and Reay).	IP	1872	1882 B		*NE*, 17 May 1882; 11 Jul. 1883; Harrison, 'Malleable iron', p. 136.
Sir Bernard Samuelson and Co.	IS	1854	1917 T	1887	BT31/31076/25072. Jeans, *Pioneers*, pp. 216-34; *Industries of Middlesbrough, 1890*, pp. 25-6; BS.SBS; CITB.
Sir Christopher Furness, Westgarth and Co Ltd.	E	1896	After 1914	1896	BT31/6939/48825. *NE*, 12 Oct. 1896.

Skinningrove Iron Co Ltd.	IS	1880	1963 T	1880	BT31: n.a. BS.SKI; *NC*, 15 Nov. 1878; Willis, *Skinningrove*; CITB.
Smithers and Jeynes Ltd	E	1905	1912 L	1905	BT31/11216/85647. CITB.
Snowden, Hopkins and Co	IS	1853	1865 M		Lillie, *Middlesbrough*, p. 99; Jeans, *Pioneers*, pp. 117-27, 149-63; Tighe, *Teesside Bridge*; CITB.
South Bank Iron Co	IS	1863	1867 D		*LG*, 14 Jul. 1867; Burdett and & Hood, *Directory 1871*; Hadfield thesis, p. 380.
South Bank Iron Co Ltd.	IP	1881	1883 L	1881	BT31/2909/16198; CITB.
South Cleveland Iron Works Co Ltd.	IS	1872	1875 L	1872	BT31/1684/6003. Burdett and & Hood, *Directory 1873*; *Kelly's Directory, 1887*; Harrison, 'Pig iron', p. 67; CITB.
South Durham Steel and Iron Co Ltd.	IP	1898	1967 N	1898	BT31/42914/60098. Willis, *South Durham*; BS.SDS.
South Stockton Iron Co. (Charles Henry Skinner)	IF/E	1840	1854 T		North, *Economic Heritage*, p. 18; *White's Directory, 1847*; John Wardell, *History of Head Wrightson*, (TA:U/HW/8/1); CITB.
South Stockton Iron Company Ltd.	IP	1881	n.a.	1881	BT31/2937/16399.
Steel Casting Co Ltd.	IF	1877	n.a.	1877/ 1904	BT31/2371/11715. CITB.
Stevenson, Jacques and Co.	IS	1865	1888 L	--	*IME*, 1893, pp. 344-5; Harrison, 'Pig iron', p. 71; CITB.
Stockton Forge Co.	IM	1872	1889		Wardell, *History of Head Wrightson*, (TA: U/HW/8/1).

			L		
Stockton Iron Furnace Co Ltd.	IS	1864	1877 L	1864	BT31/1036/1750, 1036/63715. *NC*, 2 Nov. 1866; *NE*, 17 Jul. 1877; Burdett and & Hood, *Directory 1871*; CITB.
Stockton Ironworks (John Jackson)	IP	c. 1791	1844 T		*Industries of Stockton 1890*, p. 27, CITB.
Stockton Malleable Iron Co Ltd.	IP	1861	1898	1861	BT31/559/2281. ; Griffiths' *Guide*; *Industries of Stockton, 1890*, pp. 33; Harrison, 'Malleable iron', p. 130; CITB.
Stockton Rail Mill Co Ltd.	IP	1864	1874 L	1864	BT31/1036/1749C; Harrison, 'Malleable iron', p. 136, 152; CITB.
Stranton Iron and Steel Co Ltd.	IP	1871	1873 L	1871	BT31/1666/5857; *LM*, 8 Aug. 1873; 11 Dec. 1873.
Swan Coates and Co	IS	1864	1876 B		*White's Directory of the North Riding, 1867*; Burdett and & Hood, *Directory 1871*: *Industries of Middlesbrough, 1890*, pp.11-2; CITB.
Tait, J.	E	By 1874	1921		CITB.
Tait, Wright and Co.	IF	By 1867	By 1884		*White's Directory, 1867*; *White's Directory of Yorkshire* (1885-6); *Industries of Middlesbrough, 1890*, p. 21.
Teasdale Bros.	E	1900	Open in 1976		CITB.
Tees Bridge Iron Co Ltd.	IS	1870	1930 L	1871	BT31/14425/5585. Burdett and & Hood, *Directory 1871*, *Kelly's Directory 1887*; CITB.
Tees Furnace Co Ltd.	IS	1896	1924	1896	BT31/15642/48714. *NE*, 25 Jul. 1896.

Tees Nut and Bolt Co Ltd.	IM	1876	n.a.	1876	BT31/224110654.
Tees-side Iron and Engine(ering) Works Co Ltd.	IS/IP/E	1889	1895 L/T	1889	BT31/4541/29728. Tighe, *Teesside Bridge* CITB.
Telford, James	IM	By 1851	n.a.		*Ward's Directory, 1851*.
The Cast Steel Foundry Company Ltd.	IP	1887	1891 L	1887	BT31/3867/28489. *Industries of Middlesbrough, 1890*, p. 47.
The Expanded Metal Company Ltd.	IP	1892	After 1930	1892/1900	BT31/5341/36610;48431. *TCCMJ*, July 1930
The Patent Lubricating Bag Company Ltd.	R	1885	n.a.	1885	BT31/3497/21259. *Industries of Middlesbrough, 1890*, pp. 32-.
The Stockton Steel Foundry Co Ltd.	IP	1905	1927 T	1906	Wardell, *History of Head Wrightson*, (TA: U/HW/8/1).
The Tees Scoriae Brick Company Ltd.	R	c. 1874	After1890	1874	BT31: n.a. *Industries of Middlesbrough, 1890*, pp.19-20.
Thunderbolt Patent Governor Co Ltd.	E	1902	1907		BT31/10007/74769. CITB.
Turner, J. and Co.	E	1887	c. 1919		CITB.
Turner, John.	IF/E	By 1873	c. 1892		Burdett and & Hood, *Directory 1873*.
Union Foundry.	IF	1875	1928 T	n.a.	CITB.
Vaughan, T. and Co.	IS/IP	1867	1876 B		Burdett and & Hood, *Directory 1871*; *LG*, 14 Jul. 1868, 5 Sept. 1876; Harrison, 'Pig iron'; Hadfield thesis, p. 380; CITB.

W. Shaw, Kirtley and Co.	IP	1889	1892 D		*Industries of Middlesbrough, 1890*, pp. 13-4; LG, 12 Mar. 1892; CITB.
Wake and Co.	E	c. 1896	n.a.		CITB
Walker Maynard and Co.	IS	1875	1915 T	1900	BT31/9166/67934; 16534/68092. BS.DL; CITB.
Warner and Co (originally Warner, Lucas and Barrett)	IS	1855	1968 T	1900(?)	Harrison, 'Blast furnace', p. 97; North, *Economic Heritage*, p. 24; *JISI*, (1875), pp. 427-40;CITB.
Weardale Iron & Coal Co Ltd	IS/IP	1845	1899 T	1863	BT31/806/589C. Jens, *Pioneers*, Ch.1.
Weardale Steel, Coke and Coal Co Ltd.	IS/IP	1899	1947 N	1899	BT31/37193/63715. *LpM*, 3 Oct. 1896; Willis, *South Durham*; BS.SDS/1/11/1.
West Hartlepool Iron Co Ltd.		1874	n.a.	1874	BT31: 1976/8431. *NE*, 9 Jun. 1874.
West Hartlepool Steel and Iron Co. (Gray and Gladstone).	IP	c. 1881	1898 T		*NC*, 10 Aug. 1888; BS.SDS; CITB.
West Marsh Iron Co Ltd. (originally Smith and Thomson, T.J.).	IP	1867	1873	1873 L	BT31/1923/7928. Burdett and & Hood, *Directory 1871*; Dorman Long, *Works*, pp. 7-8; Harrison, 'Malleable iron', p. 136; CITB.
West Stockton Iron Co Ltd .	IP	1865	1889 L	1865	BT31/1204/2725C. *NE*, 17 Jul 1891; Harrison, 'Malleable iron', p. 136; CITB.
West, Davies and Co.	IF	1867	n.a.		*White's Directory, 1867*.

Westgarth, English & Co.	E	1881	1896 T		*NE*, 12 Nov. 1881, 12 Oct. 1896.
White, J. and Sons	IF	c. 1896	c. 1900		CITB.
Whitwell, William and Co.	IS	1859	By 1890	n.a	BT31: n.a. Thomlinson, *Thomas* Whitwell; Industries *of Stockton, 1890*, pp. 15-7; CITB.
Wilkinson (Thornaby) Ltd.	IP	1914	n.a.	n.a.	CITB.
Williams, Edward	IS	1879	n.a.		*White's Directory*, *1885*-6; CITB.
Wilson, Copley and Co.	E	1898	n.a.		CITB.
Wilson, F.C. and Co.	E	1900	1909		CITB.
Wilson, Pease and Co, Ltd.	IS/E	1881	1889 L	1881/1901	BT31/9518/70712. *Industries of Middlesbrough, 1890*, pp. 23-4; Tighe, *Teesside Bridge*.
Wood, C. Ltd.	I (n.a.)	1900	c. 1906	n.a.	CITB.
Woolley, James	IF	By 1867	n.a.		*White's Directory, 1867*.
Worth Mackenzie and Co Ltd.	E	c. 1870	1936 L	1883	BT31/3089/17826. *Industries of Stockton, 1890*, pp. 20-1; *TCCMJ*, July 1930; CITB.
Wythes, George, and Co.	IS	1864	1881 L		*JISI*, (1871, no. 2), p. iii; Pallister, A., *Middleton St George*, pp. 131, 134-5, 147.

Appendix 2: Firms used in Logistic Regression Model

Key
S5: survived more than 5 years.
S10: survived more than 10 years.
S15: survived more than1 5 years.
S80: survived after 1880.

QR: Quaker partner/investor, or from Quaker family.
QPB: partner/investor related Pease or Backhouse family.
RM: partner/investor connected with S&DR.
QF:firm financed by Quaker investor or bank.

Before: partner/investor in iron and steel before Cleveland.

Otherinv: partner/investor has interests in other Cleveland firms.

Sector variables
w: malleable iron
p: pig iron
e: engineering
d: diversified
m: other metals

Time: date established in Cleveland *less* 1850 (beginning of the iron industry in Cleveland).

Survival of Iron and & Steel and Engineering Firms, 1840-1880									
	Survival years from formation								
	S5	S10	S10x	S15	S80	QR	QPB	RM	QF
Brown, George, and Brothers (Ltd)	1	1		1	1				
Richardson, T. and Co	1		1						
Fossick and Hackworth	1	1				1		1	1
Bolckow Vaughan	1	1		1	1				1
Sherwood and Smith	1		1			1		1	
Skinner, Charles	1	1		1		1			1
Gilkes, Wilson and Co.	1	1		1		1	1	1	1
Bell Brothers	1	1		1	1				
Weardale Iron, Coal and Coke	1	1		1	1				
Samuel Bastow	1	1		1					1
Roger, Robert and Co	1	1		1	1				
Barningham Brothers	1		1					1	
Gilkes, Wilson, Leatham and Co	1	1		1		1	1	1	1
Elwon, T.L			1						
Snowden, Hopkins and Co	1	1				1		1	
Pickerings Ltd	1	1		1	1				
Lynch White	1		1						
Cochrane and Co	1	1		1	1				
Samuelson, B. and Co.	1	1		1	1				
Pile, Spence and Co	1	1							1
Elwon, Malcolm and Co (Clay Lane)	1	1							
Warner and Co	1	1		1	1	1			
Harker and Sons Ltd	1	1		1	1	1			
Holdsworth, Bennington & Byers	1		1			1			1
Head Ashby and Co	1		1			1			1
Whitwell, William and Co	1	1		1	1	1	1	1	1
Jones, Dunning and Co	1	1		1	1	1	1	1	1
Ferryhill Iron Co	1	1		1	1				
Brown, Andrew, and Co.	1	1		1	1				
Grosmont Ironworks Co (Bagnall)	1	1		1	1				
Stockton Malleable Iron Co.	1	1		1	1				
Cochrane, Grove and Co	1	1		1	1				
Blackett, Hutton and Co Ltd	1	1		1	1				
Firth and Hodgson			1						
South Bank Iron Co			1						
Fox Head and Co	1	1		1	1	1	1	1	1
Lloyd and Co	1	1				1	1	1	1
Stockton Iron Furnace Co	1	1				1			1
Richardson, Johnson and Co			1			1	1		1
Swan Coates and Co	1	1							
Stockton Rail Mill Co	1	1							
George Wythes and Co	1	1		1	1				
Hopkins, Gilkes and Co	1	1				1	1	1	1
Patent Brick Machine (Bulmer)	1	1		1	1	1		1	
Riley Brothers	1	1		1	1				
Norton Iron Co	1	1		1	1	1			
Stevenson Jacques and Co	1	1		1	1	1	1	1	1
West Stockton Iron Co	1	1		1	1				
Blair and Co Ltd	1	1		1	1			1	
Head Wrightson and Co Ltd	1	1		1	1	1			1
Holdsworth and Co (Westbourne)	1	1		1	1				
West Marsh Iron Co (Smith and			1			1			
Norrie, J.	1	1			1				
Hill, Richard, and Co. Later Ltd.	1	1		1	1				1
Glaisdale Iron (Geo Wilson)			1						
Vaughan, T. and Co	1		1						
North Yorkshire Iron Co Ltd	1		1			1	1		1
Norwegian Titanic Iron Co	1		1						
Lishman & Leng (Lustrum)	1		1						
Bowesfield Iron Co	1		1						
Gjers Mills and Co	1	1		1	1				
Carlton Iron Co	1	1		1	1				
Cleveland Nut and Bolt Co	1	1							
McDonald and Bulman. Later	1	1		1	1				
Tees Bridge Ironworks	1	1		1	1	1			1
Worth, Mackenzie and Co	1	1		1	1				
Hjerleid and Spence	1	1		1		1			
Downey and Co	1	1		1	1				1
Jackson, Gill and Co Ltd	1		1						
Lackenby Iron Co	1		1						
Richards, W. and Sons Ltd	1	1		1	1				
R. Jaques & Co (Richmond)			1						

Jones Bros and Co	1	1		1	1	1			
Livingston, John	1	1		1	1				
Ashmore, White	1	1			1	1	1		1
Stranton Iron and Steel Co			1						
Moor Steel and Iron Co	1	1		1	1				1
Britannia Iron Co Ltd			1						1
Lofthouse Iron Co Ltd	1		1						1
South Cleveland Ironworks Co			1						
Stockton Forge Co	1	1		1	1				1
Erimus Iron Co			1						
Robson, Maynard and Co.	1		1		1				
William Bacon and Co			1						
Crewdson, Hardy and Co	1	1		1	1	1	1		1
Middlesbrough Nut and Bolt	1	1		1	1				1
I. Copley ad Co	1	1		1	1				
Eston Grange Iron Co			1						
Anderston Foundry Co	1	1		1	1				
Dorman Long	1	1		1	1				
N. Downing and Son	1	1		1	1				
Walker Maynard and Co	1	1		1	1				
Robert Punch (Tees Rivet Works)	1	1		1	1				
Smith and Storker (Egglescliffe)	1	1		1	1				
R.W. Crosthwaite	1	1		1	1				
Edward Williams (Linthorpe)	1	1		1	1				
James Butler (Smithson & Butler)	1		1		1				
Darlington Iron Co (W.Barningham)	1	1		1	1		1	1	
Pease, Hutchinson and Ledward (Skerne)	1	1				1	1	1	1
Darlington Forge Co	1	1		1	1				
South Durhan Iron Co (Ltd later)	1	1		1		1	1	1	1
Drinkfield Iron Co			1						
Whessoe Iron Co			1						
A. Kitching (Charles Ianson and Co)	1	1		1	1		1		1
Fry, Ianson and Co (Rise Carr Rolling Mi	1	1		1	1	1	1	1	1
John Harris	1	1		1			1	1	1
Thomas Sumerson and Sons (later Ltd)	1	1		1	1				
Raylton Dixon	1	1		1	1	1	1		
R. Craggs and Co	1	1		1	1				
Harkness and Sons	1	1		1	1				
Leach, Coates and Co			1						
Pearse, Lockwood and Co	1	1		1	1				
Rake, Kimber and Co			1						
Richardson, Duck and Co	1	1		1	1	1			1

Survival of Iron and & Steel and Engineering Firms, 1840-1880									
	Date est	Before	Otherinv	Sector	w	e	d	m	time
Brown, George, and Brothers (Ltd)	1800	1		E	1				0
Richardson, T. and Co	1866	1	1	W				1	26
Fossick and Hackworth	1840	1		E		1			0
Bolckow Vaughan	1840	1		D					0
Sherwood and Smith	1840			W			1		
Skinner, Charles	1840	1		W	1				0
Gilkes, Wilson and Co.	1843	1	1	E					3
Bell Brothers	1844	1		P	1				4
Weardale Iron, Coal and Coke	1845	1		P	1				5
Samuel Bastow	1846			W					6
Roger, Robert and Co	1847	1		E					7
Barningham Brothers	1850	1		W		1			10
Gilkes, Wilson, Leatham and Co (GWL)	1852	1	1	P	1				12
Elwon, T.L	1853			P					13
Snowden, Hopkins and Co	1853	1	1	P		1			13
Pickerings Ltd	1854	1		E	1				14
Lynch White	1854	1		W					14
Cochrane and Co	1854	1	1	P	1				14
Samuelson, B. and Co.	1854	1		P					14
Pile, Spence and Co	1854			D	1				14
Elwon, Malcolm and Co (Clay Lane)	1855		1	P	1				15
Warner and Co	1855	1		P	1				15
Harker and Sons Ltd	1856			E	1			1	16
Holdsworth, Bennington & Byers	1856			P		1			16
Head Ashby and Co	1859	1		E	1				19
Whitwell, William and Co	1859	1		D	1				19
Jones, Dunning and Co	1859	1	1	P	1				19
Ferryhill Iron Co	1859			P					19
Brown, Andrew, and Co.	1860	1		W					20
Grosmont Ironworks Co (Bagnall)	1860	1		P	1				20
Stockton Malleable Iron Co.	1862	1		W	1				22
Cochrane, Grove and Co	1861	1	1	W					21
Blackett, Hutton and Co Ltd	1862	1		E	1				22
Firth and Hodgson	1863	1		P	1				23
South Bank Iron Co	1863			P	1				23
Fox Head and Co	1863	1	1	W		1			23
Lloyd and Co	1864	1	1	P					24
Stockton Iron Furnace Co	1864		1	P	1				24
Richardson, Johnson and Co	1864	1	1	W	1				24
Swan Coates and Co	1864	1		P	1				24
Stockton Rail Mill Co	1864	1		W					24
George Wythes and Co	1864			P	1				24
Hopkins, Gilkes and Co	1865	1	1	D	1				25
Patent Brick Machine (Bulmer)	1865			E	1				25
Riley Brothers	1865	1		E					25
Norton Iron Co	1865	1	1	P	1				25
Stevenson Jacques and Co	1865	1	1	P	1				25
West Stockton Iron Co	1865			W	1				25
Blair and Co Ltd	1866	1		E	1				26
Head Wrightson and Co Ltd	1866	1		E					26
Holdsworth and Co (Westbourne)	1866	1	1	W	1				26
West Marsh Iron Co (Smith and	1870	1	1	W	1				30
Norrie, J.	1867	1		M			1		27
Hill, Richard, and Co. Later Ltd.	1868	1		E	1				28
Glaisdale Iron (Geo Wilson)	1868	1		P		1			28
Vaughan, T. and Co	1868	1	1	D		1			28
North Yorkshire Iron Co Ltd	1868	1	1	W				1	28
Norwegian Titanic Iron Co	1869	1		P				1	29
Lishman & Leng (Lustrum)	1869	1		W				1	29
Bowesfield Iron Co	1870	1	1	W				1	30
Gjers Mills and Co	1870	1		P				1	30
Carlton Iron Co	1870		1	P				1	30
Cleveland Nut and Bolt Co	1870	1	1	E				1	30
McDonald and Bulman. Later	1870	1		W					30
Tees Bridge Ironworks	1870	1	1	P					30
Worth, Mackenzie and Co	1871	1		E					31
Hjerleid and Spence	1871		1	W					31
Downey and Co	1871	1	1	P					31
Jackson, Gill and Co Ltd	1870	1	1	W					30
Lackenby Iron Co	1871	1	1	P					31
Richards, W. and Sons Ltd	1871	1		W					31
R. Jaques & Co (Richmond)	1871	1	1	W					31

Jones Bros and Co	1871	1	1	W					31
Livingston, John	1871	1	1	M					31
Ashmore, White	1871			E					31
Stranton Iron and Steel Co	1871	1	1	W					31
Moor Steel and Iron Co	1872	1		W					32
Britannia Iron Co Ltd	1872	1	1	W					32
Lofthouse Iron Co Ltd	1873	1		P					33
South Cleveland Ironworks Co	1872	1		P					32
Stockton Forge Co	1873	1	1	W					33
Erimus Iron Co	1873	1	1	W					33
Robson, Maynard and Co.	1873	1		P					33
William Bacon and Co	1873	1	1	W					33
Crewdson, Hardy and Co	1873	1	1	W					33
Middlesbrough Nut and Bolt	1873	1	1	W					33
I. Copley ad Co	1873	1		E					33
Eston Grange Iron Co	1874	1	1	P					34
Anderston Foundry Co	1874	1		W					34
Dorman Long	1875	1		W					35
N. Downing and Son	1875	1		W					35
Walker Maynard and Co	1875	1		P					35
Robert Punch (Tees Rivet Works)	1877			W					37
Smith and Storker (Eaglescliffe)	1878			W					38
R.W. Crosthwaite	1879	1		W					39
Edward Williams (Linthorpe)	1879	1		P					39
James Butler (Smithson & Butler)	1879	1		W					39
Darlington Iron Co (W.Barningham)	1858	1		W					18
Pease, Hutchinson and Ledward (Skerne)	1863	1	1	W					23
Darlington Forge Co	1854	1		W					14
South Durhan Iron Co (Ltd later)	1854	1	1	P					14
Drinkfield Iron Co	1866	1		W					26
Whessoe Iron Co	1870	1		W					30
A. Kitching (Charles Ianson and Co)	1845	1	1	D					5
Fry, Ianson and Co (Rise Carr Rolling Mi	1864	1	1	W					24
John Harris	1842	1	1	E					2
Thomas Sumerson and Sons (later Ltd)	1866	1		E					26
Raylton Dixon	1873	1		M					33
R. Craggs and Co	1835	1		M					-5
Harkness and Sons	1856			M					16
Leach, Coates and Co	1862		1	M					22
Pearse, Lockwood and Co	1854			M					14
Rake, Kimber and Co	1856			M					16
Richardson, Duck and Co	1853		1	M					13

Survival of I&S and Engineering Firms, 1840-1875		
	Bef*	Size
Brown, George, and Brothers (Ltd)	1	
Richardson, T. and Co		
Fossick and Hackworth	1	
Bolckow Vaughan	1	1
Sherwood and Smith		
Skinner, Charles		
Gilkes, Wilson and Co.	1	
Bell Brothers	1	1
Weardale Iron, Coal and Coke	1	1
Samuel Bastow	1	
Roger, Robert and Co	1	
Barningham Brothers	1	
Gilkes, Wilson, Leatham and Co (GWL)		
Elwon, T.L		
Snowden, Hopkins and Co		
Pickerings Ltd		
Lynch White	1	
Cochrane and Co	1	1
Samuelson, B. and Co.		1
Pile, Spence and Co		
Elwon, Malcolm and Co (Clay Lane)		
Warner and Co	1	
Harker and Sons Ltd		
Holdsworth, Bennington & Byers		
Head Ashby and Co	1	
Whitwell, William and Co		1
Jones, Dunning and Co		
Ferryhill Iron Co	1	1
Brown, Andrew, and Co.		
Grosmont Ironworks Co (Bagnall)	1	
Stockton Malleable Iron Co.	1	
Cochrane, Grove and Co	1	1
Blackett, Hutton and Co Ltd	1	
Firth and Hodgson		
South Bank Iron Co		
Fox Head and Co	1	
Lloyd and Co	1	
Stockton Iron Furnace Co		
Richardson, Johnson and Co		
Swan Coates and Co	1	
Stockton Rail Mill Co	1	
George Wythes and Co		1
Hopkins, Gilkes and Co	1	1
Patent Brick Machine (Bulmer)		
Riley Brothers	1	
Norton Iron Co	1	
Stevenson Jacques and Co	1	
West Stockton Iron Co		
Blair and Co Ltd	1	
Head Wrightson and Co Ltd	1	
Holdsworth and Co (Westbourne)	1	
West Marsh Iron Co (Smith and	1	
Norrie, J.	1	
Hill, Richard, and Co. Later Ltd.	1	
Glaisdale Iron (Geo Wilson)		
Vaughan, T. and Co	1	1
North Yorkshire Iron Co Ltd	1	
Norwegian Titanic Iron Co	1	
Lishman & Leng (Lustrum)	1	
Bowesfield Iron Co	1	
Gjers Mills and Co	1	1
Carlton Iron Co		1
Cleveland Nut and Bolt Co	1	
McDonald and Bulman. Later	1	
Tees Bridge Ironworks	1	
Worth, Mackenzie and Co	1	
Hjerleid and Spence		
Downey and Co	1	
Jackson, Gill and Co Ltd	1	
Lackenby Iron Co	1	
Richards, W. and Sons Ltd	1	
R. Jaques & Co (Richmond)	1	

Jones Bros and Co	1	
Livingston, John		
Ashmore, White	1	
Stranton Iron and Steel Co	1	
Moor Steel and Iron Co	1	
Britannia Iron Co Ltd	1	
Lofthouse Iron Co Ltd		
South Cleveland Ironworks Co	1	
Stockton Forge Co	1	
Erimus Iron Co	1	
Robson, Maynard and Co.		
William Bacon and Co	1	
Crewdson, Hardy and Co	1	
Middlesbrough Nut and Bolt	1	
I. Copley ad Co	1	
Eston Grange Iron Co	1	1
Anderston Foundry Co	1	
Dorman Long	1	
N. Downing and Son	1	
Walker Maynard and Co	1	
Robert Punch (Tees Rivet Works)		
Smith and Storker (Eaglescliffe)	1	
R.W. Crosthwaite	1	
Edward Williams (Linthorpe)	1	
James Butler (Smithson & Butler)	1	
Darlington Iron Co (W.Barningham)	1	
Pease, Hutchinson and Ledward (Skerne)	1	
Darlington Forge Co	1	
South Durhan Iron Co (Ltd later)	1	
Drinkfield Iron Co	1	
Whessoe Iron Co	1	
A. Kitching (Charles Ianson and Co)	1	1
Fry, Ianson and Co (Rise Carr Rolling Mi	1	
John Harris	1	
Thomas Sumerson and Sons (later Ltd)	1	1
Raylton Dixon	1	1
R. Craggs and Co		1
Harkness and Sons		1
Leach, Coates and Co		
Pearse, Lockwood and Co		
Rake, Kimber and Co		
Richardson, Duck and Co		1

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