COMPETITIVENESS AND SPECIALISM IN THE UK ELECTRICITY GENERATION INDUSTRY SINCE PRIVATISATION

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COMPETITIVENESS AND SPECIALISM IN THE UK ELECTRICITY GENERATION INDUSTRY SINCE PRIVATISATION

A Doctoral Investigation using Organisational Ecology based Techniques into the Impact of Public Energy Policy and Renewables Technology on the Electricity Generation Industry (EGI) between 1991-2011

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1 RESEARCH ABSTRACT

This thesis presents the results from an Investigation, using Organisational Ecology based techniques, into the impact of public energy policy and renewables technologies on the Electricity Generators since the industry's privatisation in 1991.

At the outset, the research goal was to understand how successive UK Governments' energy policies could use an inferential data based approach, to enable a long-range evaluation of the factors that define energy policy and the results arising from energy policy interventions.

Research and detailed investigation covered the following topics. Firstly, policy instruments, policy definition, policy formulation, policy modelling and evaluation, and the associated competition and regulatory frameworks. Secondly, the electricity sector in the UK over the period from the development and implementation of the first systems and networks in the late 1800s, to the business and technical frameworks currently used for UK electricity generation, transmission, distribution and supply. Then, the technological context of the study required an in-depth understanding of energy basics, traditional and renewable electricity generation techniques, emissions control, market trading mechanisms, environmental-based climate change, emissions trading systems and standards. Finally, understanding the academic research methods and techniques, making the selection of the most appropriate investigative theories, techniques and methods that underpinned the execution of a long-range population based study covering twenty years.

Once the above had been understood, the research concentrated upon the collection, of: circa 8,000 generator company vital events, 2,000 vital events for circa 570 power plants, electricity generation cost data, EU and UK government policy and legislation, policy, macro and micro financial subsidies and incentives, macroeconomic data, UK emissions data, fuel costs, and fuel usage by the UK's Generators.

The choice of the most appropriate methods and techniques utilised for the data analysis was one of the most difficult aspects of the study, but given the nature of the data, the use of organisational ecology-based theory fragments and the field's core methods and techniques were utilised. What sets organisational ecology apart from many social science approaches, and the reason for it becoming one of the central fields in organizational studies, is the empirical quantitative approach, which uses large-scale, longitudinal focused data collections that record the vital events surrounding corporate demography. This coupled with primary data analysis based upon the use of survival statistics differentiates the technique from most others in the social sciences.

Once the theoretical baseline had been determined, it was necessary to prepare the research questions, develop the proposed theories, and develop the hypotheses to conduct the detailed research. The core research constructs adopted were: energy policy objectives and policy instrument evaluation, assessment of how market competition has been impacted by energy policy and renewables technologies and lastly determining how market competition in the electricity industry was impacted by energy policy and renewables technology.

The thesis concludes with a discussion of how the research: makes a contribution to theory, makes a contribution to academic practice, makes a contribution to business practice, makes a contribution to my own work, identifies areas for further research, discusses my reflective thoughts on the doctoral journey, and finally presents my own thoughts and evaluation of the work.

2. PREAMBLE

2 PREAMBLE

2.1 DECLARATION STATEMENT

I confirm that this piece of work is the result of my own work. I further confirm that materials sourced from the work of others have been acknowledged, with quotations and paraphrasing suitably indicated, and the document has not been submitted to any other institution for the award of any prior qualification.

2.2 STATEMENT OF COPYRIGHT

2.3 ACKNOWLEDGEMENTS

In preparing my Thesis, I was mindful of the need to undertake a number of things. Firstly, the need to identify and thank those that helped and have been a source of inspiration:

- Professor László Pólos, whose inspiration and advice encouraged me to use the organisational ecology methods and techniques
- Principal Teaching Fellow Nigel van Zwanenberg whose guidance, support and attention to detail enabled me to complete this research
- The academics whose intellectual leadership and insight I remain in awe of: Philip Anderson, William P Barnett, Hans-Peter Blossfeld, Glenn R Carroll, Frank Dobbin, Stanislav Dobrev, Timothy Dowd, John Freeman, Michael T Hannon, László Pólos, and Gotz Rohwer
- Dr Mike Nicholson, Professor George Wright and my DBA tutors who were able to give their insight and experience throughout the initial 18-month taught phase of the programme
- The Doctoral Office with the Business School, and specifically Anne Bailey, Francis Paylor and Emma Robinson who have provided invaluable guidance and support throughout my studies
- My doctoral cohort colleagues for their continuous and on-going friendship and support. As those who have previously undertaken doctoral programmes will understand, such a study is probably one of the most intellectually and mentally demanding activities that a person can undertake in their lifetime. The many 'highs and lows' along the way have been 'smoothed' and overcome with the tireless help and encouragement of my cohort colleagues.

Secondly, to briefly reflect on the doctoral 'process' and to highlight that my initial conception for the programme and the final outcome are 'poles apart' and to remark that after twenty-five years of management consulting I thought I understood how to conduct research and analyse data. Sadly, this work and experience proved woefully inadequate to undertake in-depth academic research, and to undertake long-range population based studies. Nevertheless, after completing my thesis I feel 'reprogrammed' for the future phases of my life experience.

Thirdly, for those who wish to follow in my path, I would recommend that if you feel like giving up, as I did in frustration at my own inability to fully understand the 'academic way', to remain with the process. Despite trials and tribulations, the completion of the work will provide you with a set of new skills and a wider understanding of how to gather, understand and utilise information. It will also enable an expansion of one's mind and will represent the most important and experiential part of your intellectual life.

2.4 DEDICATION

I dedicate this thesis to my mother Pamela Jane Scott and my daughter Victoria Helen Scott. I recognise that without their positive encouragement, support and assistance my DBA would never have been concluded in either a timely or hopefully effective and efficient manner.

3. INTRODUCTION

3 INTRODUCTION

This thesis is the culmination of the work into a study that has researched the action and impact of energy policy and renewable technologies on the UK's Electricity Generation Industry (EGI) over the period since the industry's privatisation in 1991 to 2011.

This chapter will outline the background to the research, identify the rationale for the study, discuss the policy related issues related to the study, identify the research objectives, discuss the research philosophy, define the benefits arising from undertaking the research, outline the research activities and timeframes undertaken over the three years of the research and present the structure of the document.

3.1 BACKGROUND

The conceptualisation for the research began with my recognition that public policy can have a significant impact on the wellbeing, or otherwise, of business entities. These observations arose from my experiences of employment by the corporate world for twelve years, and subsequently a period of twenty years running my own business. However, the main difficulty with my own observations were that they had arisen from a series of feelings and experiences that could not be base lined or supported by empirical evidence from a community of populations, or indeed from a population of organisations.

The initial conception for the doctoral research was that it would be possible to use the EGI as a population of organisations to form a self-contained study to enable the evaluation of public policy and technological change. The main justification for this was that the electricity industry had undergone significant change, since privatisation, by virtue of environmentalism, technological change and government policy interventions.

Additionally, since I did not have any experience in the electricity generation sector, the doctoral study was a means of understanding the electricity industry, technology, operations and successive governments' energy policies.

The Electricity Generating Industry has experienced a very significant series of policy interventions. These include: a Royal Commission on Environmental Pollution (RECP report), seven energy White Papers, two Energy Reviews, seventeen Parliamentary Acts of primary legislation, some two-hundred Statutory Instruments enabled by secondary legislation, fifty-one EU Regulations, Directives & Decisions, miscellaneous United Nations (UN) Treaties & Guidance in the form of the Kyoto Protocol and various International Energy Agency (IEA) Guidelines. Many of the public policy interventions have required that the EGI industry adopt renewables technology for electricity generation, transmission and distribution. Further, the most recent government policies attempt to encourage the industry to replace the coal-fired power plants and undertake new-build of nuclear power stations.

The complexity identified above, suggests that a long-range population based study would be the most suitable basis for evaluating the impact of policy changes and technology changes. Such a study would also have value in providing a worthwhile contribution to an industry where very little research has conducted over the last twenty-years, albeit accepting that the research undertaken has centred upon climate change and energy demand modelling. Much of this has occurred since 2003, using MARKAL[1] type systems models, which consider the whole economy. Interestingly, the backdrop to this targeted research was the UK's self-sufficiency in energy by virtue of the North Sea oil and gas reserves.

3.2 RATIONALE FOR THE STUDY

The central rationale for undertaking the study was therefore that the UK electricity generation sector had been relatively under-researched from a sociological and social science perspective. For example, a JSTOR search using the key words electricity generation, technology, energy policy, renewables, and United Kingdom for the period 1991 – 2011 revealed just fifty-eight relevant journal articles. A wider literature search around the linkage between energy policy, technology, causality and electricity generation identified circa 550 relevant papers. The search involved the key journals of Applied Energy, Biomass and Bioenergy, Energy, Energy Economics, Energy Policy, Environmental Science & Policy, Global Environmental Change, Journal of Public Policy, Policy and Society, Renewable and Sustainable Energy Reviews, Renewable Energy, Technovation, The Journal of the Operational Research Society. Ninety per cent of the relevant articles were published in the Energy Policy journal. A further search revealed fifty-one relevant papers using the terms public policy causality (26 papers), electricity population-based studies (13), technology (1) and social networks (11) in the Administrative Science Quarterly, American Journal of Sociology, Industrial and Corporate Change, Organisation Science, Strategic Management Review and The Academy of Management Journal over the twenty year period of interest.

Despite creating an Endnote-based library containing circa 3,500 articles and references, detailed scrutiny highlighted that none of these directly addressed the specific area of interest, namely the impact of government energy policy in the UK on EGI competition and concentration.

3.3 POLICY RELATED ISSUES RELATED TO THE STUDY

The UK EGI underwent major change with the industry's privatisation in 1991. Since this time, the government has continued to intervene in the market in a variety of ways that have significantly affected the electricity generation industry. Specifically, successive governments' policy objectives have been to remove the capital investment obligation of the industry from the State (because the State could no longer afford the

[1] Markal is a macro level software model used to carry out economic analysis of different energy related systems at the country level over a period of 40 – 50 years. Various parameters are utilised by the model such as energy costs, plant costs, plant performances, building performance so that an optimal technology mix can be derived to allow energy demand to be achieved at minimum cost. The software and model are available from the International Energy Agency's website.

required level of investment); to liberalise the EGI sector and place it under private ownership, and lastly, Margaret Thatcher's desire to break the stranglehold that the unions had on the energy industry and country, specifically the miners' union who were in part responsible for ending the Conservative administration under Edward Heath's leadership (Helm, 2008).

The author's analysis of the policy backdrop has identified a range of factors that have had significant impact on industry since its nationalisation in 1948 is shown in Table 1:

Phase	Date Range	Sub Phase	Event	Start	End	Narrative
Acquisitions and Mergers, and Market Entry	Jan 1991 - Dec 2008	Acquisitions and Mergers	American Utility takeovers of UK Generators and RECS	01/1991	12/2004	This period represented the main acquisition period of activity by US energy utilities
		Acquisitions and Mergers	Takeover mania in the UK RECS	09/1995	12/1998	This period represented the main acquisition period within the RECs
		Acquisitions and Mergers	European ESI takeovers of UK Generators	07/2002	11/2006	This period represented the main acquisition period by European utilities
		De-Novo Entry	Indigenous expansion in UK	01/2005	12/2009	Centrica expands into UK CCGT Generation and acquires 20% Nuclear capability from EDF
		De-Alio Entry	Scandinavian giants go Offshore	09/2005	12/2008	Dong and Vattenfall commence operations in the UK offshore wind sector
Fuel Management	April 1975 - March 1998	Fuel Management	EU Gas Embargo on using Gas for Electricity Generation	04/1975	05/1991	Prior to March 1991 the EC Directive 75/404/EEC treated Gas a premium fuel and this legislation meant that Gas could not be used for the generation of electricity. Roosecote was the first CCGT station to adopt gas a fuel
		Generator Fuel Management	Two Main Generator's generating capacity falls	01/1990	12/1994	National Power's market share falls from 50% to 33% of generation (Workforce also declined from 17,000 to 5,000). PowerGen's share fell to 25% and staff employed fell by half
		Generator Fuel Management	Proposed relaxation in the mandatory supply of British Coal to generators	04/1990	03/1993	During the period 1990-1993 the generators (National Power and PowerGen) were obliged to honour Government imposed contracts for coal supply by British Coal
		Fuel Management	Non-Fossil Fuel Obligation (Oct 1990 - April 2002)	10/1990	04/2002	The Non-Fossil Fuel Obligation (NFFO) refers to a collection of orders requiring the electricity Distribution Network Operators in England and Wales to purchase electricity from the nuclear power and renewable energy sectors
		Fuel Management	Additional mandatory supply requirement for British Coal to supply generators	04/1993	03/1998	Recognising the risks to British Coal the Government instigated a further period 1993-1998 during which the Generators (National Power and PowerGen) were obliged to honour Government imposed contracts for coal supply by British Coal
Government Divestment	Feb 1995	Government Divestment	Government sells Remaining 40% share in National Power and PowerGen	02/1995	02 1995	Government Sells the remaining 40% Shareholding in National Power and PowerGen for £2.5Bn
Technology Management	Dec 1995 - April 2035	Technology Management	Initial Dash-for-Gas	05/1991	12/1996	Dash for Gas initial period - National Power built five CCGT plants
		Technology Management	Onshore Wind activity begins	08/1991	On-going	Commencement of onshore wind farm development
		Technology Management	Renewables Obligation (RO) - Phase 1 (April 2002 - April 2009)	04/2002	04/2009	The RO places an obligation on licensed electricity suppliers to an increasing proportion of electricity from renewable sources. In 2010/11 it was 11.1%. This figure was initially set at 3% for the period 2002/03 and under current political commitments will rise to 15.4% by the period 2015/16 and then it runs until 2037
		Technology Management	Offshore Wind activity begins	09/2005	On-going	Commencement of offshore wind farm development
		Technology Management	Renewables Obligation - Phase 2 (April 2009 - April 2035)	04/2009	04/2035	Banding was introduced in 2009 to provide differing levels of support to groups of technologies depending upon their relative maturity, development cost and associated risk

Phase	Date Range	Sub Phase	Event	Start	End	Narrative
Emissions Management	Apr 1991 - Dec 2011	Emissions Management	Flue Gas Desulphurisation (FGD)	04/1991	12/1996	Mandatory requirement to fit FGD at cost to £65.8Bn to ESI
		Emissions Management	Climate Change Levy	04/2001	On-going	The climate change levy (CCL) is a tax on energy delivered to non-domestic users in the United Kingdom. It is designed to act as an incentive to increase energy efficiency and to reduce carbon emissions
		Emissions Management	Kyoto Treaty (Feb 2005 -	02/2005	On-going	Under the Protocol, 37 countries ("Annex I countries") commit themselves to a reduction of four greenhouse gases (GHG) (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydro fluorocarbons and per fluorocarbons) produced by them, and all member countries give general commitments
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		Emissions Management	European Emissions Trading System - Phase 1 (April 2005 - April 2008)	04/2005	04/2008	The European Union Emissions Trading Scheme (EU ETS) was launched in 2005 to combat climate change and currently covers more than 10,000 installations with a net heat excess of 20 MW in the energy and industrial sectors, which are collectively responsible for close to half of the EU's emissions of CO_2 and 40% of its total greenhouse gas emissions
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		Emissions Management	European Emissions Trading System - Phase 2 (April 2008 - 31/12/2012	04/2008	02/2012	The second phase (2008–12) expanded the scope of the scheme significantly. The EU's "Linking Directive" introduced CDM and JI credits. Aviation emissions are included from 2012
Price Competition	Jun 1990 - On-going	Price Competition	Wholesale Electricity Price rises	06/1990	01/1994	Wholesale price of electricity rises by 50%
		Price Competition	Mandatory divestments	05/1998	12/1995	Offer 'Encouraged' National power to Sell 15% of Capacity (3-4MW) and a similar amount by PowerGen
		Price Competition	NETA (27 March 2001 - April 2005)	03/2001	03/2005	NETA came into force on 27th March 2001 and was designed to deliver more competitive, market-based trading arrangements for electricity (similar to those in other commodity markets like coal and oil) while still maintaining the operation of a secure and reliable electricity system by the establishment of "close to real time" balancing arrangements. NETA gives greater choice for market participants than the pool-based trading arrangements previously in place, which required virtually all electricity in England and Wales to be bought and sold directly through the pool
		Price Competition	BETTA (April 2005 -	04/2005	On-going	BETTA stands for British Electricity Trading and Transmission Arrangements. It combines an extension to Scotland of the Balancing and Settlement Code (BSC) with the Connection and Use of System Code (CUSC), a GB-wide transmission charging policy, a system operator transmission owner code (STC) and a GB-wide grid code. The Balancing and Settlement Code implements NETA, the new electricity trading arrangements which replaced the Electricity Pool of England and Wales in 2001

Phase	Date Range	Sub Phase	Event	Start	End	Narrative
Price Management	Sept 1991 - Mar 2002	Price Management	Pool Price Review 1	09/1991	09/1991	Electricity Price review by Offer and Monopolies and Mergers Commission (MMC)
		Price Management	Pool Price Review 2	12/1992	12/1992	Electricity Price review by Offer and MMC
		Price Management	Pool Price Review 3	03/1993	03/1993	Electricity Price review by Offer and MMC
		Price Management	Pool Price Review 4	03/1994	03/1994	Electricity Price review by Offer and MMC
		Price Management	Full Electricity Price Inquiry launched	02 1997	021997	Electricity Price review by Offer and MMC
		Price Management	Two-Year Generator Price-Cap	04/1998	03/2000	Two-Year Price Cap forced on National Power and PowerGen by Offer
REC Monopoly Supply, Price Competition and Price Management	Apr 1948 - May 1999	REC Monopoly Supply	REC Monopoly on Supply to Large Customers > 1MW	04/1948	04/1990	5,000 Large-sized customers were able to choose the REC supplier
		REC Monopoly Supply	REC Monopoly on Supply to Medium Sized Customers > 100 kW	04/1948	04/1994	50,000 Medium-sized customers were able to choose the REC supplier
		REC Monopoly Supply	REC Monopoly on Supply was removed for customers	04/1948	05/1999	26 Million 'Designated' (SME and Domestic) customers were able to choose the REC supplier

Table 1 - UK Government Energy Policy Interventions since 1948

In the period since the electricity privatisation, the most defining moment was the commissioning and publication of the Royal Commission on the Environment's (RECP) report in June 2000 (Royal_Commission_on_Environmental_Pollution, 2000). Since this report's release, successive governments have recognised the need to protect the environment, and the majority of the resultant government energy policy interventions, since this date have been based on the RECP recommendations. In addition, successive governments have focused on the environment as a means of deriving significant new sources of taxation that thus far the electorate have been willing to support. Interestingly, and somewhat in line with government interventions relating to market failure, predominantly the new taxation revenues raised have not been used to resolve the environmental issues in the UK, but have been used within the general taxation budget.

Focusing on the twenty-year period since 1991, successive governments, and a large part of the scientific community, has recognised that fossil fuel usage is closely linked with concern over climate change. This has manifested itself in ten major UK policy interventions: RECP, seven energy White Papers and two Energy Reviews, plus the major interventions by the European Union. The main EU policies have included policies that have allowed the use of gas fuel for electricity generation (1991) and Large Combustion Plant Directive (LCPD) in 2001, to take full effect by the end of 2015.

Further, the UK has seen itself move from a position of energy self-sufficiency to dependence on energy imports once again over the period. This more recent development has heightened government awareness in the policy objective of security of energy supply at a time when the demand for fossil fuels by Brazil, Russia, China, India, the so-called BRIC countries, has put fossil fuel supplies under significant price pressures.

The energy policy backdrop has also significantly changed over the twenty-year period: from the regulatory authorities encouraging the use of price controls, to encouraging competition, to the control of the generation technologies by means of renewables targets and emissions controls. This has occurred in parallel with the recognition that the UK will need to replace circa 30% of its generation assets (i.e. end-of-life nuclear assets and LCPD affected plants). This has also occurred at a time during which the majority of the EGI members have recognised that policy change and uncertainty are such that there is a general unwillingness to invest in anything other than Combined Cycle Gas Turbines (CCGT), or policy mandated renewables technology that are justified by compliance with government policy, government subsidies or higher consumer prices. The technology of choice for the EGI has been the CCGT, because these plants have a short build time, low capital cost and higher running cost, but also have 50% of the Carbon Dioxide emissions of coal-fired plants.

Recognising the above, the EGI provides a rich environment for observing the impact of energy policy intervention in a self-contained industry sector. The most important aspect is that, because of privatisation, in effect the period of this study commences at the start of a new industry organisation i.e. the 'Industry Clock' has been reset and this makes industry research all the more interesting.

3.4 RESEARCH OBJECTIVES

The objective of the research is to understand and explain the extent to which and ways in which UK government's energy broad energy policy goals and objectives (protecting the environment, security of energy supply, competitive markets, sustainable economic growth and protecting consumers and the fuel poor) have been achieved by consideration of the following factors. Firstly, Public and Energy Policy – how does energy policy shape and influence the organisational dynamics of the electricity generation industry? Then Renewables generator structure - has the introduction of renewables given rise to a new organisational form that is different to the organisational form adopted by fossil fuel (and nuclear) based generators? Next, Competition within the EGI population - has this changed since the industry's privatisation? Lastly, Generators' business strategies – have they adopted different strategies to cope with the energy and technological changes since the industry's privatisation?

To be more explicit, this study considers a series of different test cases. The first is energy policy and its impact on the founding and failure events for power plants. The second is energy policy and its impact on the duration of ownership by generator companies. The next evaluates how energy policy and technological change have influenced the level of competition between generating firms in the electricity industry. The last evaluates whether the electricity generating market has become more concentrated because of energy policy and technological change.

3.5 RESEARCH PHILOSOPHY

The scholarly literature promotes many different approaches to structure the research design and activity sequence. Many find Saunders et al.'s (2007) 'Research Onion' model informative in terms of a research framework:

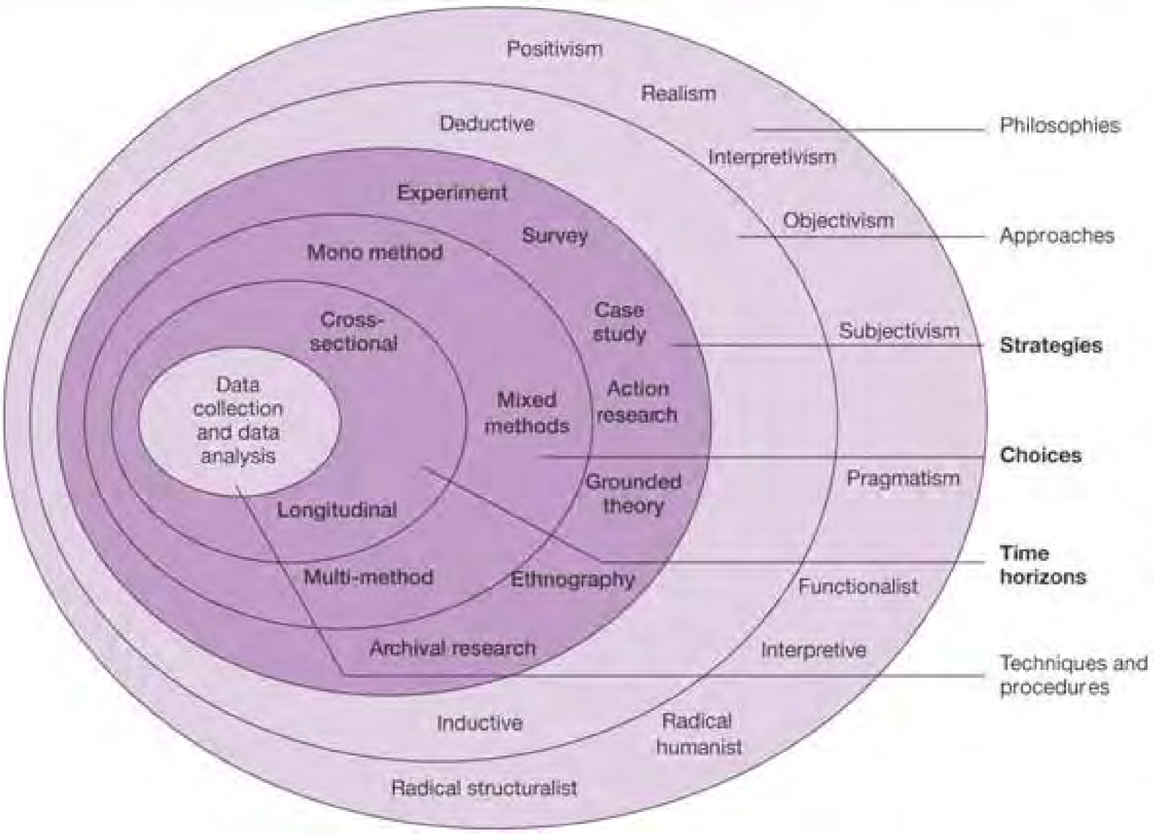

Figure 1 - Research Onion (Saunders et al., 2006)

Working from the outside into the centre implied that it is important to define five components of the research design framework. The first of these is the choice of research philosophy, which Hussey and Hussey (1997) characterised into Objectivist or Subjectivist. Burrell and Morgan (1979) hierarchy posited the first levels of this continuum into Ontology and Epistemology[2]. Following Morgan and Smirchich (1980) it was decided to define the ontological assumption for the research in a manner in which Realism will be framed as a Reality with a formal 'concrete structure'. This further requires a Positive Epistemological approach in which systematic change processes can be understood by means of models which seeks to identify concrete relationships between energy policy instruments and the EGI Generator behaviour.

[2] Ontology: The metaphysical philosophy related to nature of the principles that govern the assumptions and properties of reality. Whereas Epistemology is concerned with identifying what we know is true or not regarding knowledge (Morgan and Smirchich (1980).

The second attribute of the research design is the choice of Research Approach that is characterised as Deductive or Inductive. The deductive approach was chosen in an attempt for the research being able to identify rules that apply to the industry.

The third attribute is the Research Strategy used to obtain the necessary data. A full survey approach was utilised by virtue of the research being able to conduct a full study of all Generators over the period of the study i.e. as opposed to a sampled set of generators.

The next attribute of the ‘onion’, the Research Method, necessitates the choice between Quantitative and Qualitative (or both termed - Mixed methods). The desire at the outset was to be able to characterise the energy policy actions and impact of energy policy on electricity generators in a numerical manner and hence a Quantitative research method was selected.

The penultimate attribute is the choice of Research Time Horizon. It was necessary understand the full impact of policy over a twenty-year period this suggested that either a longitudinal or cross-sectional time horizon was necessary. In order to ensure that all events and actions were recorded, it was decided to use a longitudinal horizon.

The final attribute is the choice of Research Data Collection technique. The decision at the outset was to be able to gain all data for the whole population of generators and policy events over the twenty-year period. This meant that it would be necessary to collect and build a data set that contained all energy policies, actions, responses and outcomes.

In essence, the research design was to develop a concrete structure that adopted a deductive approach underpinned by a full survey using quantitative data on a twenty-year horizon.

3.6 INDUSTRY SETTING FOR THE RESEARCH

The industry wide study that is required in order to examine the impact of energy policy and renewables technology on the population of firms in the EGI, suggests that the organisational ecology techniques and methods used to address corporate demography may be relevant to a long-term industry population study. The corollary to this is that the application of Event History Analysis techniques, as used by Organisational Ecologists, may also be very pertinent for this study. This rationale for this is that the industry has been subjected to significant unit of change events in terms of the fuel mix, moving from coal, oil and nuclear towards gas and biomass fuel sourcing, and the mandated use of renewables technology, made up mainly from wind.

The EGI industry has also seen significant changes in ownership from domestic ownership, through major US utility ownership to the current situation in which ownership of five of the Big Six players (British Gas, EDF Energy, E.On UK, nPower, Scottish Power and SSE) is now concentrated in companies based in continental Europe. Additionally, many of the new generators are in effect under a form of long-term contractual control by the Big Six by virtue of confidential Power Purchase Agreements (PPA) which typically last 20-25 years.

3.7 BENEFITS ARISING FROM UNDERTAKING THE RESEARCH

The main benefit of undertaking this research is that it will be the first multi-faceted study of the electricity generation industry's response to the dramatic changes in energy policy and technology over a twenty-year period. This type of wide ranging study has not been attempted before in any country. What makes the topic so interesting is that the UK has one of highest levels of energy policy intervention, specifically in order to increase generator competition and mitigate climate change, whilst at the same time the investment finances are constrained by virtue of the banking sector demanding higher levels of contractual security.

The study will also provide insight into the following areas: What happens when policymakers and regulators mandate the use of technology that has a negative price performance curve to offset market externalities – the key question is whether the imposition causes undesirable changes in organisation form and technological adoption by the industry. What happens to selectional forces when energy policy is centred upon carbon taxes, electricity directives, energy efficiency standards, energy security of security considerations, politically based fuel poverty objectives, regulatory requirements and mandating technological choice, and how is competition affected by energy policy and technology targeting and how does the marketplace (in this case the generators) cope with policymakers' demands?

The above questions do not appear to have been addressed by organisational ecologists, energy systems modellers, economists, competition or regulatory oriented policymakers, or by value-chain or life cycle cost studies identified by the author. Therefore, the results will be novel not least in terms of the observations and the inferences that can be drawn from the analysis.

3.8 RESEARCH ACTIVITIES AND TIMEFRAMES OVER THE THREE YEARS

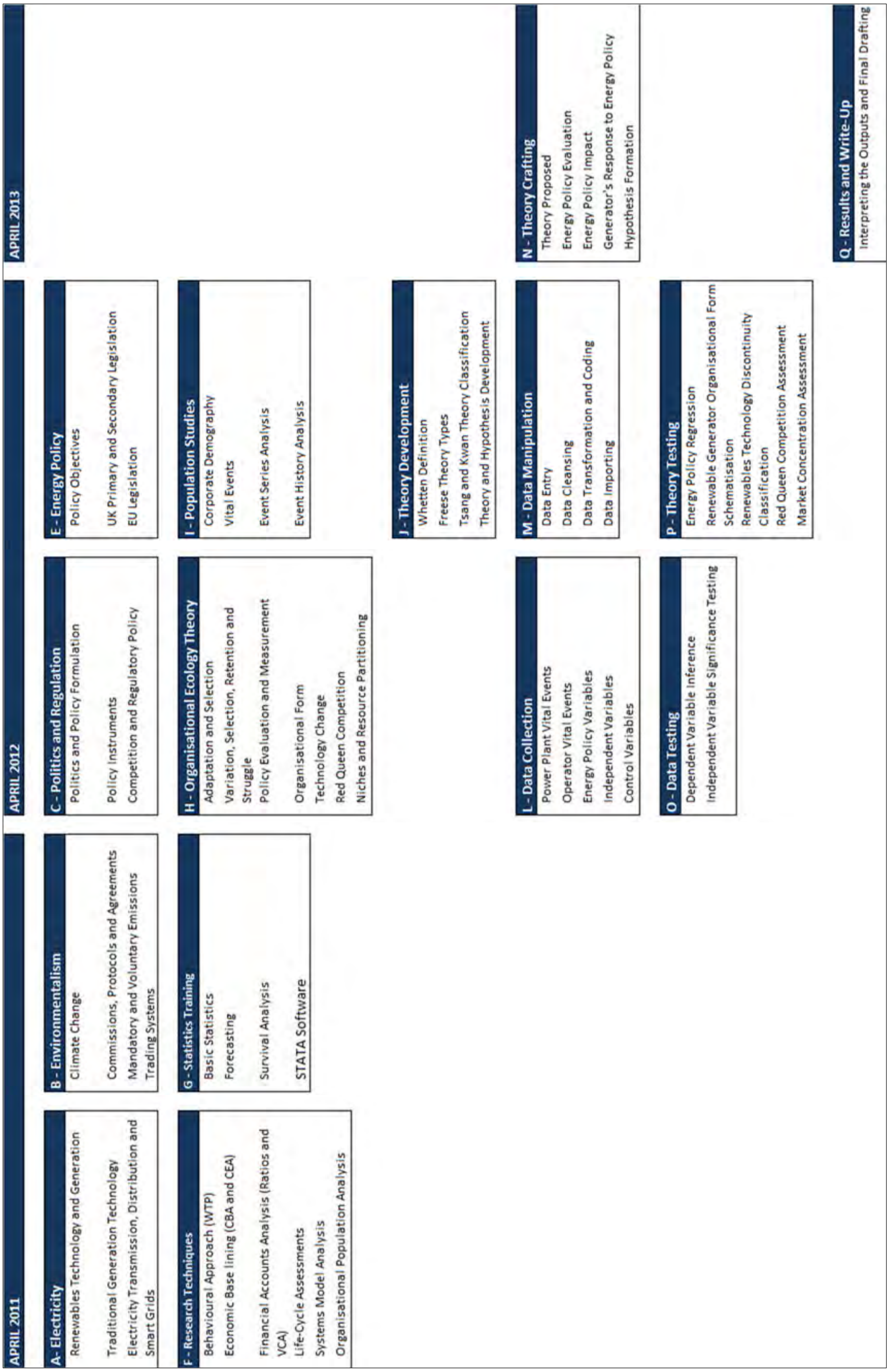

Figure 2 - Research Activities and Timeline

3.9 STRUCTURE OF THIS DOCUMENT

The thesis is structured around components, elements, and chapters as shown in table 2:

Component	Element	Chapter	Title
Preliminaries	Abstract	1	Research Abstract
	Preamble	2	Preamble
Introduction	Introduction	3	Introduction and Rationale for the Study
Empirical Setting		4	Policy Analysis and Modelling
		5	Electricity Generation in the UK
Methodological Matters	Methods	6	Methodological Matters
Research	Research Components	7	Energy Policy Theory and Testing
		8	Energy Policy Founding and Failure Analysis
		9	Energy Policy Duration Analysis
		10	Market Competition in the EGI
		11	Market Concentration in the EGI
Conclusion	Concluding Remarks	12	Summary of the Research Findings
		13	Conclusion
Bibliography	Bibliography	14	Bibliography

Table 2 - Thesis Structure

Following the presentation of the abstract, preamble and introduction. Chapters four and five provide a review and critique of policy analysis and modelling, empirical setting of the electricity generation industry with the UK. Chapter six provides a discussion of the methodological matters relating to the study including the detailed methods and research toolset used to conduct the research itself including the Organisational Ecology theory fragments, appropriateness of ecological techniques that are reviewed along with event series & history analysis techniques, and corporate demography. Chapters nine through eleven present the detailed research questions, theories, hypotheses and test results. Chapter twelve provides a summary of the research findings and chapter thirteen provides the conclusion and areas for further research.

3.10 CHAPTER SUMMARY

This chapter has sought to provide the reader with an overview of the framework that will be adopted for the research by covering: the background to the research, the rationale for the study, the policy related issues related to the study, the research objectives, research philosophy, the benefits arising from undertaking the research, synopsis of the research activities and a presentation of the structure for the remainder of the document.

4. THEORY STRANDS

4 THEORY STRANDS

This chapter will provide the reader with a synopsis of the theory strands considered as part of determining which research philosophy was most appropriate for the research. These are the of origins of competition theory, origins of regulatory policy, economics of competition and regulation, strategic and organisational analysis, organisational analysis techniques, Aldrich and Ruef's six evolutionary perspectives, unit of analysis, policy analysis and modelling and the selecting theory baseline.

4.1 ORIGINS OF COMPETITION THEORY

At the heart of policymaking is competition theory. This frames policy considerations that relate to ensuring how fair and open competition can be facilitated and maintained. This is key to understanding what constitutes competition policy?

Competition policy (or anti-trust policy as it is known in the United States) is defined as the 'set of policies and laws which ensure that competition in the marketplace is not restricted in such a way as to reduce economic welfare' (Motta, 2009). As Motta argues, this also implies to 'Restrictions on competition can arise that may not be detrimental, such as vertical restraints or restrictive clauses between a manufacturer and retailers' and 'Maintaining or ensuring economic welfare is normally the main objective of competition policy'.

The objectives behind most competition policies are that they should apply to all sectors of the economy, wherein the normal functioning of the market will allow competition – even though such competition may not operate correctly. This is in direct contrast to regulation, which applies to only those sectors where the market structure means that competitive forces cannot operate without difficulty.

Typically, the markets where regulations are required are those wherein the fixed costs are such that only one firm can be expected to operate with a profit (a natural monopoly) – an example of this is the UK Electricity 'Supergrid' that is the high voltage network that transmits electricity around the country. The cost of building and operating this network mean that only one company is unable to own and operate the system.

Other markets where regulation may be required are those industries or sectors where previously legal monopolies existed, such as privatised entities. In these cases, it would be difficult for new entrants to be able to complete on a 'level playing field' with the established organisation (s).

The other key differences between competition and regulation are that: firstly, 'competition authorities usually operate "ex post" and limit their involvement to ensuring the lawfulness of firm's activities, whereas industry regulators have more extensive powers such as imposing or controlling firm's prices, investments and product choices'. Secondly, 'competition authorities usually operate "ex post" (checking historical business practices and firm's practices), whereas regulators operate "ex ante" (typically by authorising certain business practices in advance of their performance and delivery). Thirdly, 'regulators involvement is on-going and continuous, whereas competition authorities' interventions tend to be occasional'. Lastly, 'competition authorities typically use different theoretical frameworks – usually the analysis is undertaken using "Oligopoly Theory", whereas regulatory issues are dealt with using "Principal-Agent" models. Where the "Principal" is the regulatory authority (that devises incentives to mandate or encourage change) and the "Agent" is the regulated firm' (Motta, 2009).

4.2 ORIGINS OF REGULATORY POLICY

Having briefly considered competition policy it is important to review 'What is the role of and application of regulatory policy?' Over the last three decades the impact of regulation has entered the language of public policy, law and economics (Baldwin et al., 2010).

> 'The idea that we are living in the living in an era of the "regulatory state" (Majone 1994 & 1997, Moran 2002 & 2003, cited by Baldwin et al.) has been furthered by the spread of the language of regulation across social systems as well as state organisations and government strategies. The associated suggestion is that regulation, its practice and study, are central to the interaction between economic, legal and political, and social spheres'. (Baldwin et al., 2010)

Baldwin et al. further argues that 'the past thirty years have witnessed a crystallisation of paradoxes in regulatory dynamics that has been characterised by three dynamics: Firstly, 'Concern over the 'evils' of regulation, including "red tape", overload, and excessive bureaucratisation of economic and social life'. Secondly, 'The quality and direction of regulation that has stemmed from deregulation in key industries such as the utilities as a result of privatisation and long-term contracts that have liberalised the landscape of the previously state-owned enterprises. Lastly, 'The response to the above with the rise of better regulation - which has demanded coherence and consistency between the "red tape" and "regulatory quality" pressures of the first two dynamics.

In discussing regulation, it is worth reviewing the regulatory event timeline and its evolution since the 1950s:

- **'1960s and 1970s** – The adoption of the "**Command and Control**" frameworks - which have been deemed to be restrictive and inflexible
- **1980s** – Witnessed the implementation of "**Alternative Modes of Influence"** – such as taxation regimes and systems of information disclosure
- **1990s** – Where the focus of attention (driven by bodies such as the UK's Better Regulation Task Force in 2003) has been upon more **Market-based Strategies** such as the use of franchising and implementation of trading regimes
- **2000s** – Moved incrementally from the frameworks of the 1990s to adopt a the "**Meta Regulation"** and '**Steering**' approach that could be operated by the corporations themselves' (Braithwaite 2000 & 2003, Coglianese and Lazar 2003, May 2003, Power 1997 and Parker 2003 cited by Baldwin et al.).

The trends above highlight that there has been a series of major changes away from:

- **'Blame shifting'** based compliance and deterrence approaches' (Baldwin 1995, cited by Baldwin et al.), towards
- '**Responsive regulation'** (Ayres and Braithwaite 1992, cited by Baldwin et al.), towards
- '**Smart Regulation'** (Gunningham and Grabosky, 1999, cited by Baldwin et al.), towards
- '**Problem Centred Regulation**' (Sparrow 2000, cited by Baldwin et al.)
- The focus has therefore moved from the '**principal-agent**' mode of regulation, to a focus on '**risk-based'** and **'principles-based'** approaches, towards '**regulatory enforcement**' and '**cultural theory**' approaches that consider side effects and the behavioural implications (Sparrow 2000, cited by Baldwin et al.).

Baldwin et al. suggest that the above calls into question Philip Selznick's seminal definition of regulation as:

> 'The sustained and focused control exercised by a public authority over activities valued by the community' (Selznick 1985 p363, cited by Baldwin et al.).

4.3 ECONOMICS OF COMPETITION AND REGULATION

The economic aspects of regulation have been characterised by 'the replacement of state ownership with private sector ownership plus regulation, part due to the natural tendency for "regulatory creep", and the apparent inability of the government to roll-back regulation' (Veljanovski, 2010).

The scope of regulatory economics embrace both 'Normative theory (what it should be) and Positive theory (what is) aspects.

The scope of methods and techniques for analysis of the economics of competition and regulation include the field of economics that undertakes the economic analyses of prices, access, quality, entry, and market structure, and embrace four components. Firstly, Economic Regulation, which deals with economic issues affecting firm performance, industry structure, pricing, investment and output. Secondly, Social Regulation that considers health and safety, environmental, anti-discrimination and other such laws. Thirdly, Competition and Merger Legislation that is associated with the control of monopolies, cartels, abusive practices, and mergers and joint ventures that assess the risks associated with giving firms excessive market power. Lastly, Legal Systems that are concerned with the rules, procedures and enforcement of the above measures.

A second strand of methods and techniques include Impact and Cost Benefit Assessments related to empirical studies of specific legislation. A comparative review of software-based energy models[3], by the author, identified three dedicated techniques to understand the policy interventions. The first uses of economic techniques such as Cost-benefit analysis (CBA), Cost-effectiveness analysis CEA, Contingent Valuation Techniques (CVT), Cost Utility Analysis (CUA), Impact Assessment (IA), Levelised costs (LVLC), Lifecycle Costs

[3] Selected models include: Aeolius, Balmorel, Bchp Screening Tool, Compose, E4cast, Emcas, Eminent, Emps, Energyplan, Energypro, Enpep-Balance, Gtmax, H2res, Homer, Hydrogems, Ikarus, Inforse, Invert, Leap, Markal/Times, Mesap Planet, Message, Minicam, Nems, Orced, Perseus, Primes, Prodrisk, Ramses, Retscreen, Simren, Sivael, Stream, Trnsys16, Unisyd3.0, Wasp, Wilmar Planning Tool

(LCA), and Value Chain Analysis (VCA). The second uses environmental techniques: Environmental Impact Assessment (EIA), Environmental Cost Benefit (ECB), and Marginal Cost Abatement (MCA). The third uses behavioural techniques such as Willingness-To-Pay type approaches. This is line with Sorrell's (2007) research, namely that the vast majority of energy policy studies adopt econometric analysis and economic modelling. In-line with the introductory remarks to this study, it can be seen that none of the systems models are dedicated broad approaches that can be applied to a population-based study of the electricity generators because none of them readily permits long-range population studies to be undertaken. Further, each approach suffers from different limitations that relate to a focus on a single organisation or single objective or policy project based study.

The last strand of methods and techniques considers organisational and legal applications by examining the behaviour of institutions and regulatory agencies and lastly, the development and design of rules, standards, and enforcement procedures' (Veljanovski, 2010).

In a generic sense, there are two predominant theories of apparent, the Normative and Positivist Economic Approaches:

4.3.1 NORMATIVE ECONOMIC APPROACH

This aspect builds on economic efficiency and market failure (and Government Failure) and the relationship between efficiency, market and non-market failure, distributive justice, and regulation.

4.3.1.1 EFFICIENCY

The core building blocks are the constructs of economic efficiency and are comprised of two sub elements (Veljanovski, 2010). The first is terms Pareto Efficiency 'where an efficient outcome occurs when the welfare of one individual cannot be improved without reducing the welfare of others. This implies that where all parties benefit or none are harmed by the reallocation of resources, goods, assets, or a change in the law'. This is based upon two value judgements. 'That the he individual is the best judge of their own welfare and that the welfare of a society depends on the welfare of the individuals that make it up. The main difficulty with Pareto Efficiency is that it is almost impossible to get to an outcome in which nobody is harmed, especially if major change is being promoted. Economists attempt to overcome this dilemma by insisting that the gainers compensate the losers'. The second is the Kaldor-Hicks Efficiency (Wealth Maximisation or Allocative Efficiency) is an alternative mechanism to overcome the difficult with Pareto Efficiency. 'A policy is deemed to be Kaldor-Hicks efficient if those who compensate the others, that have been harmed, can do so and are still economically better off' (Veljanovski, 2010).

4.3.1.2 MARKET FAILURE

The second normative approach is the concept of a perfectly competitive market. If a market is not perfectly competitive, it suffers from market failure that may give sufficient justification for state or collective action. There are four main reasons for market failure (Veljanovski, 2010). This approach considers four sub elements.

> 'Firstly, Market Power where one firm (monopoly) or several firms (oligopolies or cartels) can profitably raise prices above a level which is Pareto Efficient. Secondly, Externality that recognises that some activities impose external losses or benefits on third parties that the market does not fully take into account e.g. pollution, congestion, global warming, anti-social behaviour and crime. Thirdly, that Public Goods[4] are those goods for which consumption by one individual does not detract from that of any other individual i.e. there is non-rivalrous consumption e.g. an army stands ready to defend its citizens. A competitive market may fail because non-payers cannot be excluded resulting in 'free-loading' and thereby give rise to an inability to appropriate and adequate return. Lastly, Asymmetric Information is imperfect information that can result inefficient markets and choices. If the information between the buyer and the seller is unequal this can give rise to two elements. The first is Adverse Selection where one party cannot distinguish between two or more categories of good or service which have different costs, benefits, or risks and makes a choice on the average value of these, and the second is Moral Hazard where the prospect of compensation to cover risks and losses increases the likelihood and size of the losses because risk taking behaviour cannot be monitored or priced appropriately, but the losses are still compensated'. (Veljanovski, 2010)

4.3.1.3 NON-MARKET FAILURE

The market failure approach makes an implicit assumption that regulatory intervention is costless and does not generate its own distortions and inefficiencies. In this respect, Veljanovski suggests that economists have exaggerated the incidence and extent of market failure. These are such that markets often fail because economists' models have ignored the costs of using the market and the expense of proposed remedial measures. He further suggests that the market failures approach 'did not recognise that the costs involved in using the market generated self-correcting forces. As a result, a false dichotomy was drawn between market and non-market activities. However, many seemingly non-market institutions evolved as a cost-effective response to the costs of using the market.' The consequence of this is that 'the firm replaces market transactions costs with principal and agency costs of internal administrative controls'. (Veljanski, 2010)

[4] Note: Public goods are not those which are collectively or state provided or produced goods and services.

4.3.1.4 DISTRIBUTIVE GOALS, FAIRNESS AND JUSTICE

Veljanovski highlights that because markets generate winners and losers it is important to recognise that individuals will be concerned how laws impact upon their wealth and that of others in society – thereby implying that a normative theory should consider the non-economic factors. The distributional issues are also important because an efficient market outcome is determined in part by the 'ex ante' distribution of income and wealth. Veljanovski introduces 'the linkage between wealth distribution, economic efficiency, market outcomes and by implication regulation'. He further suggests that regulatory economists have 'a schizophrenic approach whereby regulation is assessed in terms of economic efficiency alone, on the implicit assumption that distributional goals can be achieved at less cost by direct, ideally lump sum, wealth transfers, and at the same time or that economists' Positive Theories of regulation are driven by politicians and interest groups who primarily fight over wealth transfers.'

4.3.2 POSITIVE THEORIES

The objective of Positive Theory is to explain competition and regulation 'as it is', and is used by economists to develop the Normative Turned Positive (NTP) theory of competition and regulation. The NTP theory makes the implicit assumption that governments seek to correct markets in efficient and a fair manner.

The Positive Theory was first promoted by (Stigler 1971, cited by Veljanovski) to promote the hypothesis 'that regulation was secured by politically effective interest groups, invariably produces or sections of the regulated industry, rather than consumers'.

Stigler's model (further developed by Peltzman 1976, cited by Veljanovski) has four main features of assumptions:

> 'Firstly, that the primary 'product' transacted in the political marketplace is wealth transfer. Secondly, that demand for regulation comes from cohesive coordinated groups, typically industry or special interest groups, and hence differs from the real marketplace, where all consumers are represented. Thirdly, the effectiveness of these groups is seen as a function of the costs and benefits of coordination (which also explains why consumer groups find it hard to organise as an effective lobby group). The supply side of legislation is less easy to define given the complex nature of political, legislative, and regulatory processes. Lastly, the state has a monopoly over the one basic resource: the power to coerce using legitimate means. This coupled with the behavioural assumption that politicians supply regulation to maximise the likelihood that they will be kept in office'.

4.4 STRATEGIC AND ORGANISATIONAL ANALYSIS

In combination with considering competition and regulatory policy considerations, policymakers must also be mindful of the need to recognise that policymaking interventions is in effect a macro strategy, because the policymakers actions set the framework and environment for the firms and individuals in the society. With this recognition in mind it is important to consider the contribution of strategic analysis.

A traditional mechanism to undertake such an analysis is to conduct a detailed study of the environment and the companies that it supports to determine whether or not their strategic alignment has altered during the period that environmentalism and renewables technology have affected the EGI.

4.4.1 STRATEGIC ANALYSIS

If one considers the findings from strategic analyses, many studies highlight that previously successful organisations make major strategic changes that subsequently flounder and fail. Such analysis is usually conducted (Barnett and Pontikes, 2005), by means of two main types of process analysis.

The first is termed 'Organisational Decision-making Processes' – where the analysis focuses on the detailed decisions and the decision making process that were undertaken by the organisation (e.g. March et al., 1991; Denrell, 2003), These make use of the organisations' design and capability based features by means of:

- **'Innovation and Differentiation Capability** – wherein some organisations have the potential that enable it to exploit its innovation or differentiation capabilities (Wernerfelt, 1984; Barney, 1991)
- **Market Fit** – using the organisation's business strategy or operating structure to exploit the market opportunities (Scott, 1975; Venkatraman and Prescott, 1990)
- **Market Positioning** - where the better-performing organisation has a market position that is protected from competition (Porter, 1980)
- **Social Network Positioning** – exploiting an organisation's privileged or dominant in a social network of organizations (Pfeffer and Salancik, 1978; Burt, 1992)
- **Strategic Interaction** – in which an organisation may have enhanced capabilities that enable it to develop supply chains across multiple joint-venture partners (Dixit and Nalebuff, 1991; Saloner, 1991)
- **Transaction Costs Advantages** – that use an organisation's superior cost structures to minimise its transaction costs (Williamson, 1991)'

The second is termed 'Organisational Adaptational and Selectional Processes' where the focus is on either the impact that the organisational environments has upon the incompatible organisational features (e.g. Tushman and Anderson, 1986; Carroll and Teo, 1996), and attempts by organisations to change direction, which prove to be difficult and hazardous (Hannan and Freeman, 1984; Hannan et al., 2003).

The two are based upon the assumption what is based implicitly on what March and Olsen (1989), cited by (Barnett and Pontikes, 2005). They suggest that process analysis is based upon the assumption of 'historical efficiency, that by making 'the cause-effect relations in our rationale will play themselves out to steady-state equilibrium quickly, uniquely, and independently of the particulars of the development processes.

'Typically, process analysis tends to be focused upon a 'static' reference that are based upon cross-sectional research designs, which yield what are termed 'static' theories. However, in contrast to the static approach taken my some researchers, others adopt an evolutionary perspective using a dynamic path-dependant approach. Unlike the static models that trend towards the adaptational approach, the dynamic models tend to use a more evolutionary selection-based and random variation assumptions to conduct their strategic analyses' Barnett and Pontikes' (2005).

Barnett and Pontikes highlight that there are three main benefits of this approach. First, 'It requires that we specify a dynamic model. This means constructing theory that can predict patterns of change, including rates of change (the speed at which change occurs) and alternative paths of change (particular sequences of events). A dynamic model can predict convergence toward a steady state, several possible steady states, or possible ranges rather than states' (Tuma and Hannan, 1984; Anderson, Arrow, and Pines, 1988). But regardless of their treatment of equilibrium conditions, evolutionary models attend to the pace and path of strategic change.

Second, an evolutionary perspective allows for variation in the possible strategies that organisations pursue. Most theories in strategic management take the 'strategy space' of possible variants as a given and then predict which would prevail if organisations pursuing the different possible strategies were to enter into competition. The key considerations with an evolutionary approach are: 'But how do new strategic variants develop? How do organisations search for and learn about strategic options, especially given well-known constraints on organisational rationality' (Cyert and March, 1963; March, 1981)? 'How adaptive is this process of searching' (Levinthal and March, 1981; Mezias and Lant, 1994)?

These questions invite the study of the rate and path of innovation among and within existing organisations, when organisations grow (Ijiri and Simon, 1977; Penrose, 1968), when strategic initiatives are launched within firms (Burgelman, 1983a; Garud and Van de Ven, 1992), or when new jobs are created (Miner, 1990). These questions also suggest that it is necessary to study the degree to which innovations arise from existing organisations vs. through the founding of new organisations (Freeman, 1995)

In either of the first two cases, 'an evolutionary perspective allows that many variations arise essentially at random-a possibility sometimes built into evolutionary models' (Cohen, March, and Olsen, 1972; Padgett, 1982; Levinthal, 1991; Nelson, 1994). 'More commonly, random development represents a baseline model, serving as the null hypothesis. Theory is then challenged to explain variation or selection beyond that which arises stochastically' (Nelson, 1994).

Third, evolutionary inquiry asks 'how selection processes affect, and are affected by the pace and path of strategic change. This approach focuses research on selection among organisations that have proliferated within the research project of organizational ecology (Hannan and Freeman, 1989), with a strong emphasis on processes of organisational founding and failure' (Barnett and Pontikes, 2005).

4.5 ORGANISATIONAL ANALYSIS TECHNIQUES

Analysis of organisation theory suggests that organisation analysis can be conducted using either a Theme, School or Perspective approach in figure 3:

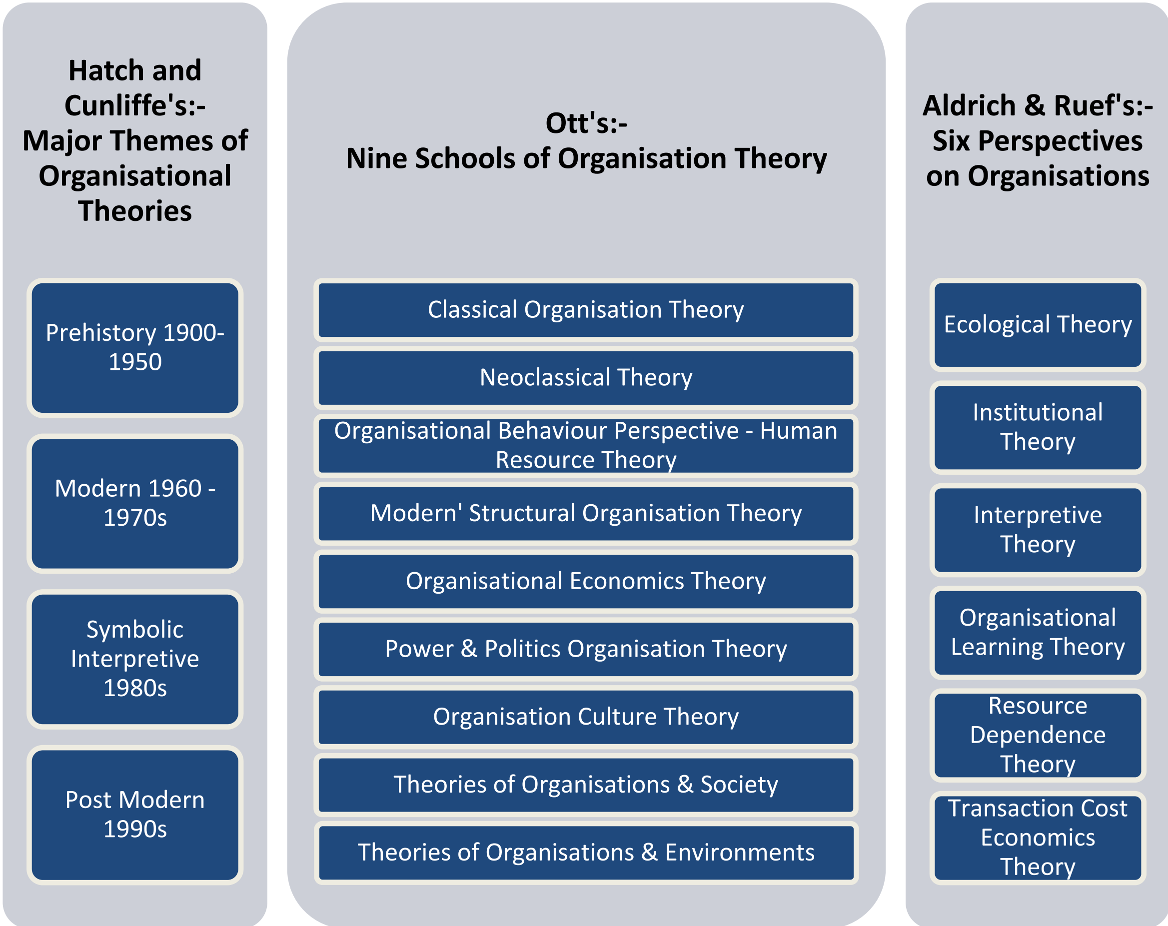

Figure 3 - Themes, Schools and Perspectives of Organisation Analysis

Space prevents a detailed discussion of the above but the following diagrams are illustrative of the main concepts and contents of each of the frameworks:

4.5.1 HATCH AND CUNLIFFE'S - MAJOR THEMES OF ORGANISATIONAL THEORIES

Figure 4 illustrates the major themes of organisational theories:

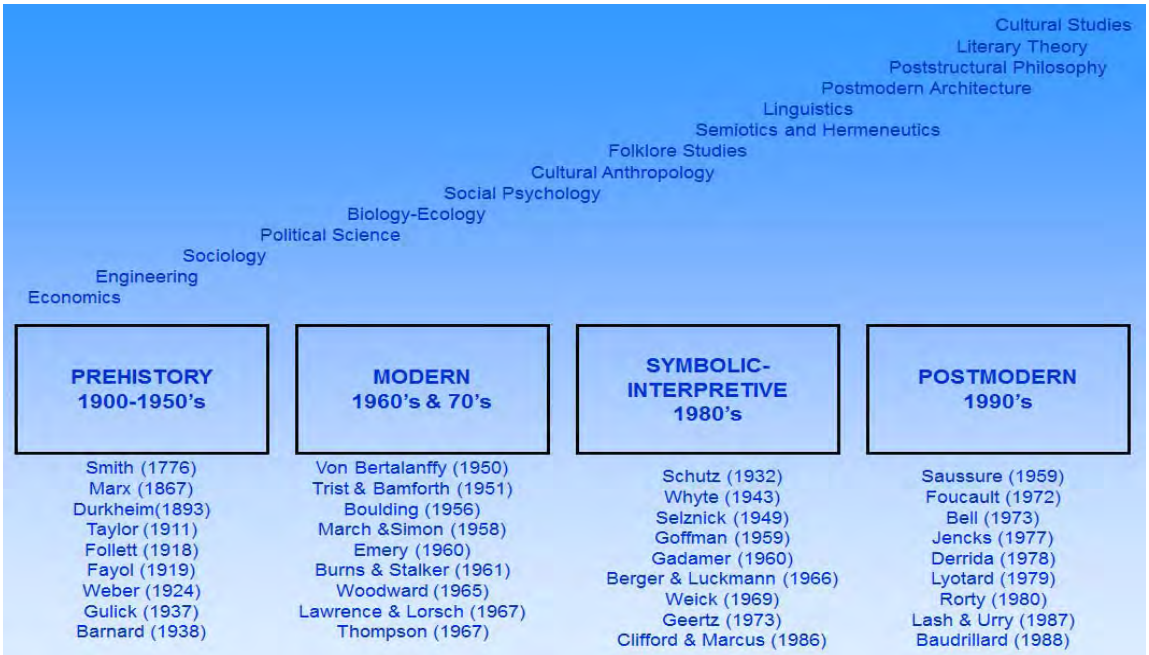

Figure 4 - Major Themes of Organisational Theories (Hatch and Cunliffe, 2006)

This illustrates how organisational analysis has progressed from the economic and scientific approach through to the cultural approach.

4.6 ALDRICH AND RUEF'S SIX EVOLUTIONARY PERSPECTIVES

Six of the key perspectives used by researchers to conduct organisational analysis (Aldrich and Ruef, 2006) are shown in table5:

Perspective	Variation	Selection	Retention
Ecological	Variation introduced via new organisations	Selection results from fit between organisations and environment	Retention through external pressures and internal inertia
Institutional	Variations introduced from external origins, such as imitation	Selection via conformity	Retention through transmission or shared understandings
Interpretive	Variation introduced as people negotiate meaning through interaction	Selection via emergent understandings and compromise	Retention is problematic; depends on learning and sharing
Organisational Learning	Variation via problemistic search or information discontinuities	Selection results from fit to target aspiration level or existing organisational knowledge	Retention in programs, routines or culture
Resource Dependence	Variation introduce as managers try to avoid dependence	Selection via asymmetric power relations	Retention a temporary result of coalitions and bargaining
Transaction Cost Economics	Variation introduced via intendedly rational action	Selection involves actions to minimise transaction costs	Retention via transaction-specific investments

Figure 5 - Aldrich and Ruef's (2006) Six Evolutionary Perspectives

As can be seen from the figure above, the Evolutional Organisational Perspective highlights that there are six different theoretical constructs, including:

- **Ecological Theory** – used insights from biology, economics, sociology and statistical analysis to understand how organisations are founded, grow and suffer mortality. This field of research is attributed to Michael T Hannan and John H Freeman (1977)
- **Institutional Theory** – focuses upon the social structure of organisations by considering their norms, routines, rules, and schema. Powell and DiMaggio (1991) define the 'new institutionalism' by defining 'supra-individual' units of analysis for the basis of cultural and cognitive explanations for organisational behaviour. W Richard Scott, 1995, identifies that for organisations to survive and thrive they must conform to the beliefs and rules operating within the environment
- **Interpretive Theory** – focuses on the meaning the social actions have for participants at the micro level of analysis. Interpretive the theorists are not interested in actors as individuals but rather as members of social categories
- **Organisational Learning Theory** – focuses on how individuals, groups, and organisations notice and interpret information and use it to alter fit with their environments
- **Resource Dependence Theory** – is used to study how the external resources available to organisations affects their behaviour. The research identifies that because organisations are dependent upon resources in the environment these resources have a material effect on the development and power of the organisation. This research is attributed to the publication 'The external control of organisations: A resource dependence perspective' by Pfeffer and Salancik, 1978
- **Transaction Cost Theory** - relates to the financial cost of making an economic exchange and relates to the study of the smallest unit defined by classical economists (labour) and what the Hedonic economists call the 'exchange of commodities'. The term 'transaction cost' is attributed to Ronald Coase, 1937.

4.7 UNIT OF ANALYSIS

One major decision is to determine at what 'unit of analysis' should be used when designing research. The first dimension is to determine whether a static or dynamic study should be undertaken, and the second dimension evaluates at what level in the structural hierarchy for the entity that will be investigated. Biologists will frequently conduct ecological analysis at the: individual, population or community level, but the organisational analyst will need to choose one of levels: members, subunits, individual organisations, populations of organisations, and communities of organisations (communities of populations) (Hannan and Freeman, 1977). The third considers the level of analysis and the orientation as defined by Astley and Van de Ven, in figure 6:

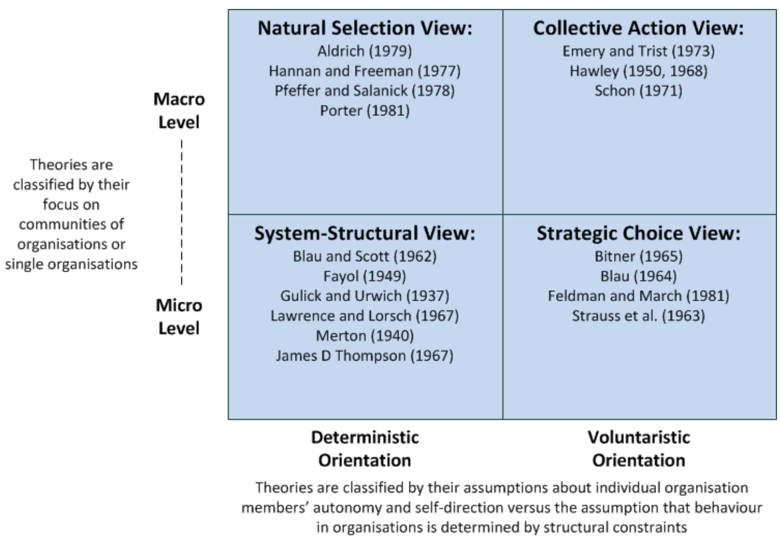

Figure 6 - Organisation Theory View

The fourth dimension takes into consideration Scott and Davies systems classification in figure 7:

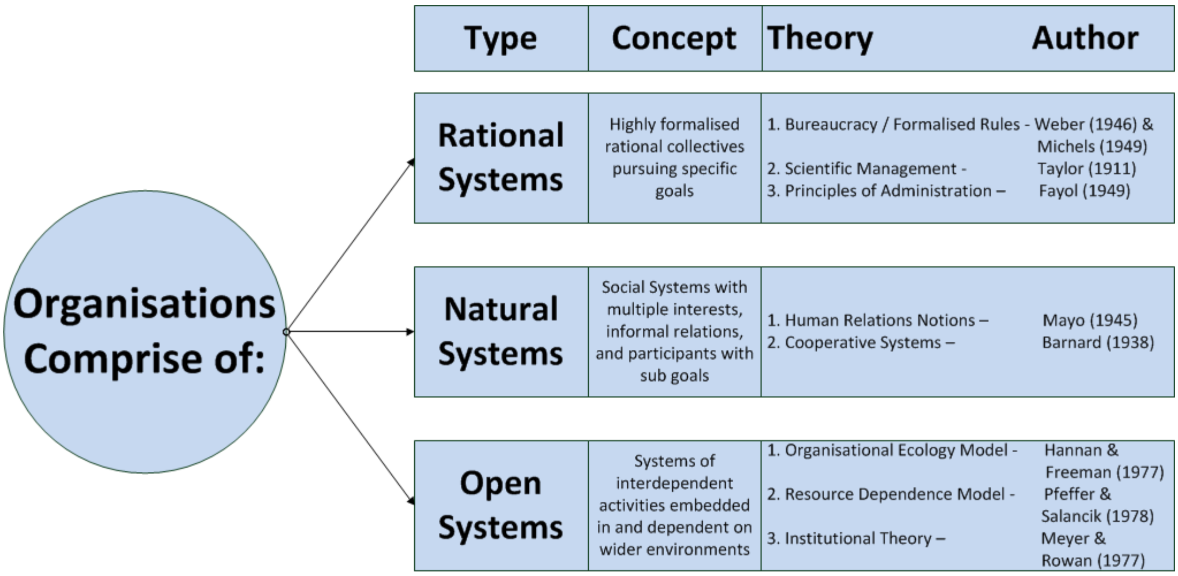

Figure 7 - Systems Based Classification (Scott and Davies, 2007)

The fourth dimension reflects one of the major difficulties with many research studies that are undertaken is that they adopt a 'survivor only selection' bias. This means that many studies only look at the successful organisations, which by implication means that they ignore those organisations that failed and were unsuccessful. Clearly, focusing on those that survived prevents full analysis of 'cause and effect'.

As Weick highlights 'Such research invites retrospective rationality, as illustrated by notorious cases where strategic analysis consisted of post hoc rationalizing of events that, in fact, developed over time in unexpected and unplanned ways' (Weick, 1995), cited by (Barnett and Burgelman, 1996).

A comprehensive study of policy must therefore take many factors into consideration when researching organisation failures. Much of what is undertaken will be guided by the research Theme, Schools or Perspectives of Organisation, coupled with a decision to undertake static or dynamic analysis and a decision about what unit of analysis of appropriate.

4.8 POLICY ANALYSIS AND MODELLING

This chapter will present a synopsis of the techniques that can be used for policy modelling, concentrating on those that have relevance and application to the field of energy policy. It will consider the need for models, the background to modelling, the types of model used, modelling approaches, and specific models and techniques. The majority of the literature used in this chapter is the result of a search within 'Energy Policy' using the key words of 'energy policy' and 'policy analysis', this identified circa two hundred relevant articles.

4.8.1 THE NEED FOR POLICY MODELS

In the UK, the need for energy modelling relates back to the nationalisation period of the EGI in 1947, when models were used to plan the relationship between electricity supply and demand. Webb's research of the UK government's energy policy, as recorded in the Energy Policy Consultative Document (1978) identified that UK energy policy was based on three policy objectives, the provision of adequate energy supplies (so as not to constrain economic growth), security of energy supplies at the least social cost, and the efficient allocation of energy resources. His paper further remarked that UK government was charged with responsibility for the 'change of pattern of energy use' and adopted a focus on market-based mechanisms to ensure resources allocation using an energy pricing mechanism that premised upon long-run marginal (social) costs (Webb, 1985).

As Webb was conducting his research, the UK government was starting to prepare for privatisation. The Government's focus comprised five main energy policy targets: the promotion of efficient allocation of resources to stimulate competition, provision of incentives for marginal efficiency, reduction or elimination of government interference in the operation of the UK industrial base. Additionally, there was an ideological objective to reduce the size of the state (by removing industries from the state umbrella), and lastly an economic objective to reduce the size of the Public Sector Borrowing Requirement (PSBR).

Sorrell (2007) notes that in defining energy policy there is a strong bias towards econometric analysis of secondary data and economic modelling. He also remarks that policy evaluation was relatively weak in many areas (Sorrell, 2007). His observation is very significant because it highlights that an alternative modelling approach would be of both academic and commercial value. This supports one of the crucial underlying justifications for this thesis, namely the need to understand how empirical appraisal of energy policy can exploit understanding of the key frameworks and policy analysis models.

4.8.2 BACKGROUND TO POLICY MODELLING

The 20th Century has seen the public sector being subject to intense scrutiny, with rising evidence of public frustration and disappointment in public sector delivery (Capros and Samouilidis, 1988).

The 1960s and 1970s witnessed a period during which a series of common policy prescriptions were evident. These were firstly the belief that electricity pricing should be based on marginal cost, energy resource actualisation rates, secondly the sustainable extraction of depletable natural resources, next the use of linear programming in the operational planning of oil refining, and lastly investment planning in the electricity sector. However, these policy prescriptions also suffered from a microeconomic focus that gave rise to wider problems. Specifically, energy was treated in isolation, energy demand was viewed as being directly related to economic growth, and the feedback effects between energy consumption and the economy were considered insignificant (Capros and Samouilidis, 1988).

Despite these early constraints and limitations, Britain was becoming a trendsetter in the privatisation of utilities, and having privatised the electricity sector, the government turned its attention to the regulatory regime necessary to control prices (typically using RPI-x type price controls), and to enhancing the level of competition in the electricity markets. In part this was a result of unbundling the generation of electricity from its supply and from the monopoly transmission and distribution networks (Dastan, 2011). This implied that the policy actions by government were to privatise first and then determine the most appropriate control mechanisms. This sequence of events was clearly not the most efficient.

In addition to privatisation, the UK's model of utility regulation was widely adopted by many jurisdictions across the world. The desire to adopt the UK's policy prescriptions was often associated with conditionalities attached to the receipt of aid from donor countries and institutions (e.g. The IMF, World Bank, European Union et al.). The model was also promulgated by many of the international consulting firms (who implemented standardised regulatory frameworks and templates) or as a response to an energy crisis. All of which effectively produced a form of coercive globalisation (Dastan, 2011).

The frameworks and shortfalls identified above, led to a renewed focus on the development of energy policy modelling in the UK. The result was the adoption of Markal-based models, such as those used in the modelling of the UK 2007 Energy White Paper and the 2007 Climate Change Bill. Although the approach gained traction, many researchers identified that this approach also suffered from a number of limitations. For example, the UK2R Markal model is useful for national and regional policies related to carbon dioxide emissions and renewable energy policy (Anandarajah and Strachan, 2010), but it does not specifically attempt to model energy policy impacts or policy outcomes directly. Other limitations include the fact that benchmark models typically are only able to address specific analytical questions, therefore highlighting the tension between the policymakers (who want specific answers) and the modellers (who can only give insights) or the realisation that the recent focus of modelling has been predominantly linked to long-term decarbonising scenarios, and not to wider policy evaluation (Strachan et al., 2008). Strachan et al. (2008) recognised that the evaluation of energy models should concentrate upon the extent to which their focus could be based on defining baseline policy measures, their flexibility in achieving energy goals, the substantive mechanisms within the model that can accommodate technical change and their evaluation of policy benefits.

4.8.3 TYPES OF ENERGY POLICY MODEL

Focusing upon the types of models that are used in energy policy analysis, Bejan and Bejan (1982) identified that most models were demand-only models, whereas they argued that policy formation should be focused on the supply side considerations (Bejan and Bejan, 1982). Berglund et al. (2006) also identified that many energy models are E3-models (energy, economy and environment based), and are therefore were either top-down or bottom-up models that typically focused upon analysis of emissions management or technological choice.

Anandarajah and Strachan (2010) remarked that energy system modelling could be further categorised as 'Top-Down' input-output models based on macroeconomic computable equilibrium models (which focus on endogenous market adjustments or technological details), 'Bottom-up' integrated energy system models that seek to achieve dynamic optimisation, or 'Hybrid' models that seek to minimise the trade-offs (between technological explicitness, microeconomic realism, and macroeconomic completeness) (Anandarajah and Strachan, 2010).

A more precise definition of the aggregate demand models, developed by organisations such as the IEA, EPRI, OECD, US DOE, and US EPA, made use of input parameters based on population, trade, fiscal policy, land supply, population productivity, GDP & GDP sector mix and housing stock parameters to model the emissions and GNP losses as outputs (Strachan, 2011).

4.8.4 POLICY MODELLING APPROACHES

In addition, to the systems models described above, there are six other modelling approaches discussed in the literature. These include energy back casting, evidence-based policy & practice (EBPP), exergy versus energy, gaming, behavioural, and energy security models.

Energy Back casting (backwards looking analyses, as opposed to forecasting) modelling was defined by Amory Levin, as a means of indicating the relative implications of different policy goals. It recognises that plant and equipment lifespans for energy and electricity generation are typically 25-75 years (Robinson, 1982).

The Energy Back casting method uses the framework shown in table 3:

Step	Description	Tasks
1	Specify goals and constraints	For the modelling activity
2	Describe current energy consumption and production	Develop a detailed description of present energy consumption and production, by source, fuel, sector, type and end-use and specify primary and secondary production and consumption, and, as far as possible, tertiary consumption.
3	Develop outline of future economy	Choose end-point date
		Construct a model of the end-point economy
		Choose mid-point dates; and
		Derive a demand scenario (list of end-use demands) that corresponds to the results of the model
4	Undertake demand analysis	Determine demand management measures necessary over time to attain these secondary profiles
		Specify the costs of the measures outlined in the demand scenarios.
5	Undertake supply analysis	Develop an inventory of available supply sources
		Match available supply sources to secondary consumption profile
		Derive energy supply industry requirements to supply the energy required
		Develop a primary energy requirements profile by adding together the results of the above two steps
		Determine those supply policy measures necessary overtime to attain the primary consumption profiles
		Specify the costs of the measures outlined
6	Determine Implications of the analysis	Analyse the social, environmental, economic, political and technological implications of the supply and demand analyses.

Table 3 - Energy Back casting Model, summarised by the author using Robinson (1982)

Evidence-based Policy & Practice (EBPP) models are systematic reviews used in many policy areas (healthcare, education, social work, urban regeneration etc.). EBPP models 'integrate experience, judgement and expertise with the best available external evidence from systematic research (Davies, 1999) cited by (Sorrell, 2007). EBPPs seek to balance formal research evidence and systematic research.

Exergy versus energy models recognise that no energy source is environmentally neutral and that energy modelling must recognise that interaction between nature and society in a more explicit manner (Dincer, 2002). The differences in this approach are summarised in table 4:

Energy	Exergy
Is dependent on the parameters of matter or energy flow only, and independent of the environment parameters.	Is dependent both on the parameters of matter or energy flow and on the environment parameters
Has values different from zero (equal to mc2 in accordance with Einstein's equation)	Is equal to zero (in a dead state by equilibrium with the environment)
Is guided by the first law of thermodynamics for all the processes	Is guided by the first law of thermodynamics for reversible processes only (in irreversible processes it is destroyed partly or completely).
Is limited by the second law of thermodynamics for all processes (incl. reversible ones)	Is not limited for reversible processes due to the second law of thermodynamics.
Is motion or ability to produce motion	is work or ability to produce work
Is always conserved in a reversible process, so can neither be destroyed nor produced	Is always conserved in a process, but is always consumed in an irreversible process
Is a measure of quantity	Is a measure of quantity and quality due to entropy

Table 4 - The main differences between Energy and Exergy, Dincer (2002)

Gaming models utilise an alternative approach to policy analysis which is suited to situations in which stochastic situations involve a high degree of risk taking' (Saaty et al., 1977). They comprise free games (in which rules, relationships, new actors can be admitted to the game as it proceeds – used in strategic planning or political science), or rigid games where the parameters chosen at the outset are fixed. Such games can be framed at the macro scale which are composite scenarios (that define the forces controlling the situation, actors and their objectives), or micro scale which are inter-industry models and are used to test the impact of policy models (economic growth models, micro equilibrium models and economic Input/Output models, energy consumption, and environmental pollution) (Saaty et al., 1977).

Behavioural models recognise that the success of energy policy crucially related to the level of public support. This implies that policy support is in part driven by risk perceptions, affective and emotive reactions, and cognitive beliefs (Truelove, 2012).

Energy security models concentrate on one of the main tenents of governmental energy policy. There are a number of alternative approaches to defining energy security modelling and indication (Hughes, 2012). The first is the use of the Sankey diagram that presents whole economy energy flows diagrammatically. The second is the use of 'aggregated energy related indicators' as used by the OECD to assess nations against one another. One such comparative approach is utilised by the IEA to measure the availability (energy inputs and outputs), affordability (cost of energy conversion and transportation) and acceptability (environmental acceptance). The third approach is to use a basket of indicators as exemplified by the twenty dimensions and two-hundred metrics adopted by (Sovacool, 2011).

Considering these models i.e. energy back casting, evidence-based policy & practice (EBPP), Exergy versus, energy, gaming, behavioural, and energy security models it can be seen that none of them is specifically designed to conduct or allow analysis of the impact of individual energy policy instruments, or groups of policy instruments, on corporate demographic or technology-change based vital event data.

4.9 SELECTING THE THEORY BASELINE

This section will define the rationale for the choice of theory base that has been adopted by considering the choice of research tools, why organisational ecology, and research theory base.

4.9.1 CHOICE OF THEORY UMBRELLA

Having presented a very detailed synopsis of the origins of competition theory, origins of regulatory policy, economics of regulation, strategic and organisational analysis, organisational analysis techniques, Aldrich and Ruef's six evolutionary perspectives, unit of analysis and policy analysis and modelling it is now imperative to determine which of the above should be utilised in the practical research.

The first consideration is whether the research should be conducted using a normative or positivist philosophy. The key objective at the outset of this research was to understand how energy policy instruments, and their umbrella policy objectives, operated. Secondly, to understand the impact of energy policy on generators. This suggested that the study was an investigation into 'what the EGI is' as opposed to 'what it should be'. The focus was therefore on an analysis of the 'As Is' situation that could be used to draw inference from the manner in which energy policy interventions had affected the EGI. Clearly, this places the research into the Positivist camp; it also implies that the traditional economic framing of market and non-market failure analysis is not applicable.

Adopting Barnett and Pontikes' (2005) rationale that states that research broadly falls into two main types of process analysis i.e. whether to adopt a strategic or organisational perspective to the research. The former will mandate research into the organisational decision-making processes (i.e. based on decisions made by the organisation), whereas the latter requires research of the organisational adaptational and selectional processes. Given that the study will span twenty-years and will involve upwards of two hundred and fifty organisations, wherein much of the data is proprietary and many of the key players have left the industry, implies that the study must adopt adaptational and selectional processes.

Following Barnett and Pontikes' (2005) the choice is whether or not to conduct a static model that uses the adaptational approach, or a dynamic model that uses an evolutionary selection-based model based on random variation. Having considered the justifications for each it was decided that a dynamic approach was more pertinent to 'unknown' nature of policy intervention on the industry.

Following Aldrich and Reuf (2006) there are six main theoretical frameworks available. Having carefully considered each of these, and their research techniques[5], it was decided that because the study would involve a population 'unit of analysis' the most applicable theory was an ecology theory.

[5] Particularly the corporate demography and event history analysis methods.

4.9.2 CHOICE OF RESEARCH TOOLS

Notwithstanding the above, as the study progressed it was deemed important to determine whether energy policy modellers had any dedicated tools that be used could to assist with the data collection and analysis. The review of literature has highlighted that most of the recent energy policy research has been focused on whole-economy systems modelling with software-based models such as POLES, PRIMES, MARKEL (Rafaj and Kypreos, 2007, Smekensramirezmorales, 2004, Strachan, 2011). At the outset, it was decided that this approach should not adopted, because it does not provide an obvious framework from which to incorporate energy policy variables. The main justification for this is that the models operate at the level of the whole economy and do not operate specifically within the electricity generation sector, nor do they attempt to evaluate energy policy instruments individually.

Economic baseline modelling techniques such as Cost-Benefit Analysis (CBA), and Cost-Effectiveness Analysis (CEA) also suffer from a number of limitations such as: the lack of availability of proprietary and commercially confidential financial data (i.e. costs, prices and management accounts for the circa 210 EGI generators), and the fact that markets for pollution and emissions are imperfect and that pricing may be unrealistic (Klick and Smith, 2010, Loschel and Otto, 2009, Ürge-Vorsatz and Novikova, 2008).

The behavioural approach associated with 'Willingness-to-Pay' (WTP) considerations is based on behaviour evaluations that would be difficult to implement across the EGI population in a consistent manner over the twenty-year historical period (Devine-Wright, 2011, Litvine and Wüstenhagen, 2011, Masini and Menichetti).

The political science approaches of seeking to understand public policy by considering how energy policy was developed, how applicable policy instruments were selected to support the chosen energy policy, and reconciling how competition and regulatory policy enter the political science mix, were discounted. This was because they are based on economic arguments, the testing of which require financial data that would be impossible for a single independent researcher to obtain (Brooks and Krugmann, 1990, Capros and Samouilidis, 1988).

Value-Chain Analysis (VCA) and Life Cycle Assessment (LCA) techniques, which can be used to assess the environmental loads of a product or a system, were also deemed to be inappropriate because of the challenge of obtaining uniform and consistent data for 704 power plants (some of which no longer exist) across the relevant twenty-year period (Lund, 2009, Varun et al., 2009, Zheng et al., 2009).

The above suggests that it is necessary to identify tools and techniques that overcome the lack of financial and empirical data (because of difficulties of availability, confidentiality, consistency and uniformity over a twenty-year period). Given the above, it is imperative that indirect indicators of energy policy, technology price performance and availability will have to be used. Further, given the complexity and labour effort in collecting the necessary data it is also vital that the tools have been proven in similar environments.

The review of the literature identifies the following relevant articles (Barnett, 2008, Dobbin and Dowd, 1997, Russo, 2001, Sine et al., 2005, Sine and Brandon, 2009, Tushman and Anderson, 1986). These highlight the successful employment of such techniques in studies of regulatory policy, independent power producers and wind turbines in a US context, further these authors have used techniques built upon the fundamental principles of organisational ecology analysis.

4.9.3 WHY ORGANISATIONAL ECOLOGY?

Looking in more detail at the use of Organisational Ecology (OE) techniques suggests that this theoretical baseline might be appropriate to this research study because of the following factors: OE theory fragments have been applied to long-range studies, predominantly in the US context, but with a few investigations also into the European automotive sector. OE techniques have been in use for some forty years, since the publication of the seminal work by Hannan and Freeman (Hannan and Freeman, 1977).

The OE approach of adopting organisational vital events (birth/founding rates, growth rates and death/failures rates) to indirectly model the impact of selectional forces on populations of organisations (and not just individual organisations) sets the technique above most others in terms of its application and at the outset appeared highly relevant to the twenty-year history of the EGI. A significant proportion of the research work in this thesis adopts the use of founding and failure duration rates as an inferential means for analysing the behaviour of the generator companies that own the electricity generation plants. The benefit of this approach is that it can also utilise the duration of power plant ownership and the initiating of vital events that preceded investment or divestment decisions by the owners.

OE typically adopts a quantitative and empirical approach based upon the use of secondary data from published and readily available data sources, and does not rely on personal observation or interpretation in the same way as would be the case with qualitative data. Finally, OE allows the use of organisational form (Hannan et al., 2007), technology (Sood et al., 2012, Tushman and Anderson, 1986), competition (Barnett and Carroll, 1987), and organisational strategy (Boone and van Witteloostuijn, 2004, Voepel et al., 2003) to be assessed and measured.

4.9.4 THE RESEARCH THEORY BASE

The theoretical construct used to develop the research draws from a number of key insights. The first is Hawley's (1968) statement that the 'Diversity of forms is isomorphic to environmental variation', which Burns & Stalker (1961) and Stinchcombe (1965) extended to recognise that 'Organisation structures contain a large inertial component' that prevent rapid change and adaptation in response to changes in environmental conditions. The work by Blau & Scott (1962) suggested that an organisational ecology perspective has some differences to the bioptic world because 'Unlike biological organisations, individual and organisation populations can expand almost without limit'.

Attempting to understand how organisations might thrive or decline in environments Hannan and Freeman (1972) suggested that organisational 'Fitness is the probability that a given form exists in a certain environment'. This was placed in to an empirical setting by Levins (1962, 1968) and Hutchinson (1957) who suggested that fitness could be understood by the 'Theory of Niche Width suggests that a niche is a combination of resource levels that allow Populations to survive and reproduce themselves'. In this situation, Hannan and Freeman stated that 'Niche theory operates unless the duration of environmental states is short-lived, in which case resource Partitioning may arise'.

Placing this into the energy policy setting, to assess how policy instruments and policy objectives relate to environmental conditions Dobbin and Dowd (1997) remarked that 'Policy creates competition in the first place by establishing the legal framework, monetary system and rules of exchange'. However, this statement was at variance with the OE founding father's views in as much as that Dobbin and Dowd identified that Hannan and Freeman (1995) were wrong. They stated that 'Regulatory directives in any population do pre-emptively affect population evolution before selectional and adaptational forces operate'.

Looking at how the evaluate the impact of energy policy suggests that an evaluation of competitive viability might be insightful using Barnett's (2008) observation that 'Competitiveness is not a property of markets, but varies from organisation to organisation'. Having considered competitiveness it is also important to evaluate how market concentration might be impacted by energy policy. This highlighted Witteloostuijin & Boone's (2005) amalgamation of organisational ecology and industry organisation to conduct analysis of the EGI market and further recognised that Dobrev et al.'s (2002) research findings that 'Almost all important variations in market concentration can be attributed to crowding and concentration'

Recognising the factors above, organisational ecology theory and techniques were selected as the basis of the study, to provide: New Organisational Dynamic Knowledge – Studying the impact of energy policy specific to renewables on a population of organisations under the same form of ownership, i.e. privately owned, will yield new organisational knowledge. New Technical Impact Knowledge – EGI players have been required to implement new technology that has a negative price/performance curve (i.e. renewables are more expensive that the generation technologies based on fossil fuels). The study will yield new knowledge about the impact of forcing technology with a negative cost curve upon an industry. New Electricity Policy Knowledge – Previous studies by Russo (1992), Sine et al. (2005), and Sine & Brandon (2009) were in the US setting and considered ownership of generators under both public and private ownership. This study will provide insight into how policy instruments influence the EGI and will provide new knowledge. New Geographic Knowledge - in a European context in the EGI – most organisational ecology studies have focused on the US, and those that have not (and in this domain) are at least ten years old. A Multi-faceted Study – unlike most research studies, this research is conceptually and methodologically multi-faceted underpinned by multiple theories and empirical techniques, with the data being collated from 2,000 power plant vital events and 8,000 organisational vital events over the period 1991-2011.

4.10 CHAPTER SUMMARY

This chapter has provided the reader with a synopsis of the theory strands that were reviewed as part of determining which research philosophy was most appropriate for the research. This was discussed under the headings of origins of competition theory, origins of regulatory policy, economics of competition and regulation, strategic and organisational analysis, organisational analysis techniques, Aldrich and Ruef's six evolutionary perspectives, unit of analysis and policy analysis, modelling and the selecting the theory baseline.

The purpose of the chapter is to relate the theoretical framework and approach to the research design and implementation that will be discussed in the following chapters.

5. ELECTRICITY GENERATION IN THE UK

5 ELECTRICITY GENERATION IN THE UK

This chapter will examine the empirical setting of the UK electricity generation industry (EGI), the Importance of the EGI to the UK economy, Electricity transmission and distribution in the UK, The regulatory framework, System resilience and Summary of the EGI high-level structure.

5.1 THE EGI IN PRACTICE

The early electricity industry was characterised by engineering-led organisations responsible for the design, development, implementation and operation of the electricity supply in the UK. This extended to the National Grid (as part of the CEGB) which consisted of the Super Grid - 9,000 miles of, the high voltage transmission that in the 1950s and 1960s was consolidated into a network that operated at 275kV and 400kV. It also covered the Low voltage distribution network – 40,000 miles of facilities that were developed to link the high voltage system to the industrial, commercial and retail consumers. Lastly were the High voltage interconnectors between Scotland (1GW capacity) and France (2 GW) that allowed the purchase or sale of electricity (The Electricity Council, 1987).

The productive capability of the EGI in terms of its MW output capacity is illustrated in figure 8:

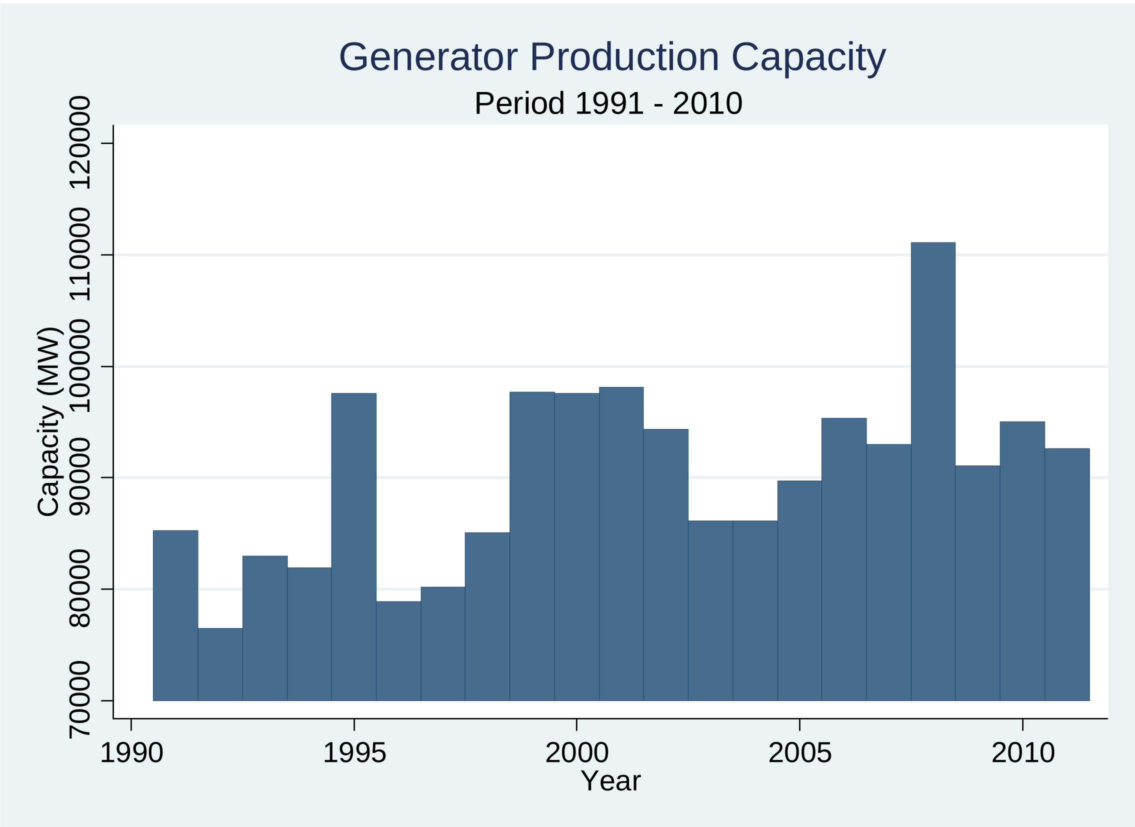

Figure 8 - Generator Production Capacity (1990 - 2010)

It is interesting to note that in common with most other utilities, the UK's high voltage transmission and local electricity distribution networks are 'natural monopolies' in economic terms. This fact would ensure that they would be subject to a different regulatory requirement than the generators or suppliers of electricity after privatisation.

5.1.1 THE EGI IN ENGLAND AND WALES

The CEGB comprised five regions that oversaw the power stations and electricity transmission plus the central service facilities (planning, R&D etc.).

The National Grid's function within the CEGB was controlling and scheduling the power stations and electricity flows through the Grid using a cost driven 'merit order' system that was designed to minimise the cost of generation and ensure adequate load on the system (National_Audit_Office, 2010).

The twelve Area Boards, as distinct from the CEGB, were responsible for the local (low voltage) distribution of power and supply of electricity to domestic, commercial and industrial consumers within their geographical regions. The Area Boards managed low voltage distribution to circa 20 million customers.

With the exception of a few large electricity users, who had the right to buy electricity directly from the CEGB, all other consumers had to deal through the Area Boards to purchase their electricity.

Alongside the CEGB, and the Area Boards, an Electricity Council provided a co-ordinating role on matters of industry-wide concern including pay bargaining, marketing, research and development, and provided advice to Government.

5.1.2 THE EGI IN SCOTLAND

In Scotland, there were two state-owned electricity boards, one for the North of Scotland and one for the South of Scotland. Each board was vertically integrated and controlled electricity generation, distribution and supply in its area (Parker, 2012). The North of Scotland Hydro-electricity Board's (NSEB) pedigree dated back to 1943, and the South of Scotland Electricity Board (SSEB) can be traced back to 1955. The SSEB was the larger of the two entities with nearly four million customers and about six GW of generating capacity.

5.1.3 THE EGI IN NORTHERN IRELAND

In Northern Ireland, the electricity delivery was somewhat different given the size of the province there was just one, vertically integrated, state-owned supplier (Parker, 2012).

5.2 IMPORTANCE OF THE EGI TO THE UK ECONOMY

The EGI was the major customer for the coal, nuclear and power plant industries in Britain, typically purchasing about three quarters of the British coal industry's output ahead of the miners' strikes in 1984-1985 (Parker, 2012). In addition to the revenue expenditure during the 1980s, the CEGB had a capital expenditure programme of some £750 million per annum, whilst the 12 Area Boards also had an expenditure of around £400 million per annum. Around 75 per cent of the electricity industry's costs at that time could be accrued to the generation of electricity.

Many commentators have highlighted that the EGI industry was generally successful during the post-war years in providing a reliable electricity supply, especially with its ability to meet winter peak demand even if subjected to plant and transmissions faults (Helm, 2008, Parker, 2012). However, other commentators suggested that the industry had become too technically led, was overly fond of complex costly engineering solutions, and that it placed an over-reliance on nuclear generation (whose costs were far from transparent) (Simmonds, 2002).

The critics also accused the EGI of adopting a 'cost-plus mentality' to pricing policy, building excessive generation and transmission redundancy into the system, and like many public corporations at the time being subjected to over-manning and union dominance (Newberry and Green, 1992).

5.3 ELECTRICITY TRANSMISSION AND DISTRIBUTION IN THE UK

The electricity transmission and distribution system is based upon: the physical system; the wholesale and retail markets; the balancing mechanism; the transmission, distribution, exports & imports; the generators and suppliers; the policy framework, the regulatory framework, and the system's resilience (National_Audit_Office, 2010).

5.3.1 PHYSICAL SYSTEM

The structure of the UK's electricity system is hierarchical. At the origin of the system large-scale generation assets can be found and these generate at voltages in the range 11-15kV. Once the electricity generation has occurred, a 'step-up' transformer increases the voltage to either 400kV or 275kV, (these high voltages minimise the losses associated with transmission of the electricity to the load centres (e.g. cities and towns). The network formed by these very high voltages is termed the 'super grid' and comprises some 25,000 km of cabling that can be 'seen' transmitting the electricity pylons around the country (Parliamentary_Office_of_Science_and_Technology, 2007):

The sub transmission network, between the super grid and the distribution grid (used at the local level), operates at 132kv. It is at this level in the system hierarchy that all small independent generators (e.g. Combined Heat and Power [CHP] plants and other larger renewably sourced generators) typically interface to the electricity system. This means they do not generate at the centre (like the traditional large-scale fossil generators) but are 'embedded' in the distribution network and are termed Distributed Generators.

At the load centres, (i.e. where the electricity is ultimately used) the very high voltage transmission system connects to 'step-down' transformers which reduce the voltage to either 33kv, 11kv, 6.6kv so that the electricity can be distributed to the radial distribution networks across the country to factories, offices and domestic homes. The small-scale embedded renewables generators also connect to the electricity system at the remote points in the hierarchy (near to the consumers). In the UK there are circa 800,000 km of distribution network cabling installed across the country (Weedy and Cory, 2004)

The physical system is represented diagrammatically (National_Audit_Office, 2010), shown in figure 9:

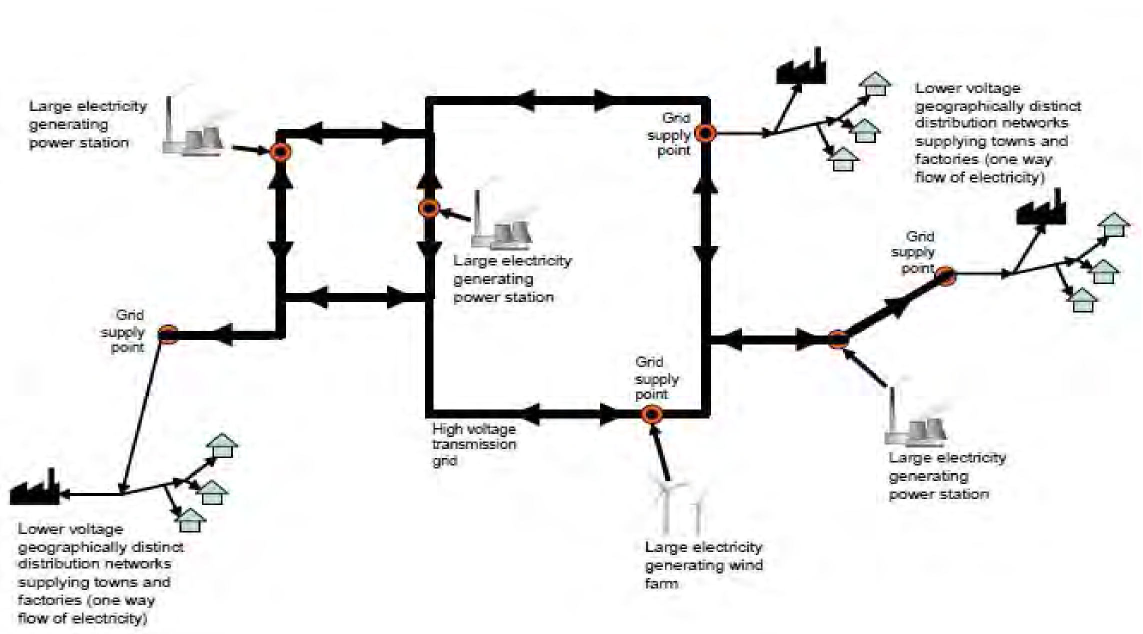

Figure 9 - The Physical System - Conceptual View

5.3.2 WHOLESALE AND RETAIL MARKETS

The electricity market comprises both the wholesale and retail markets; these represent the British Electricity Transmission and Trading Arrangements (BETTA), which along with the statutory legislation frame the electricity markets in the UK. Currently, in excess of 95% of UK generated electricity trades within the wholesale market i.e. between generators, electricity suppliers, and industrial & commercial companies. Diagrammatically (National_Audit_Office, 2010), shown in figure 5:

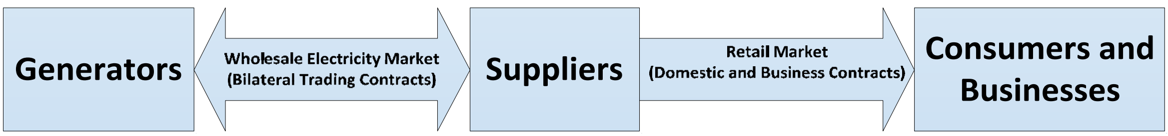

Figure 10 - The Wholesale and Retail Markets

5.3.3 BALANCING MECHANISM

Electricity storage, at cost-effective rates, is generally not available at present and consequently it is necessary to attempt to match the minute-by-minute demand between generators and consumers on a real-time basis. The organisation charged with the coordination and scheduling of the system is the National Grid (which is licensed by OFGEM), although in practice this role is contracted out to Elexon – who recover their costs through charges (Balancing Services Use of System) that are levied onto the generators and suppliers (National_Grid, 2010). The trading arrangements operate on a rolling half-hourly slot, 24 hours per day and for every day of the year. 'Gate closure' is the finalisation of the arrangements one-hour ahead of the consumer's demand time. The balancing system operates by means of 'bids' and 'offers' by generators and suppliers and they set out the price that they would be willing to increase generation or reduce demand (bid), or reduce generation and increase demand (offer). At 'Gate Closure' the system operator chooses the bids and offers to enable a balance between supply and demand (National_Audit_Office, 2010), show in figure 6:

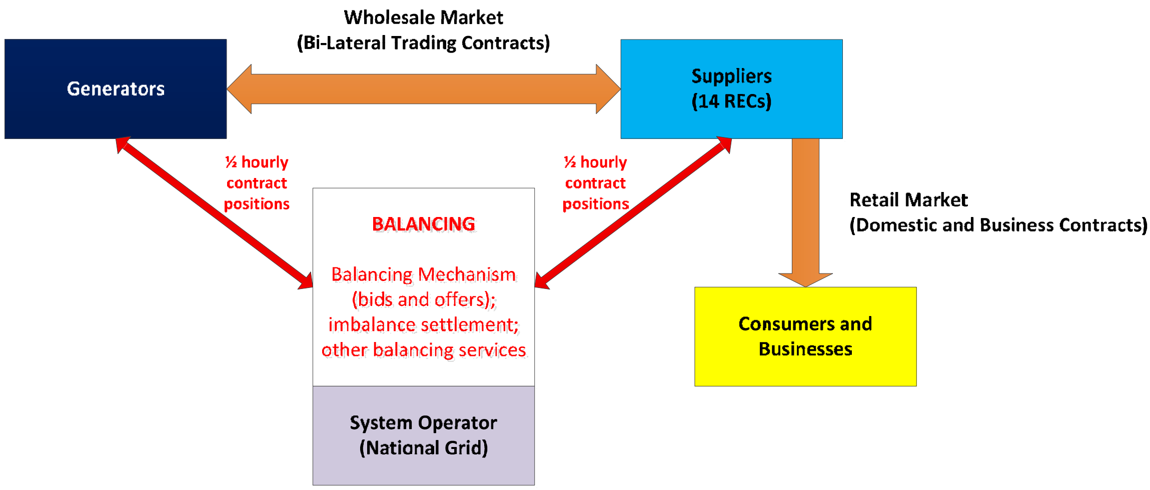

Figure 11 - The Balancing Market

5.3.4 TRANSMISSION, DISTRIBUTION, EXPORTS AND IMPORTS

The technical attributes of the transmission and distribution system were outlined above, and now the discussion will focus on understanding the commercial attributes. The transmission network is a monopoly operated by the National Grid (in England and Wales), whose costs are recovered from generators and suppliers through the Transmission Network Use of System (TNUoS) charges. The distribution network in the UK is operated by two different entities. The first is the Distribution Network Operators (DNOs) and the second are non-geographically based Independent Distribution Network Operators (IDNOs). Both types of operator recover their costs through the Distribution Use of System (DUoS) charges.

In addition to the local onshore networks, there are two other components within the system: the Interconnectors (which link the networks in England with France, Netherlands, Northern Ireland and Scotland), and the Offshore Grid that will link the wind farms in the North Sea. This is still in development (Grid, 2010).

The relationship between the entities is shown in figure 7:

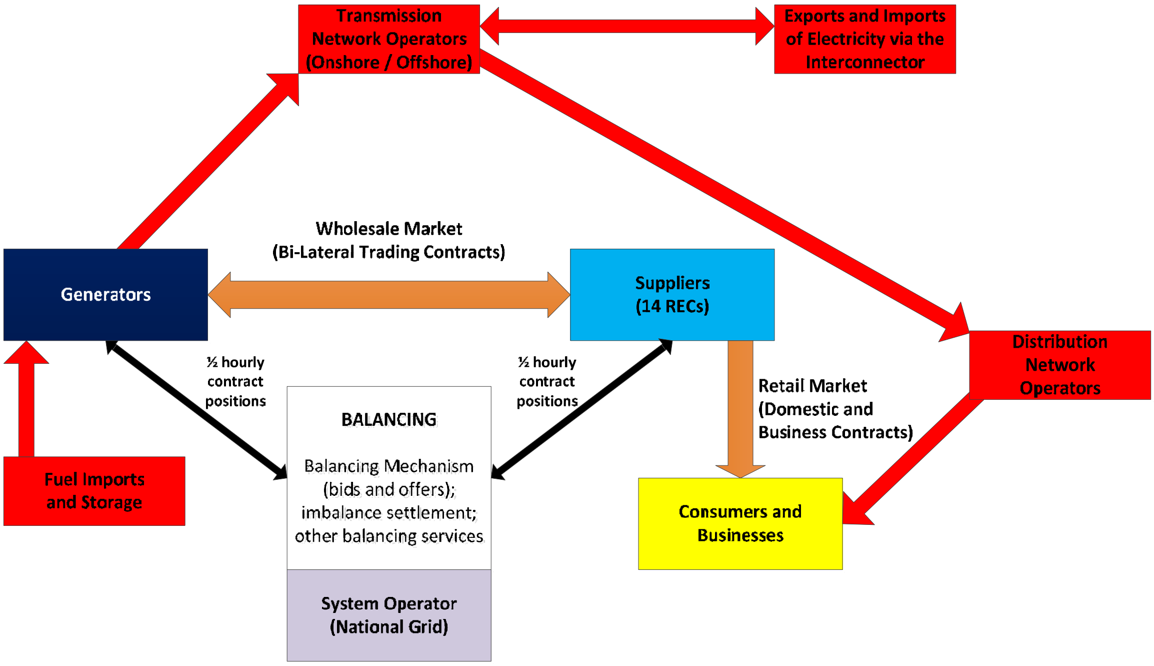

Figure 12 - Transmission, Distribution and Interconnection (National_Audit_Office, 2010):

5.3.5 UK GENERATORS AND SUPPLIER RELATIONSHIP

The producers and suppliers in the UK electricity system are shown in figure 9. In addition, to the entities shown below there are also mainstream generators and the independent generators who operate independently and frequently through long terms contracts with the 'Big Six', as shown in figure 8:

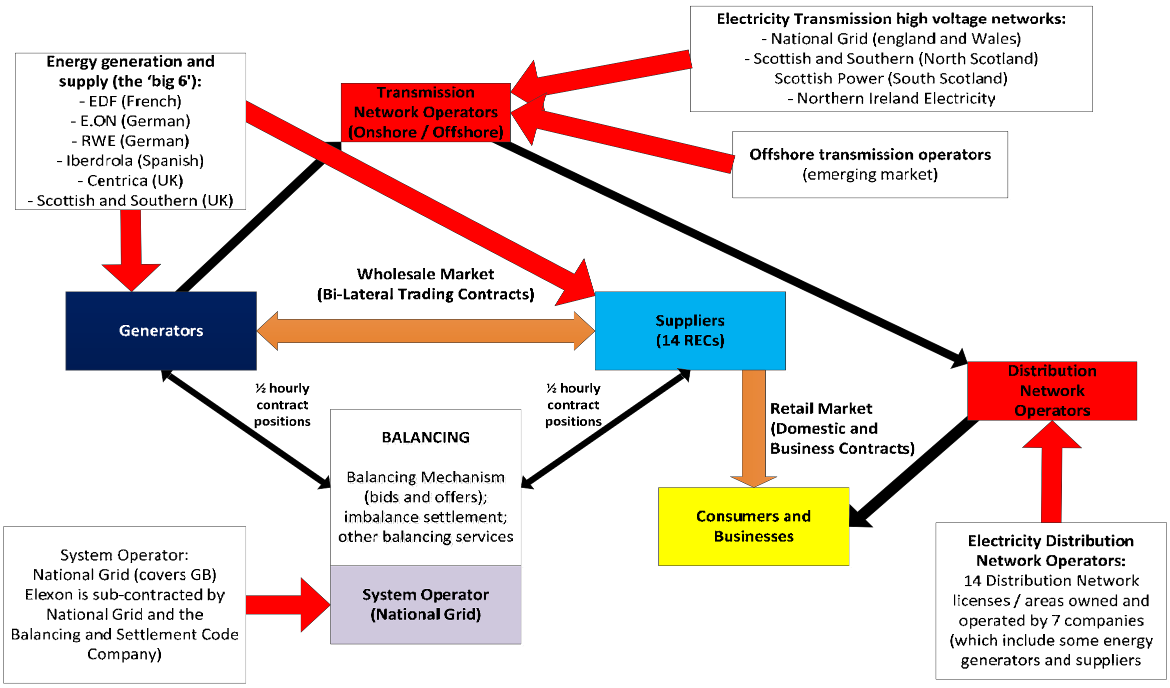

Figure 13 - The Main Players in the UK Electricity System (National_Audit_Office, 2010)

5.3.6 UK ELECTRICITY SUPPLY INDUSTRY – POLICY FRAMEWORK

The detailed policy framework adopted in the UK is shown in figure 9:

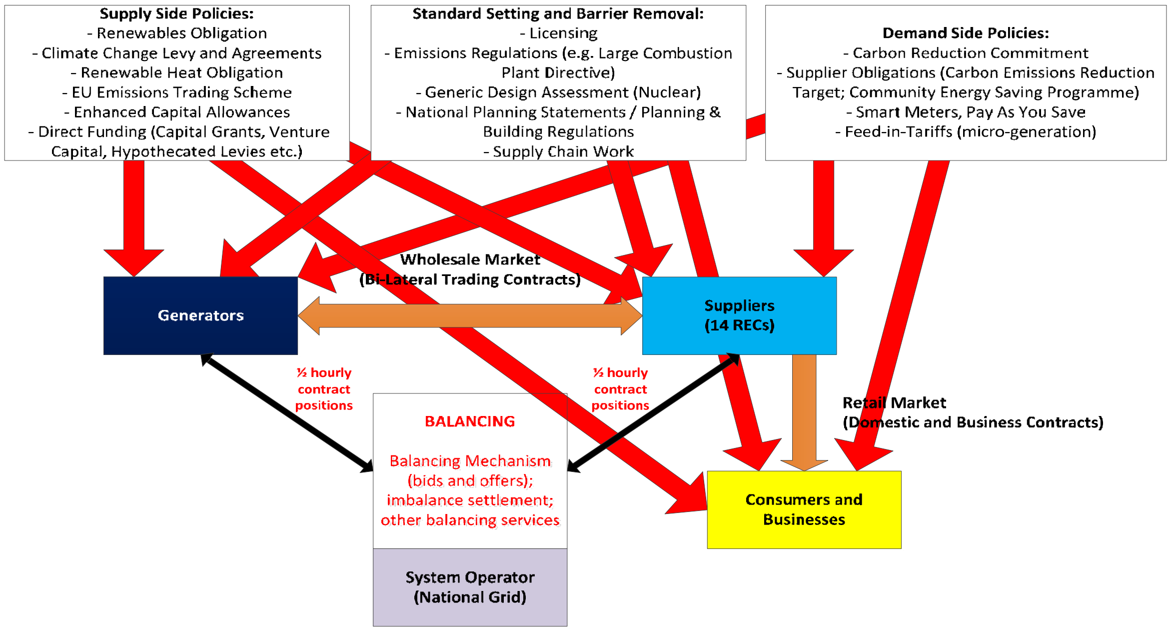

Figure 14 - The Electricity Industry Policy Framework in the UK (National Audit Office, 2010)

5.3.7 THE REGULATORY FRAMEWORK

The regulatory framework is shown in figure 10:

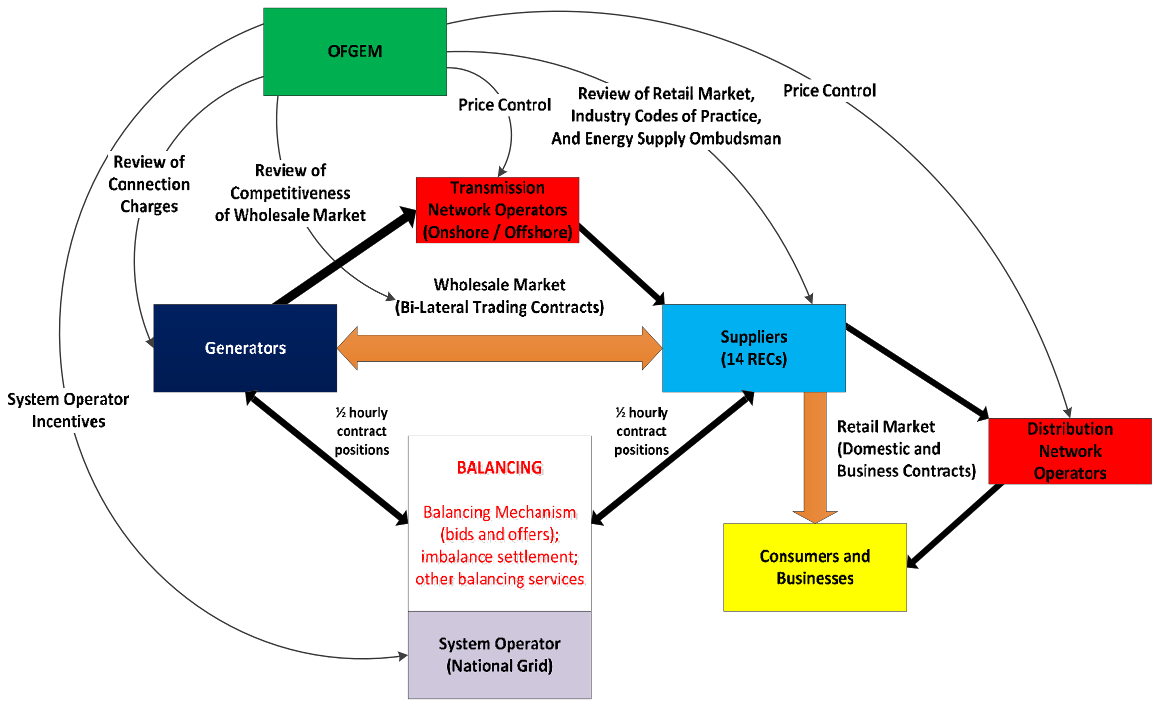

Figure 15 - The Regulatory Framework (National Audit Office, 2010)

5.3.8 SYSTEM RESILIENCE

The last element in the discussion of the transmission and distribution system relates to the techniques and options that allow the system to operate with resilience as shown in figure 11.

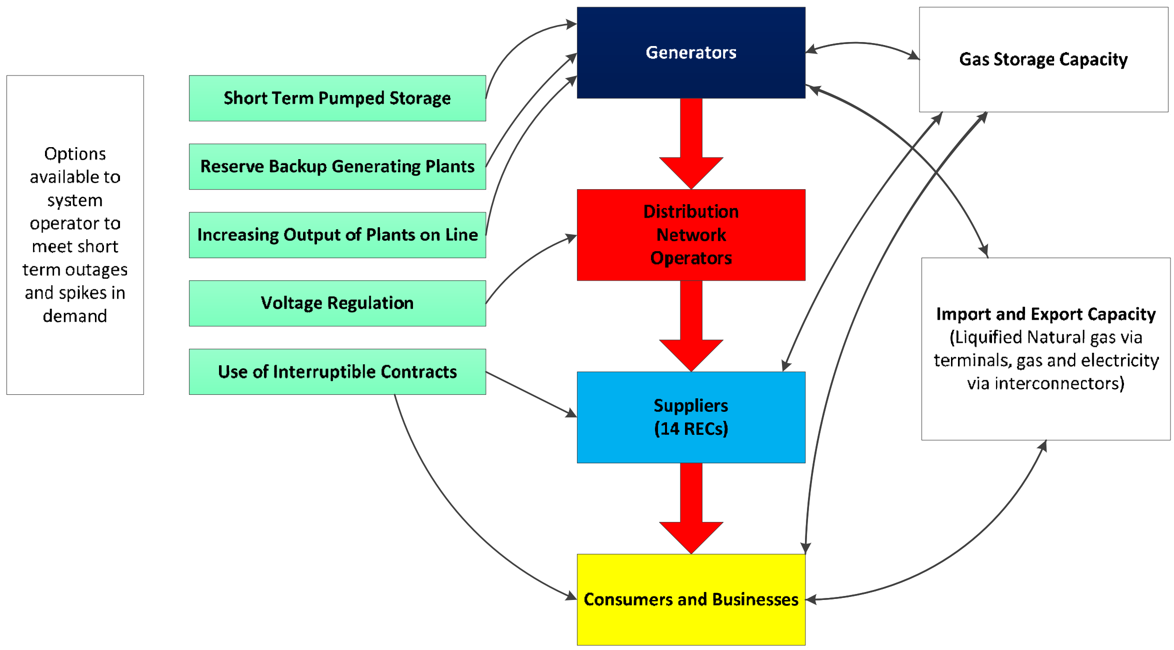

Figure 16 - Resilience Measures in the UK Electricity System (National Audit Office, 2010)

Figures 11 thru 16 show the relationships between the key players and components of the UK electricity system. It is also important to note that the front and the back of the industry are unregulated (i.e. Generation and Supply), but the Transmission and Distribution activities are deemed to be natural monopolies and are regulated and subject to price controls.

5.4 SUMMARY OF THE EGI HIGH LEVEL STRUCTURE

The high-level relationships are shown in figure 17:

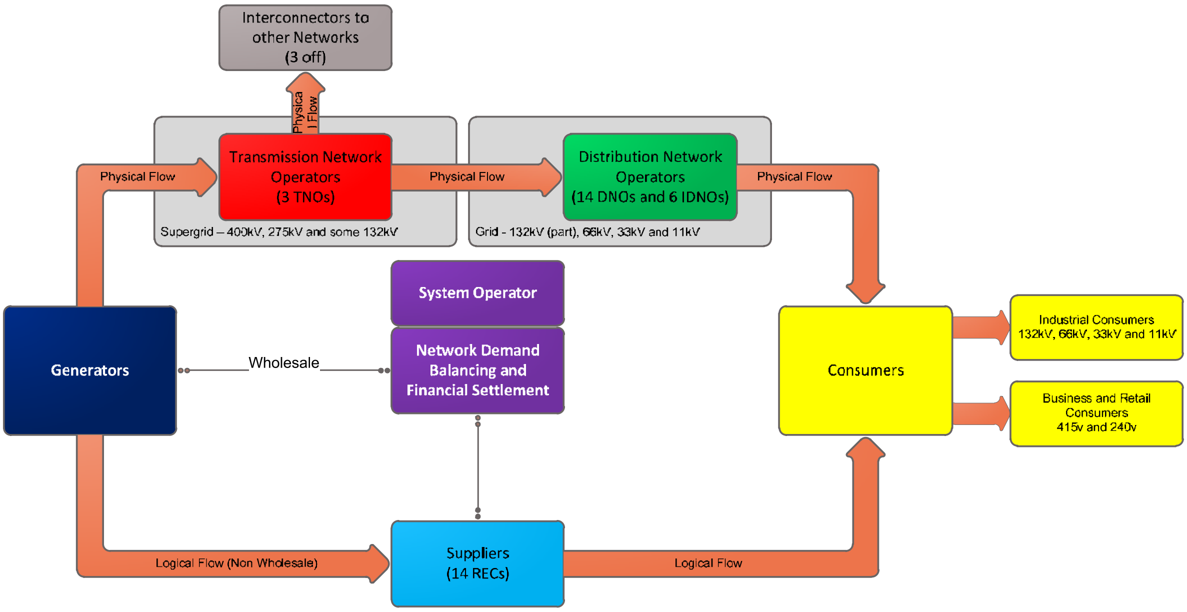

Figure 17 - Summary of High Level EGI Structure

The consumer's primary relationship (and financial flow) is with the supplier, with a consumer being able to purchase electricity from any supplier (or directly from generator in the wholesale market for large consumers). However, the physical flow of electricity is from generator to the consumer via a physical transmission network that embraces generators, TNOs, DNOs or geographically independent DNOs (IDNOs). The System Operator is responsible for balancing demand and supply and for billing the various entities in the market. Suppliers sell the electricity that they have purchased either directly from generators or from the wholesale electricity market, but do not get involved in its production or delivery.

Competition exists because suppliers can buy electricity from any generator, either directly or via the wholesale electricity market, and consumers can buy from any supplier.

The System Operator ensures that overall network capacity and demand is managed correctly by organising and managing an auction system that requires Generators to make bids for the supply electricity to the network through a system called BETTA (British Electricity Trading and Transmission Arrangements).

As can be seen the transmission network (managed by TNOs, DNOs and IDNOs) is a natural monopoly and is currently regulated on an RPI - x% basis by the market regulator, OFGEM, which is held responsible by the Department of Climate Change and Energy (DECC).

UK electricity generation (production) uses circa 570 power plants, owned by over 210 companies, using 34 generic fuel types to deliver a generating capacity of circa 90GW[6]. In terms of electricity demand, 26.8 million domestic customers use 112.5 Giga Watt Hours (GWh), and a further 2.4 million industrial and corporate businesses use 192.1 GWh of electricity per annum.

5.5 CHAPTER SUMMARY

This chapter has examined provided the reader with a high-level view of the UK electricity generation industry (EGI) and highlighted why it is important to the UK economy. It has also set out how the electricity transmission and distribution, regulatory framework, system resilience and high-level structure of the EGI are configured to enable the reader to have an overview of the industry's empirical setting.

[6] Ignores the embedded or distributed micro generators

6. METHODOLOGICAL MATTERS

6 METHODOLOGICAL MATTERS

This chapter discusses the methodological matters relating to the choice and suitability of the different approaches to the research that will be utilised in the subsequent chapters. This discussion will consider: organisational ecology backdrop, organisational theory fragments, statistical metrics and measures, statistical techniques discussion, survival models, statistical techniques tests, bivariate testing, survival analysis, and the research framework utilised.

The purpose of this discussion is to equip the reader with sufficient background underlying the methods and techniques considered and selected for the research.

6.1 ORGANISATIONAL ECOLOGY BACKDROP

Organisational Ecology was first proposed by Messer's Michael T. Hannan and the late John H. Freeman in their American Journal of Sociology article entitled 'The population ecology of organisations' (Hannan and Freeman, 1977). The principal concept underpinning organisational ecology theory is its examination of the environment in which organisations compete and experience processes similar to those like natural selection. The core framework of organisational ecology is focused upon the birth of new organisations (organisational founding), the death of organisations (firm mortality), and the intervening organisational growth and change trends.

Organisational ecology theory encompasses eight 'theory fragments'. The most important of which consider organisational: Inertia and change, Niche width, Resource partitioning, Density dependence, and Age dependence (see next section for further details).

The key publications outlining the relevant theory and practice are: Organizational Ecology (Hannan and Freeman, 1989), The Demography of Corporations and Industries (Carroll and Hannan, 2000), and Logics of Organization Theory: Audiences, Codes, and Ecologies (Hannan et al., 2007).

What sets organisational ecology apart from many social science approaches, and the reason for it becoming one of the central fields in organisational studies is its use of an empirical quantitative approach, which undertake large-scale longitudinal focused data collections[7] to record the vital events surrounding the corporate demography of populations of organisations. The primary data analysis techniques used by ecologists involve survival statistics, thereby differentiating the technique from most others in social studies.

The key question is how organisational ecology can assist in evaluating the impact of energy policy and the energy policy interventions that have occurred within the UK electricity industry. The main difficulty with energy policy measurement and evaluation is the size of the problem. Specifically, being able to operate at

[7] In organisational ecology studies, the datasets can often span several decades, and sometimes even centuries.

the whole economy level, and at the same time being able to differentiate the policy specific factors from the other environmental changes that have occurred over time.

There are two main advantages to adopting an organisational ecology approach. The first is that by working at the population level, as opposed to the individual organisational level, the broad effects of energy policy interventions can be assessed across multiple organisations. The use of foundings, growth and failure rates for each organisation in the population enables the impact of energy policy change to be determined using an inferential data technique. Lastly, using selected organisational theory fragments, and their associated statistical techniques, enables the researcher to exploit a range of analysis methods and techniques.

Looking more closely at the methods and techniques typically used for energy policy evaluation reveals that it is common for researchers to use one of a number of techniques. These frequently include: experimental design, quasi-experimental design, non-experimental design (including inferential non-theory based), comparative evaluation of programmes (using techniques such as evidence based policy), theory & replication, and cost-benefit analysis (using techniques such as cost-benefit analysis, cost effectiveness analysis, cost utility analysis, multi-criteria analysis and contingent valuation method) as outlined by researchers Cartwright and Hardie (2012), Weiss (1972), and Wolpin (2013).

However, the focus of this research, and specifically the corporate demography vital event-based data collection, has been premised on a long-term population based study evaluating the impact of energy policy on the UK electricity industry over the period 1991-2011 using founding and failures and durations of ownership of power plants by generator companies. This suggests that organisational ecology theory fragments should prove relevant and appropriate. The broad nature of energy policy objective definition and outcome recording also suggests that many of the methods available for energy policy evaluation might not be pertinent because the evaluation is being conducted Ex Post, for example the experimental and quasi experimental approaches require intervention Ex Ante or concurrently.

Further, the types and level of data collected also reduce the range of evaluation mechanisms available. For example, cost benefit evaluations are not appropriate because data and suitable measures are not available when considering a twenty-year longitudinal study. Lastly, the nature of the energy policy definition over the period does not permit comparative evaluation of different programmes because the high-level policy objectives have remained reasonably constant over the period, albeit that the interventions have changed frequently. This suggests that the most suitable evaluation techniques will involve the use of inferential non-theory and theory & replication based approaches. Both of which have been used in the research conducted.

In terms of the inferential non-theory approach there are four techniques commonly used to conduct policy programme evaluations, as shown in figure 18:

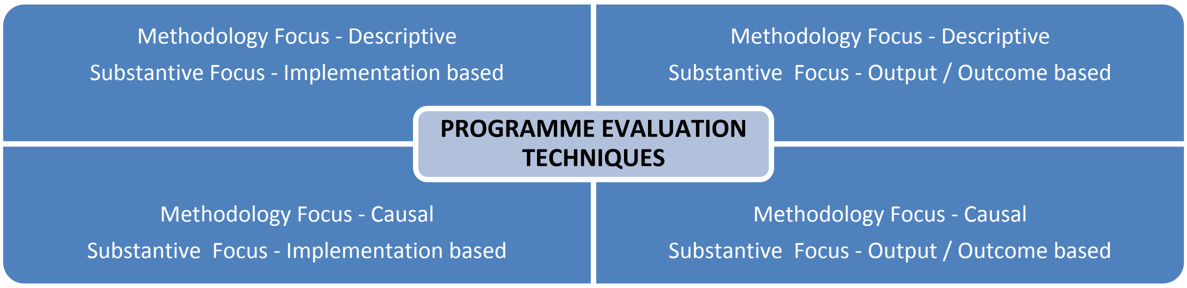

Figure 18 - The Four Basic Types of Programme Evaluations (Langbein & Felbinger, 2006)

The four questions arising from the above are: 'Does programme X cause outcome Y?, Does programme X have outcome Y? (i.e., does X cause Y to occur?), What causes outcome Y to vary? (i.e., over place and / or over time?), and Why does outcome Y vary? (i.e., what causes Y to vary?)' (Langbein & Felbinger, 2006). The use of the inferential non-theory technique adopted by this research is a causal methodology with outcome based substantive focus.

In terms of theory and replication approach, using the development of theory as defined by Tsang and Kwan (1999), summarised and extended by the author, highlights that theory development can take one of eight different forms, shown in table 5:

Data Used	Theory	Same Analysis Measures	Different Analysis Measures
Same Data Set	Existing	Checking Analysis (CA): of the prior theory using the same measures and the same data / population	Re-Analysis (RA): of the prior theory using different measures with the same data / population
Same Population	Existing	Exact Replication (ER): of prior theory using the same measures, but with different data set drawn from the same population	Conceptual Extension (CE): or prior theory using different measures, and a data set drawn from the same population
Different Population	Existing	Empirical Generalisation (EG): of prior theory using the same measures, with a different data set, and different population	Generalisation and Extension (GE): of prior theory using different measures, with a different data set, and a different population
Same or Different Population	New	Theoretical Generalisation (TG): new theory using the similar measures, with a different data set, and the same or different population	Theoretical Development (TD): new theory using different measures, with a different data set, and the same or a different population

Table 5 - Theory and Replication Testing Framework Available and Adopted

Looking in detail at the research technique adopted in the later chapters of this thesis, these followed three different testing and evaluation techniques. Firstly, for the energy policy evaluation assessment a non-experimental inferential non-theory approach was adopted using a Theoretical Development (TD) approach, these can be found in chapters nine and ten. Then to evaluate the impact of government energy policy on the market competition (see chapter 11), and market concentration (see chapter 12) two alternative techniques were utilised. The latter two techniques adopted a 'Theory and Replication' (EG) and 'Generalisation and Extension' based approach respectively.

6.2 ORGANISATIONAL THEORY FRAGMENTS

Organisational Ecology has a broad theory base derived from application of evolutionary principles underpinned by eight theory-fragments that are supported by various extensions developed by researchers (Hannan et al., 2007).

The eight theory-fragments (Hannan et al., 2007) are: Organisational Forms and Populations; Structural Inertia and Change; Age Dependence; Dynamics of Social Movements; Density Dependence; Niche Structure; Resource Partitioning; and Diversity of Organisations. These are summarised in figure 14:

Theory Fragment 1 Organisational Forms and Populations

- 'This fragment addresses questions about how to define forms and populations and how to classify them meaningfully into higher-order forms. Early ideas focused heavily on patterns of exchange among organisations and other environmental actors. More recent theory and research centres on ideas about social identities and social codes (Baron, 2004, Carroll and Harrison, 1994, Hannan et al., 2008b, Hannan et al., 2008a, Rao et al., 2003, Rosa et al., 1999, Ruef, 2004a, Scott, 2011, Zuckerman, 1999).

Theory Fragment 2: Structural Inertia and Change

- This inertia fragment develops arguments about the rigidity of organizational structures and argues that strong inertia makes selection an important motor of change in the world of organisations. It addresses the main possible mechanisms behind such phenomena, including the predilection in modern society to value accountability and reliability, as well as inertia's evolutionary implications. (Amburgey and Kelly, 1993, Baron et al., 2001, Delacroix and Swaminathan, 1991, Hannan et al., 2003a, Hannan et al., 2002, Hannan et al., 2003b, Hannan et al., 2004, Haveman, 1992, Kelly and L., 1991, Ruef, 1997).

Theory Fragment 3: Age Dependence

- Theory and research on age dependence asks how and why the age of organisations matters for their structures and life chances. The proposed answers to the problem, which involve issues such as knowledge, capabilities, bureaucratization, and obsolescence, transcend the seemingly narrow question. Yet theoretical progress in the fragment has been clouded by conflicting empirical evidence (Baron et al., 1999, Carroll, 1983, Freedman et al., 1983, G-Le. et al., 2010, Hannan, 1998, Levinthal, 1991, Polos and Hannan, 2002, Sorensen and Stuart, 2000).

Theory Fragment 4: Dynamics of Social Movements

- Social movement research in organizational ecology emphasizes the organisational basis of collective action, especially that related to the competition and mutualism of movement organisations. It also ties movements to the rise of new organization forms. Social movement theorists naturally focus on the possibility that institutions can sometimes be changed and they stress the importance of attending to movement audiences and their dynamics (Greve et al., 2006, Hannan and Freeman, 1987, Ingram and Simons, 2000, Koopmans and Olzak, 2004, Minkoff, 1999, Olzak and Uhrig, 2001, Sandell, 2001).

Theory Fragment 5: Density Dependence

- This theory fragment comprises what is perhaps ecology's most sustained research programme on population dynamics, the model of density dependence in legitimation and competition. The core theory posits relationships between Density (Number of organisations in a population); and Legitimation of the form of organization and competition among the population's members. Its main empirical implications are non-monotonic relationships between density, on the one hand, and population vital rates on the other hand. Extensions to the theory attempt to: extend the model to explain late-stage declines in population density, an observed empirical regularity; and treat legitimation as 'sticky' or not easily reversible (Barron, 1999, Carroll and Hannan, 1989a, Ruef, 2004b).

Theory Fragment 6: Niche Structure

- An organization's niche summarizes its adaptive capacity over the various possible states of its environment. Theories in this fragment build on the concept of: Niche width and the span of environmental states in which an organization can thrive. These theories claim that a broad niche comes at the expense of viability in a stable, competitive environment, but that environmental uncertainty and variability affect the trade-off between niche width and viability (Barnett and Woywode, 2004, Barron et al., 1994, Baum and Singh, 1994, Carroll, 1985b, Dobrev et al., 2003, McPherson, 1983, Podolny et al., 1996).

Theory Fragment 7: Resource Partitioning

- This fragment can be seen as a variant of general niche theory, one based on different assumptions and scope conditions. This fragment explains the endogenous partitioning of markets (environments) as an outcome of competition between populations of generalists and specialists (Boone et al., 2002a, Carroll et al., 2001, Carroll and Swaminathan, 2000, Dobrev and T-Y, 2006, Liu and Larsen, 2010, Swaminathan, 1995, Swaminathan, 2001).

Theory Fragment 8: Diversity of Organisations

- Research in this fragment deals with the social and economic consequences of the level of diversity among the types of organisations in a community or sector. An initial stream deals with the interplay of careers of individuals and the organizational ecologies within which careers play out (Haveman and Cohen, 1994, Phillips, 2001, Sorensen and O., 2007)'.

An extract from (Hannan et al., 2007)

Figure 19 - Description of the Core Organisation Ecology Theory Fragments[8]

With the exception of theory fragment number four 'Dynamics of Social Movements' (which is not relevant because the EGI population is not a social movement i.e., such as a charity or labour union), all the theory fragments above can be viewed as equally applicable for use in the EGI study.

The key organisational perspectives relevant to this research are shown in figure 20:

[8] Readers who wish to gain a greater understanding of organisational ecology theory should see 'Logics of Organisational Theory', Hannan, M. T., L. Pólos, et al. (2007) Princeton University Press.

Figure 20 - The Key Organisational Perspectives relevant to this Research

However, in order to provide some bounds to the breadth and scope of the research it was necessary to concentrate the study directly on the two most relevant Theory Fragments. These were Niche Width and Resource Partitioning. These were complemented by means of the supplementary research extensions developed by other researchers such as Barnett (2008), Boone and Witteloostuijn (2006), Dobbin and Dowd (1997), Dobrev et al. (2002), and other bespoke methods.

Whilst there are many who believe that organisational ecology has much to offer researchers, there are also critical commentators on the field – see (Astley, 1985, Carroll and Hannan, 1989b, Cresswell, 2009, Dahlgren, 2005, David Knoke, 2009, Donaldson, 1995, Dyner et al., 2009, Freeman and Hannan, 1989, Frishammar, 2006, Lomi, 1995, Martin Ruef, 2004, Singh and Lumsden, 1990, Young, 1988, Young, 1989).

6.3 STATISTICAL TECHNIQUES DISCUSSION

Having outlined the key range of metrics and measures that were considered, the discussion now concentrates on the specific statistical techniques that were used in the course of executing this research. These are discussed under the headings of: concentration and diversity measures, covariance tests, distribution models, regression techniques, longitudinal models, event history analysis, survival models, and statistical significance tests.

6.3.1 CONCENTRATION AND DIVERSITY MEASURES

A large number of the papers used by OE researchers involve determination of diversity, isolation or concentration measures for the population under study (Dowd, 2004, Statistics, 2004):

Diversity measures include Gini coefficient – a statistical measure of dispersion (1 is maximum inequality and 0 equals minimum inequality), Richness Index – to determine how many different types the dataset contains, Shannon Diversity Index – a popular diversity index used in ecology, and True Diversity Index- used to determine the effective number of unique types of entity.

Isolation measures include: Isolation index – which is used to measure the segregation of the activities of populations, and Lieberson isolation index or Bell's isolation index – population isolation indices.

Concentration measures include: Concentration Ratio – measures the total output by a given number of firms in an industry or population. Typical a 4-firm or an 8-firm concentration ratio are calculated and the results are interpreted[9], Herfindahl-Hirschman Index (HHI) – measures the size of firms in relation to the industry as an indication of the amount of competition between them. It is traditionally used to measure either all firms in the population if there are less than 50, or the top 50 firms if there are more than 50 firms in total. (It is equivalent to the Simpson index), and Market concentration index – measures the function of the number of firms and their share of the total population.

The concentration measure adopted was the Gini Coefficient (of generator concentration of fuel and output) – used to measure the spatial dispersion of the population. This metric is the one used by most organisational ecology research papers, such as Carroll (1983) and Dobrev et al. (2002) and statistically it is a technique that uses the full extent of the data values.

[9] The concentration measure are interpreted thus: 0% - perfect competition, 0-50% - low concentration, 51-80% - medium concentration, 81% - 100% - Oligopoly to monopoly.

6.3.2 COVARIANCE TESTS

In statistics, there are a number of covariance measures that can determine the extent to which two variables are related to one another. The most simplistic measure is to use a bivariate statistical measure that will yield covariance (Cov_{xy}) and the 'correlation coefficient' (called 'r').

The form of this approach is shown below in figure 15 (Makridakis et al., 1998 pp 35):

Bivariate Statistical Measures

- **Covariance Cov_{xy}**– measures how much two variables "co-vary" from one another.
  - Covariance is the summation of the product of the deviation from the mean for each of the two variables divided by one less than the number of observations:
  - $Cov_{xy} = \frac{1}{n-1} \sum_{i=1}^{n}(Xi - \overline{X})\,(Yi - \overline{Y})$

  Note units are problematic i.e. dollar-mpg

- **Correlation coefficient *r***- is a special covariance measure that takes care of the scale problem just mentioned. Correlation is the covariance divided by the product of the standard deviation of the two variables:

$$r_{xy} = \frac{Cov_{xy}}{S_x S_y} = \frac{\sum(X_i - \overline{X})\,(Y_i - \overline{Y})}{\sqrt{\sum\,(X_i - \overline{X})^2}\sqrt{\sum\,(Y_i - \overline{Y})^2}}$$

The values are always between -1 to +1, where minus is a negative correlation and positive numbers are a positive correlation.

It should be noted that correlation are measures of linear association between the two variables – they not appropriate to curvilinear relationships.

Figure 21 - Bivariate Statistical Measures

The covariance and correlation coefficients are statistics that measure the linear relationship between two variables and can be used to find explanatory links between X and Y, but do not indicate whether or not the value between $Y_t \; and \; Y_t - 1$ can explain the value in subsequent periods.

Autocorrelation and Auto covariance are equivalent measures used to discover relationships between Y_t and $Y_t - 1$ I.e. observations between lagged observations of the same variable. These measures are computed as shown in figure 16 (Makridakis et al., 1998 pp. 39):

Auto covariance and Autocorrelation Statistical Measures

- **Auto Covariance C_k** – measures how much two lagged variables "co-vary" from one another.
  - $C_k = \frac{1}{n}\sum_{t=k+1}^{n}(Y_t - \overline{Y})\,(Y_{t-k} - \overline{Y})$
- **Correlation coefficient r_k**- is a special covariance measure that takes care of the scale problem just mentioned. Correlation is the covariance divided by the product of the standard deviation of the two variables:

$$r_{xy} = \frac{\sum(Y_i - \overline{Y})\,(Y_{t-k} - \overline{Y})}{\sum_{t-1}^{n}(Y_t - \overline{Y})^2}$$

The values are always between -1 to +1, where minus is a negative correlation and positive numbers are a positive correlation.

The autocorrelations at lags 1, 2, …. n are termed the autocorrelation function (ACF)

Figure 22 - Auto covariance and Autocorrelation Statistical Measures

Now that we have considered the covariance of each of the variables on their own, and as bivariate relationships, it must be highlighted that that these measures and relationships whilst valuable do not allow modelling of multiple variables in the same equation. Instead, it is necessary to look to multivariate techniques such as Spearman and Kendall's' rank correlation to determine how the combination of multiple variables affects the modelling relationship.

The use of bivariate, auto covariance and multi-variance measures provides an indication of how the variables relate to one another. However, it does not explain the nature of the relationship between the variables, for which further tests are required. The first technique is ANOVA (ANalysis Of VAriance). ANOVA provides a statistical test that determines whether the means of several groups are equal and therefore generalises the t-test into more than two groups.

A more detailed analysis of the variables utilises the MANOVA (Multivariate ANalysis Of VAriance) test. Unlike the ANOVA test, which uses the means, MANOVA uses the variance-covariance between the variables to test the statistical significance of the mean differences (Makridakis et al., 1998 pp. 213).

6.3.3 DISTRIBUTION MODELS

The definition of statistical models is typically developed in terms of the hypothesis (e.g. parameter-based assumptions), distributional assumptions (e.g. Form of distribution assumed and manner of sample selection for comparative studies or treatment allocation for designed experiments) and design structure (e.g. response variable including identified and unidentified parts) (McPherson, 2001 pp. 336). This is relevant to the regressions perfomed in chapters 9 through 12.

Most models are based non-parametric or parametric survival techniques, typically adopting one of the exponential families of distributions:

- **Non Parametric**: - do not assume the data or population have any characteristic structure or parameters:
    - Binomial distribution – used for the study of proportions or success rates
    - Logistic distribution – used when the response variable is binary or when there is an underlying (or latent) variable and the observed response is ordered categorically
    - Multinomial distribution – used when the response variable is unordered categorically.
    - Normal distribution – used for comparing means between groups
    - Poisson distribution – used when the response is in the form of counts that represent the number of occurrences of the independent events.
- **Semi-Parametric** – assumes that the model that has parametric and nonparametric components (i.e. the underlying hazard function in a Cox regression)
- **Parametric** - assumes that the data has come from a type of probability distribution and makes inferences about the parameters of the distribution:
    - Exponential (negative exponential distribution) or Gamma distributions – used when the response is in the form of the time between successive occurrences of independent events
    - Exponential-logarithmic distribution – used when the lifetime of an organisation is expected to exhibit decreasing failure rate (DFR)
    - Gompertz – used when the hazard risk is estimated to be linear across all episodes
    - Log-Logistic distribution – used when single covariate accelerated failure model is required
    - Weibull distributions – used when accelerated failure modelling is appropriate (Hosmer et al., 2008 p.29-40).

6.3.4 REGRESSION TECHNIQUES

Regression is a statistical technique for estimating the relationship between the variables under consideration. There are several types of regression including:

- **Binomial regression** is a form of logistic regression in which the response is the result of a series of Bernoulli trials (i.e. using two possible outcomes of success '1' or failure '0'). The regression is described in terms of the generalised linear model (GLM). The GLM is a generalisation of the ordinary linear regression that allows for response variables that have distributions other than those found in the normal distribution (e.g. Logistic or Poisson distributions). The negative binomial model is a special case wherein the distribution model is a discrete probability distribution in which a failure is classified as a '1' and all non '1's are considered successes.
- **Linear Regression Model** – which models the relationship between a dependent variable and one or more independent variables Generalised least squares regression – uses the ordinary least squares (OLS) method to estimate the unknown parameters in a linear regression model. This is undertaken by minimising the sum of squared value of the terms between the observed responses and the responses predicted by the linear approximation.
- **Logistic Regression** – attempts to predict the outcome of a categorical dependent variable (i.e. wherein the dependent variable can adopt a limited number of categories). Logistic regression can be binomial (where there is only one of two possible outcomes) or multinomial (where there are three or more possible types)
- **Nonlinear Regression** – when the dependent variable is modelled by a function that is a nonlinear combination of the independent variables. Nonlinear regression can take many forms including:
  - Nonparametric regression – is used when the dependent variable does not take on a predetermined form but is rather modelled according to the information contained in the data. This approach is valid if the shape of the model is unknown, the shape of the response is dependent upon the other predictors, and the response is either quantitative or a binary variable
  - Parametric regression – is the process of fitting models to data using numerical responses. Parametric regression is used when the regression estimates the parameters from the data
  - Semi Parametric regression – utilises models that combine both parametric and nonparametric models.
- **Robust Regression** – attempts to overcome the limitations of the parametric and non-parametric methods by seeking to find the relations between the independent variable(s) and the dependent variable. This approach is less sensitive to outliers and adopts models other than 'maximum likelihood type' estimations e.g. using Least Trimmed Squares (LTS)
- **Stepwise Regression** – adopts a mechanism that allows a choice of predictive variables to be automated in the estimation process. Typically, this is done using a sequence of F-tests but other techniques are possible (Stolzenberg, 2004 p.165-209).

6.3.5 LONGITUDINAL MODELS

Having discussed the range of statistical techniques suitable for the research it is important to recognise that the data collected for this research was focused on changes in relationships between energy policy, technology and the electricity generating companies.

The most important observation is to recognise that the organisational ecology base of the study gives one very important insight and research technique. Therefore, this study utilises three different test cases. The first is energy policy and its impact on the founding, failure and durations for generators and power plants). Next, it evaluates how energy policy and technological change have affected the level of competition between generating firms in the electricity industry. The final evaluation is whether the electricity generating market has become more concentrated because of energy policy and technological change.

Unlike most social science research, which analyses the relationships between variables at some fixed instant in time, studies of change are used to consider 'the nature of variation and how the change comes about, that is they attempt to understand change' (Tuma, 2004 p. 310-327).

This implies that the core analysis must rely on modelling change, where change is understood to be the 'variation of change' (i.e. with the objective to understand the impact of change), or the analysis of some phenomenon as it varies over time. This means that there are two approaches possible, the first is to develop 'models of change', and the second is to 'model change'. Tuma posits that there are two continuums that can be adopted, the first is the 'Theory Dominant' which is frequently used in the physical sciences and which uses phenomena to develop theory. The second is 'Data Dominant' and is more commonly used, especially in the social sciences, to use the phenomena and correlation techniques to describe patterns of change, to associate patterns of change with other patterns, to explain patterns of change, and to predict patterns of change.

To consider change it is necessary to review Tuma's work pertaining to the analysis of dimension, timeframe, intention, variables, scale, type, nature and implications of change. The following table 8 has been prepared by the author but is based on Tuma (2004) as shown in table:6:

Classification of Change	Category	Option	Description
Dimension	Model Type	Agent-based	Studies the sequence of actions and interactions of agents over time
		Variable-based	Studies the changing variables describing the unit of analysis
	Time	Continuous	Continuously variable
		Discrete	Variable within predefined limits
	Intension	Dynamic models	Consider social processes and the consequence of continuous change
		Models of difference	Variable-based models
	Variable type	Dependent variables	The outcome of interest
		Independent variables	Which can be explored variables because the outcome, or control variables and the associated with Explanatory variable and dependent variable
Measurement scale of variables	Continuous		The measurement scale can be mapped onto segment of what mathematicians call a "real-life" or continuum of numbers
	Discrete	Nominal	Values are arbitrary and cannot be ordered
		Ordinal	Values can be ordered the distances between values are arbitrary
		Interval	Both values and distances between values can be ordered
		Cardinal	There is a meaningful, non-arbitrary zero point
		Binary	Indicator, dummy, or zero – one variables
		Polytomous	Have more than two distinct values
Type	Deterministic models		Posits specific relationships among variables specific rules
	Probalistic models		Posits that particular variables have certain probabilistic relationships to one another (can be agent-based or variable based)
Nature	Social		Actions on one actor depend explicitly on actions of another actor
	Asocial		The outcome of one unit of analysis is ordinarily assumed to be statistically independent of the actions and characteristics of other units of analysis
Implications	Computational		Used when interactions in 'time path of change' and not simply in an equilibrium or final result. Especially valuable for probabilistic models and few cases involved, or when some probability of a certain kind of change can be deduced mathematically
	Deductive		Models of changed and deduced mathematically e.g. using one differential equation models, two Markov probabilistic models, and three scenarios simulating various hypothetical conditions

Table 6 - Longitudinal Model Definition

As has been intimated above, this research project focuses on changes in the electricity industry over a twenty-year period. Therefore, the research framework of the project should adhere to Tuma's conceptualisation to determine the research approach.

The first consideration is the dimension of change and the choice of model type appropriate to the data collected. I.e. relating to events and specifically to the dates and times at which changes in ownership or changes in technology introduced at each power plant in the UK over a twenty-year period. This suggests the most appropriate model is a variable-based model type. The nature of time within the data is continuous, meaning that the unit of analysis is the date of the event and the duration in terms of numbers of days until the next event. This suggests a continuous time dimension. The intention of the research is to attempt to build a variable-based model that correlates energy policy and technology change relevant to the durations of ownership for each power plant, this suggests a model of difference as opposed to a dynamic model. The last aspect relating to direction considers the variables, and in this sense the data collected comprises dependent, independent and control variables.

The second consideration is the measurement scale of the variables, and given that the unit of analysis will be days over a twenty-year period, it is reasonable to assume that the measurement scale of the data is continuous.

The third consideration is the type of change, and it is anticipated that the model is probabilistic as opposed to deterministic because there are no specific relationships hypothesised, at this stage, amongst the variables.

The fourth consideration is the nature of the model, and given that the generators operate in a free-market making their own management decisions the model nature is assumed to be asocial because the time between events in one power plant does not directly relate to the social activity of other actors i.e. other generators.

The last consideration is to consider the implications of the above, and whilst the inductive approach might have been adopted, it was decided to utilise the deductive approach of identifying a theory, developing hypotheses, collecting the data, developing the testing frameworks and confirming the outcome.

In summary, this means that the research should adopt a dimensional variable-based model, a continuous timeframe, with the intension of a dynamic model of difference, using dependent and independent variables, across a continuous scale, based on a probabilistic model type, with an asocial nature, and a model that draws implications using a computational approach. In line with many other social science-based research projects in the organisational ecology field a regression-based modelling approach was used to understand the relationships between the variables.

The data collected for the research is a corporate demography for the electricity industry since its privatisation in 1991 until 2011. The demographic approach has been a full investigation of all of the generators and power plants that were operational at the time of privatisation and all those that started generating after that date. In each case the name of the power plant, the ownership of the power plant, technical parameters relating to the size, fuel and technological base and the date at which each vital event relating to the power plant occurred were all recorded.

In effect, the demography collected was a date-based collection of all changes in technology or changes in ownership relating to each power plant over the period of the study. The data collected is such that it is possible to calculate the rates for and time (in terms of the number of calendar days between the first vital event and each subsequent vital event that occurred in the life of the power plant). It is also possible, by aggregating the power plants under the owner name, to identify vital events by owner by power plant. This data conforms to a longitudinal model because it records changes to vital event types over the period of study.

Further, the key dependent variable in the data is either the number of founding / failure rates, or days between the first vital event and the second vital event i.e. a duration in terms of numbers of days. Thus when a new generating station starts to produce electricity this gives rise to a starting (founding) event, and when the owner of the generating station decides to sell that station, for example, this gives rise to an ending (failure) event for the original owner of the power plant. What this means is that the dependent variable takes the form of a: founding rate (new generators or power plants), failure rates (exist by existing generators) or the ownership duration between the different types of vital event that are recorded in the dataset. The implication of this is that the external environmental factors (i.e. the independent and control variables that include government policy and the availability of renewables technology for example) will cause the owner of the generating station to evaluate their continued ownership, upgrade, or modify the technology base of the power plant. Therefore, by using these vital events it is possible to get an indirect measure of how power plant owners respond to environmental factors i.e. the independent and control variables that were collected.

The use of the founding, failure rates and durations is very important because these reflect the decision making and the behaviour of the power plant owners in relation to the independent variables existing before the power plant acquisition was made or in the period of power plant ownership. This is of interest for this thesis because the founding rate reflects the vital events related to the initial decision to purchase and to hold the power plant investment i.e. the factors that were pre-existing in the period before the acquisition and the factors that encouraged the owner to hold the investment after this period. Likewise, the failure durations show the vital events and factors that were pre-existing before the decision to divest the investment in the power plant. The key here is that the vital events are fixed i.e. they are specific corporate demography events but the durations are 'variable' in as much as the energy policy factors, for example, reflect the circumstances pertaining to the external environmental factors.

6.3.6 EVENT HISTORY ANALYSIS

The discussion above has centred on change, and specifically changes to ownership or technical parameters by electricity generator or their power stations over a twenty-year period. It also highlighted how measuring the time between changes (i.e. vital events) were used as a proxy for modelling and understanding the impact of environmental factors on the ownership period of each power plant by the relevant owner. This suggests that change was measured by the rate of change or the occurrence of events, or the duration of calendar days between the occurrences of separate vital events.

'Event history analysis' is the term used to describe a variety of statistical methods designed to describe, explain, or predict the occurrence of events. Outside of the social sciences, these methods are often called survival analysis, as statisticians who analyse the occurrence of deaths etc. originally developed them.

'There are also many other names for event history methods, including failure time analysis, as of analysis, transition analysis, and duration analysis' (Allison, 2004 p.369). These techniques are suited to a population-based study of electricity industry sectors privatisation, and used as the basis of the research in this thesis.

Despite their biomedical origin, the same methods are perfectly suitable for studying a range of social phenomenon such as births, marriages, divorces etc. (Allison, 2004 p.369). They are therefore directly relevant to study the analogous events of power plant starting, power plant vital events and power plant ending.

Before embarking on a detailed discussion of the survival modelling it is worth exploring the background techniques behind the statistical analysis. The first consideration is what type of statistical regression can correlate the dependent variable (i.e. event rate or duration) to the independent variables? Logistic regression might be a logical place to start because it can be used for binary data and could be well suited to the coding of public policy i.e. implementation of a new energy policy could be coded as a one or zero. However, the main difficulty with logistic regression is that it does not allow the researcher to account for the specific time of the event, i.e. it only can be used to say that a new energy policy was implemented or not over the period of the study. Because of the inability to use the timing information this approach is not particularly helpful to survival analysis.

Linear regression is another approach, but it suffers from two major limitations. Firstly, the technique is not well suited to distributions of time that do not follow the normal distribution. A second less serious issue concerns the presence of right censored data. Censoring occurs for example when events take place earlier than or later than the periods under or where observation data might be missing (these are called intervals). Because most event history data sets are composed of non-symmetric, non-normally distributed and right censored data this approach is not suitable to survival data analysis.

The approach traditionally used by survival analysts makes use of nonparametric techniques to describe data and then using semi-parametric and parametric statistical techniques to allow event history data sets to be regressed with independent variables.

Looking at the vital event history within the EGI, we can see the distribution of vital events shown in figure 23:

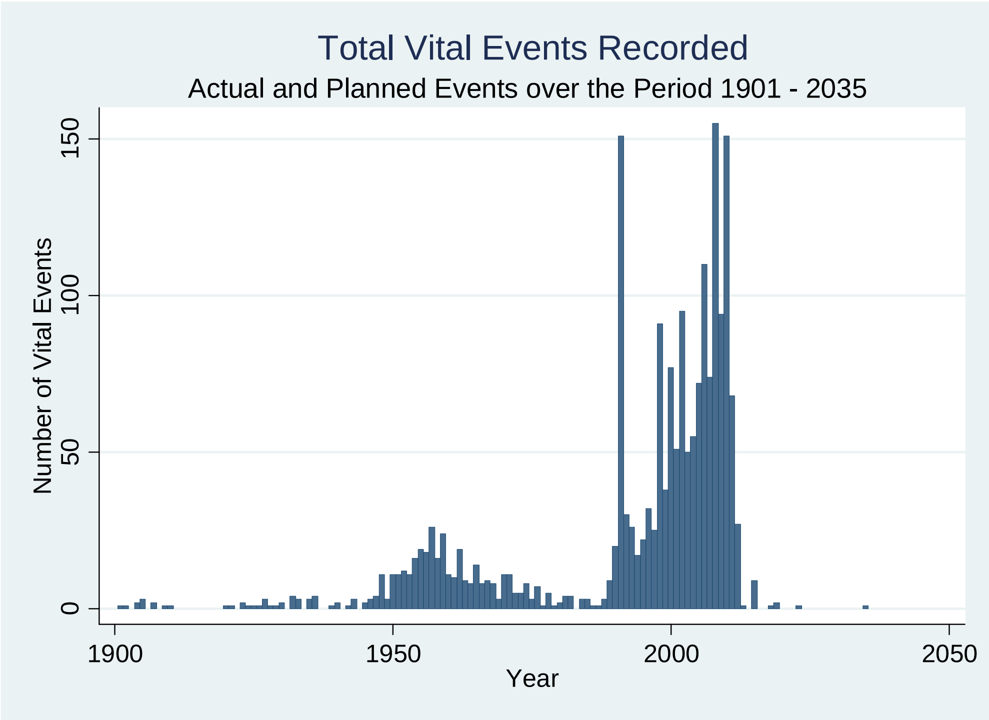

Figure 23 - Distribution of EGI Vital Events (1901 - 2035)

This can be broken down into events that are related to generator company corporate actions (events related to the generator companies organisation and structure) in figure 24:

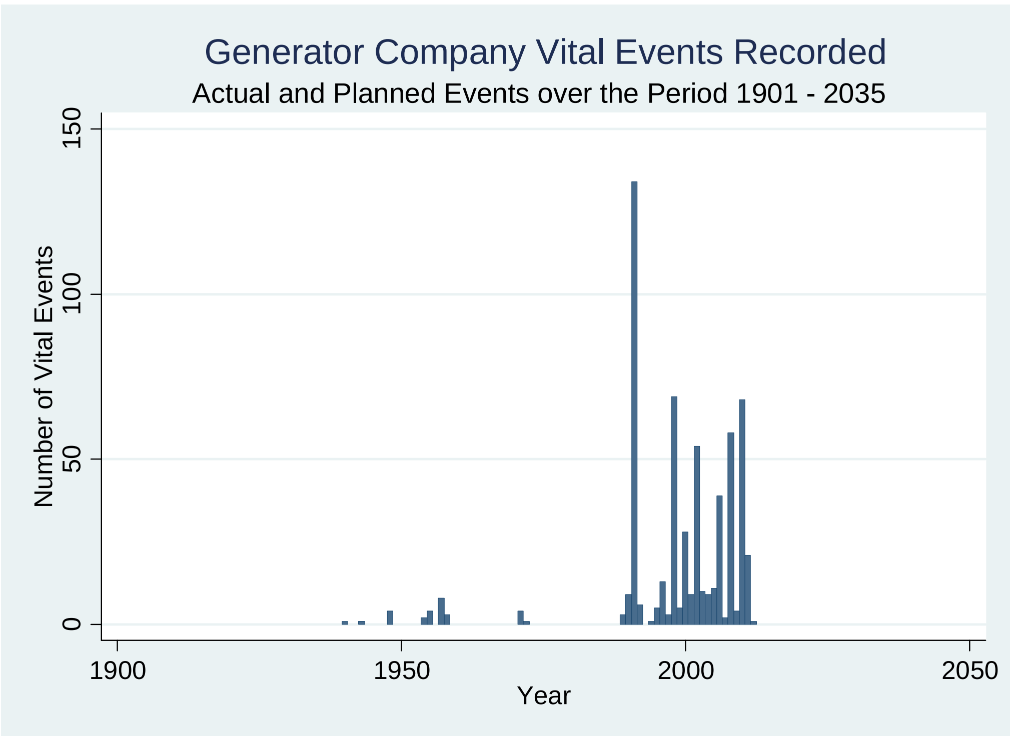

Figure 24 - Generator Company Corporate Events (1901 - 2035)

Further analysis, shown in figure 25, highlights the events that were related to the Power Plants owned by the generators:

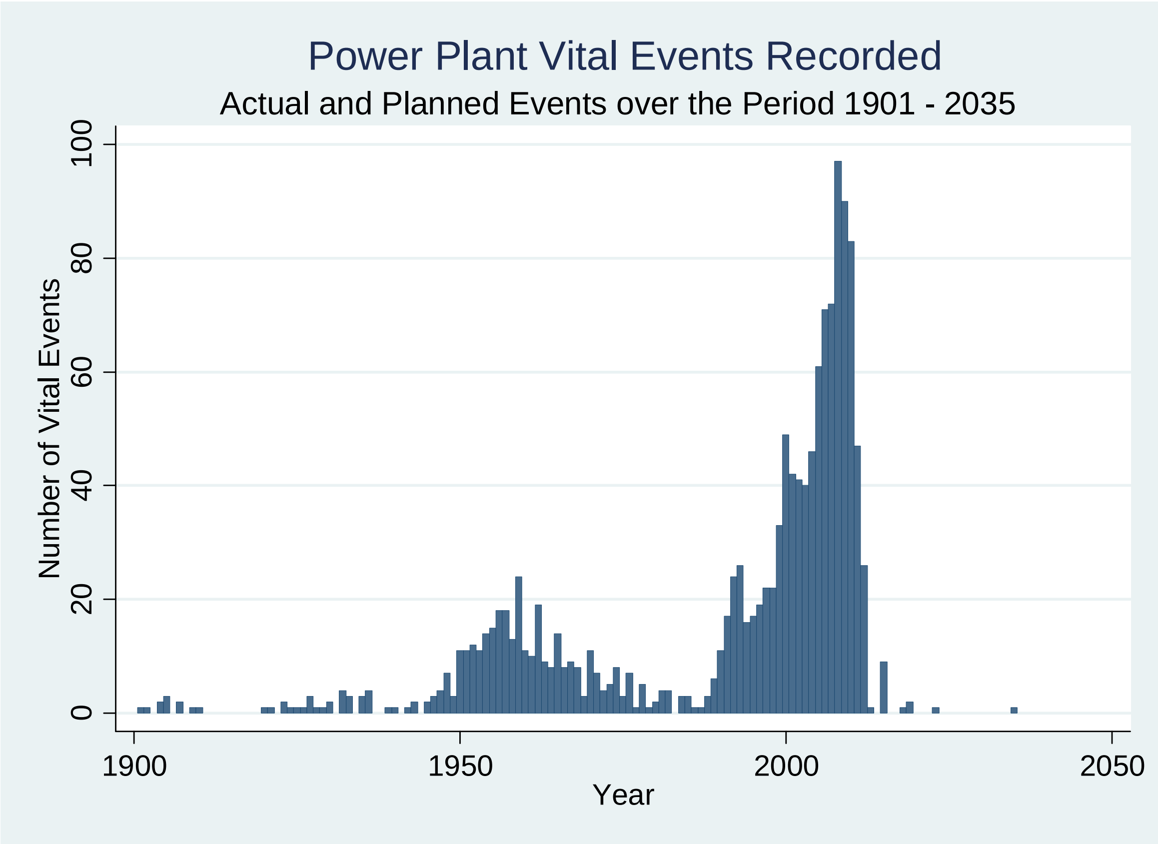

Figure 25 - Power Plant Vital Events (1901 - 2035)

6.3.7 SURVIVAL MODELS

As stated above, survival models are concerned with death of biological organisms or the failure of mechanical systems. The technique is termed 'event history analysis' by sociologists or 'duration analysis' or 'duration modelling' by economists (Tuma and Hannan, 1984). Survival models relate the time that passes before some event occurs to one or more covariates included in the model.

The two techniques directly relevant to this research are the proportional hazards i.e. the Cox semi-parametric approach and parametric constant exponential regression approach (Blossfeld et al., 2007 p.186-196, Cleves, 2010 p.2-5, Stata_Press, 2011).

Proportional hazards models assume that a unit increase in a covariate is multiplicative with respect to the hazard rate. This is different to other types of survival models (i.e. accelerated failure time models) which do not utilise proportional hazards. The most attractive aspect of the semi parametric approach has been attributed to Sir David Cox. He found that if the proportional hazard assumption holds (or is assumed to hold) then it is possible to estimate the effect of the independent parameters without being concerned about the underlying hazard function i.e. it is not necessary to understand the shape of the underlying distribution. This is termed the Cox proportional hazards model (Blossfeld et al., 2007).

On the other hand, the parametric Gompertz exponential model uses the maximum likelihood estimation (to estimate the hazard rate and the effect of the covariates) on the assumption that the observed survival times may be terminated either by failure or by censoring (withdrawal). It further assumed that conditionally the times to failure are independent of the times to withdrawal. Lastly, the model makes the estimation based upon piecewise segments by dividing the time scale into intervals. Typically it is also assumed that the last interval may be considered infinite in length (Friedman, 1982).

For this research, the two survival regression techniques are of direct relevance because they are able to relate (regress) the dependent variables to the independent variables, unlike the non-parametric methods that only utilise the information contained in the dependent variable.

6.3.8 STATISTICAL SIGNIFICANCE TESTS

The significance tests available are (Diamond and Jefferies, 1988):

- **F-test** (of equality of variances) – a statistical test which assumes that the statistic has an F-distribution under the null hypothesis. Typically, this test is used when comparing statistical models that have been fitted to a data set, in order to identify the model. Exact F-tests are mainly encountered for models that have been fitted to the data using least squares method
- **T-test** - is a statistical hypothesis test that is used to determine whether the null hypothesis (test of difference) is supported. It may be used to determine if two sets of data are significantly different from each other, and is adopted when the data could be assumed to follow a normal distribution. It is used for small samples ($n < 30$) and where the variance is unknown
- **Z-test** - is a statistical test that is used to test when the null hypothesis can be approximated by a normal distribution for large samples ($n > 30$). Because of the central limit theorem, many test statistics are approximately normally distributed for large samples. For each significance level, the Z-test has a single critical value (for example, 1.96 for 5% two tailed). This makes it more convenient than the t-test, which utilises separate critical values for each sample size. For this reason it is common to perform statistical tests as approximate Z-tests

P-value - is the probability of obtaining a test statistic that is at least as extreme as the one that was actually observed, when it is assumed that the null hypothesis is true. The null hypothesis is rejected when the p-value is less than the predetermined significance level α (Greek alpha), which is often 0.05 or 0.01, indicating that the observed result would be highly unlikely (respectively 0.5 times and once in a hundred) under the null hypothesis.

Further post-estimation tests used for the survival modelling will be discussed below.

6.4 BIVARIATE TESTING

The key dilemma facing researchers is how to reduce the number of data variables collected into a distilled set for the detailed modelling and regression analysis. The key technique used by survival analysts is bivariate testing between the founding or failure rate dependent (survival) variable, and each of the independent variables i.e. one dependent and one independent variable for each regression.

Following Hosmer et al. (2008), bivariate tests were conducted to understand the relationship between the independent variables, both the founding and failure event data, in order to allow identification of the variables that were significant. The testing involved the use of the STATA 'stcox' command (using a dependent variable for the survival parameter). Once the significant variables were identified these were used as independent and control variables to perform a proportional hazard model regression.

The bivariate testing utilises a generic hypothesis (i.e. using both a 'Null' and 'Alternate' hypothesis):

- $Null\ Hypothesis, H_0 =$ $The\ coefficient\ is\ equal\ to\ zero\ and\ is$ not $significant\ to\ the\ change\ behaviour\ of\ the\ depedent\ variable$
- $Alternate\ Hypothesis, H_1 =$ $The\ coefficient\ is\ not\ equal\ to\ zero\ and\ is\ significant\ to\ the\ Proportional\ Hazard\ model$

$i.e.\ the\ independent\ variable\ does\ not\ significantly\ influence\ the\ behaviour\ of\ the\ dependent\ variable.$

The testing is made on the basis that the null hypothesis proposes that each independent variable has a non-significant exponential relationship (using Cox regression) with the dependent variables. In practice, three tests were performed on each independent variable, one with the founding rate of the organisation (or power plant) as the dependent variable, the second with the failure rate of the organisation (or power plant), and the third using the duration between starting and ceasing operations of the generator (or power plant) as the dependent variable (or the duration based variable).

The results of a typical STATA test output can be viewed in figure 26.

```
Cox regression -- Breslow method for ties

No. of subjects =          360                     Number of obs   =       495
No. of failures =          126
Time at risk    =  511.2607803
                                                   LR chi2(1)      =      1.20
Log likelihood  =   -564.64092                     Prob > chi2     =    0.2743
```

_t	Haz. Ratio	Std. Err.	z	P>|z|	[95% Conf. Interval]	
gisloan	.8324642	.1410786	-1.08	0.279	.5971887	1.160432

Figure 26 - Result Format from the STCOX Regression

Where the results are interpreted thus:

- t – the variable name that is being tested using the Breslow ties method
- Hazard Ratio – this is the risk of death or survival, $\hat{\beta}$, using the 'nohr' option it is also possible to obtain the coefficient
- Std. Error – the standard error, $\widehat{SE}(\hat{\beta})$
- Z – The result from the Wald statistic, which tests for the significance of the coefficient.
  - The Wald statistic is $= \frac{estimated\ coefficint}{estimated\ standard\ error} = \frac{\hat{\beta}}{\widehat{SE}(\hat{\beta})}$
- $P > |z|$- The p-value, which provides the result of the test, which is used to assess whether the Null or Alternate hypothesis is valid. This is the result from the two-tailed test, which is used because the direction of any relationship is not important at this stage
- [95% Conf. Interval] – the confidence interval estimates for the proportional hazards model containing the variable, t, i.e. with p<=0.05.

In this form of hypothesis testing there are three main tests used:

1. P-value - which, as stated above, is used to test the Null and Alternate Hypothesis
2. Wald statistic test – which is used to test the significance of the coefficient in the PH model
3. Score test (z^*) – which is a simple statistical test of a simple null hypothesis. It is used to test that the parameter of interest $(\theta)$is equal to some particular value (θ_0). $The\ test\ is\ equal\ to\ the$ $\frac{Derivative\ of\ log\ partial\ likelihood}{Square\ root\ of\ the\ observed\ information, all\ evaluated\ at\ \beta=0}$

To undertake bivariate testing the STATA 'stcox' command was used on each of the 183 variables that were collected in the course of the research. I.e. each individual variable is entered into the bivariate model and its contribution is checked for significance using a p-value, where the bivariate model contains a single independent variable and either the founding / failure rate or duration as the dependent variable. If a variable has a chi-squared significance less than 20%[10] then it was retained for subsequent modelling.

6.5 SURVIVAL ANALYSIS

The main decision when undertaking regression analysis is to determine which analysis modelling technique(s) to adopt. In many respects, in a study of this nature the decision is made for the researcher. The main consideration is the format and structure of the data. In a long-range event history study, the main limitations with linear regression techniques, the problems posed by non-normality of the distribution and censored data (both left and right censored data). These issues suggest that survival analysis techniques are better suited to vital event data than other forms of regression (Hosmer et al., 2008 p.67).

6.5.1 TESTING THE OBSERVED DIFFERENCE FOR STATISTICAL SIGNIFICANCE

The Kaplan-Meier estimator (also known as the Product limit estimator) is a survival estimator that allows the incorporation of information from all censored and uncensored observations, by considering survival to any point in time as a series of steps defined by the observed data (Cleves, 2010 p.45).

The observed data are used to estimate the conditional probability of confirmed survival at each observed survival time, which are subsequently multiplied (because of the proportional hazard requirement) to obtain an estimate of the overall survival function (Hosmer et al., 2008 p. 17). Once the survival function estimates have been calculated, it is necessary to obtain point-wise confidence interval estimates. In STATA, these can be obtained using the 'sts test' command.

[10] The test results were assessed by looking for a p-value that was less than 0.2 to 0.25 UNIVERSITY_OF_CALIFORNIA. 2013. *Statistical Computing Seminars - Survival Analysis with Stata* [Online]. Available: http://www.ats.ucla.edu/stat/stata/ado/analysis/ [Accessed 2 June 2013..

The key tests and their attributes are (Cleves, 2010 p.124-126), as shown in table 7:

Hypothesis Test	Description
Long-rank	Takes into account the entire survival experience and not just a specific point in time. This test gives equal weight to the contribution of each failure time to develop the overall test statistic
Wilcoxon	This is also a long-rank test, but places as much weight on the failures at the earlier failure times
Tarone-Ware	Similar to the Wilcoxon test, but without as much weight being given to the earlier failure times as is the case with the Wilcoxon test
Peto-Peto-Prentice	Uses the same weight function as with the K-M survivor function, but is not as susceptible to the differences in the censoring patterns
Generalised Fleming-Harrington	This test allows the user to develop a weighted system based on two values (p,q). When $p>q$, more weight is given to the earlier survival events. When $p<q$, more weight is given to the later survival times, and when $p=q$, then the test reduces to the log-rank test

Table 7 - Hypothesis Tests for the Kaplan-Meier Estimator

The outputs for these tests are the p-values, which identify if the survivor functions are the same for all survival events.

6.5.2 SURVIVAL REGRESSION MODEL DEVELOPMENT

In developing regression models, the main difficulty arises because there is usually more data than can reasonably be included in the regression model developed. The key is to determine what information should be included by considering the importance and setting of the data, confounding variables and statistical significance. The objective is to understand which factors have influenced the survival rate of the core parameter (dependent variable) by use of a regression model to make the estimates.

Hosmer et al., suggest that there are four techniques that can be used by researchers to select the most appropriate set of covariates: purposeful selection, stepwise selection, best subsets selection and multivariate fractional polynomials (MFPs). The first of these, purposeful selection, is undertaken by the data analyst and the last three are undertaken using statistical techniques (Hosmer et al., 2008 p.132).

6.5.2.1 PURPOSEFUL SELECTION

Purposeful selection is based upon a seven-step process that is used to fit the data into a multi-variate model (Hosmer et al., 2008 p.133-136). The model steps are summarised in table 8:

Step	Name	Description
1	Uni-variate Contribution Assessment	Each variable is entered into the multivariate model and its contribution is checked for significance using a p-value. If a variable has a chi-squared significance less than 20-25% then it is retained
2	Multivariate Model Development	Using the Wald test, the variables that can potentially be deleted are identified. The decision of whether or not to delete them is made by using a partial likelihood ratio test's p-values. Those variables that are non-significant are also dropped
3	Variable Removal Validation	This involves checking that the remaining variables coefficients have not been reduced by more than 20%, compared to the model developed in step 2.
4	Preliminary Main Effects Model	If the coefficients have been reduced by more than 20%, then it is necessary to add back each variable until the 20% coefficient reduction test is adhered to. This ensures that neither the statistical significance, nor the important confounders have been omitted
5	Main Effects Model	This step is used to examine the scale of the continuous covariates, and is used to determine if the effect of the covariates is linear in the log hazard model, and if not linear, to determine what transformation of the covariates is required to make the effect linear. This is undertaken by means of the Fractional Polynomial function in STATA (fracpoly)
6	Identify Covariate Interactions Necessary in the Model	An interaction term is a new variable that is the product of two remaining covariates. Whilst it is difficult to decide which combinations of covariates are necessary, the process is undertaken by introducing the interaction covariates into the Main Effects Model. Their validity is tested by means of the partial likelihood ratio test being above 5%, after firstly using the Wald test p-value to select which should be included. Clearly, adding unnecessary interaction covariates increases the standard error estimate of the model
7	Preliminary Model Evaluation	The final step is to check for adherence to the key model assumptions, using a case wise diagnostic statistics to test for influential observations and to test for goodness-of-fit

Table 8 - Purposeful Selection Methodology

Within the confines of the data, this model was used as the framework for the testing used in the testing of the energy policy models. The main limitation was that due to the limited number of founding and failure events in some instances the Fractional Polynomial function could not be computed.

6.5.2.2 STEPWISE SELECTION

A second approach to model development is to use the STATA 'stepwise' command, which automatically identifies which covariates are suitable for inclusion in the proportional hazard regression model. 'The basis for covariate inclusion is determined by using a forward selection, followed by a backwards elimination of the covariates' (Hosmer et al., 2008 p.154). This command is supported for a variety of STATA regressions, including stcox and streg.

6.5.2.3 BEST SUBSETS SELECTION

The use of the stepwise selection method only considers a small number of the total possible models. 'The Best Subsets model overcomes these limitations. Best Subset software screens all models containing the specified number of covariates, to build a specified number of models. Unfortunately, in STATA, the software only supports 'Best Subsets' for linear regression modelling (Hosmer et al., 2008 p.159).

6.5.2.4 MULTIVARIATE FRACTIONAL POLYNOMIALS (MFPS)

'The MFP algorithm combines the elements of backward elimination of non-significant covariates with an interactive examination of the scale of all continuous covariates using either closed or sequential test procedures' (Hosmer et al., 2008 p.163).

The techniques above were used for the regressions undertaken in chapters 9 and 10, albeit that the limited dataset prevented the use in many of the regressions.

6.5.3 ASSESSMENT OF SURVIVAL REGRESSION MODEL ADEQUACY

Most of the techniques used to assess model adequacy can be undertaken using the point or interval estimation of the measures that affect the outcome because of the covariates i.e. in a proportional hazards regression, the hazard rate. Assessing the model adequacy can be undertaken by residual analysis, assessing the proportional hazards assumptions, identifying the influencing and poorly fitting subjects and assessing the overall goodness-of-fit (Hosmer et al., 2008 p.169).

6.5.3.1 RESIDUAL ANALYSIS

The combination of data, model and likelihood in proportional hazard models makes the definition of residuals much more difficult than in other statistical contexts. Despite this, there are a number of residual calculation measures supported by STATA stcox post estimation 'estat predict' command (Hosmer et al., 2008 p.169-177) as shown in table 9:

Residual Measure	Description	STATA Command	Hosmer et al. Page
Schoenfeld Residual	Based on the contribution to the deviation or the log partial likelihood	schoenfeld	170
Scaled Schoenfeld Residual	Implements scaling of the Schoenfeld residual calculation by an estimator of its variance to yield a greater diagnostic power	scaledsch	171
Cox & Snell Residual	Uses a censored sample with an exponential distribution and a parameter equal to 1.0	csnell	175

Table 9 - Residual Analysis Techniques in STATA

6.5.3.2 ASSESSING THE PROPORTIONAL HAZARDS ASSUMPTIONS

The proportional hazards (PH) assumption is necessary for the interpretation and the use of a fitted proportional hazards model. This assumption characterises the model as a function of time and not as a function of the covariates per se.

The approach recommended by Hosmer et al (Hosmer et al., 2008 p.180) to assess these assumptions is to use the STATA stcox PH assumption tests i.e. the 'estat phtest', as shown in table 10:

PH Test	Description	STATA Command
Analysis time	Use the identity function of analysis time itself	time(varname)
Natural log	use natural logarithm time-scaling function	log
K-M estimate	use 1 - KM product-limit estimate as the time-scaling function	km
Rank	use rank of analysis time as the time-scaling function	rank
No option	Provides the global test result	-

Table 10 - PH Assumption Tests in STATA

The above process provides outputs of the score test and the p-values for the PH for each of the covariates and the Global test for the model.

6.5.3.3 IDENTIFYING THE INFLUENCING AND POORLY FITTING SUBJECTS

An important aspect of model evaluation is to use the regression diagnostic statistics to determine whether the model has: 'an unusual configuration of the variables, exerts an undue influence on the estimates of the parameters, and / or has an undue influence on the fit of the model'. The key focus if to identify the influencing and poorly fitting subjects using the STATA stcox post estimation predict plots (Hosmer et al., 2008 p.184), as shown in table 11:

Purpose	Test	Statistic	STATA Command
Identify subjects with high leverage of influence in the values of a single coefficient	Unusual configuration of the covariates	Score residuals	scores
	Exert undue influence on the parameters	Scaled score residuals	scaledsch
Assess the influence of vector coefficients	Likelihood displacement statistics	Likelihood displacement values	ldisplace

Table 11 - Influencing and Poorly Fitting Tests in STATA

6.5.3.4 ASSESSING THE OVERALL GOODNESS-OF-FIT

There are many tests that can be used to assess the goodness of fit of the regression model, many of which are computationally complex. The two main techniques used are the Martingale residuals (STATA stcox post estimation predict mgale) – which can be used after the stcox or streg commands, and the R-squared coefficient of determination using STATA stcox command (Hosmer et al., 2008 p.193). Since much of the modelling used for energy policy modelling utilised the STATA streg command the dedicated post estimation commands in STATA were followed.

6.6 RESEARCH FRAMEWORK UTILISED

The previous sections presented a discussion about the methodological matters and the range of suitable research techniques deemed relevant to the research. This section describes the specific techniques and approach adopted, by outlining the broad formulation of the research covering the four research themes of energy policy instruments, energy policy themes, energy policy impact on market competition, and the energy policy impact on market concentration.

In addition to these themes, two others were investigated. The first was the assessment of whether renewable technology represented a technological discontinuity (Sood et al., 2012, Tushman and Anderson, 1986), and the second was to assess the impact of renewables technology policies on the organisational form of the generators i.e. do renewables only generators represent a new organisational form in the EGI. Data limitations and lack of discussion space meant that these two research themes were not included in the final thesis.

6.6.1 BROAD FORMULATION OF THE RESEARCH

The research scope itself covered the following areas of investigation and analysis. These involved understanding: how public policy was formed and enacted, investigating and categorising public policy instruments and their application to the electricity sector, reviewing UK and EU energy policy and legislation between 1950-2011, understanding the climate change mitigation and emissions control objectives, becoming familiar with the structure of the UK electricity industry (i.e. generation, transmission, distribution and supply), understanding the traditional and renewable generation technologies, understanding organisational ecology theory, collecting the corporate demography vital event data for the EGI, and research techniques, and the theory and usage of survival analysis statistical research techniques.

Once the above had been investigated and understood, the research concentrated on development of the four main themes. The first two investigated how energy policy instruments and energy policy objectives have affected the EGI over the twenty-year period from the industry's privatisation until 2011. The third investigated how energy policy has affected the level of competition in the EGI market. The last investigated how energy policy has affected the level of market concentration in the EGI market.

6.6.1.1 ENERGY POLICY INSTRUMENTS RESEARCH

The first research theme was to identify which of the public policy instruments had any bearing and relevance to the EGI. This showed that energy policy instruments could be categorised under the following. Firstly, government funding broad programmes (i.e. covering Buildings - Low Carbon Buildings Programme (LCBP), Environment - Environmental Innovation Fund (EIF), Networks - Low Carbon Network Fund (LCNF), Products - Market Transformation Programme (MTP), Research - Innovation Funding Incentive (IFI), and Technology - High Technology Fund (HTF) Technology, and Marine Renewable Deployment Fund (MRDF), Secondly, Grants, Schemes and Incentives that were focused at individual energy projects (i.e. Equity Investments, Demonstrator Grants, Implementation Grants, Information and advice, Research Grants, Loan Incentives, and

Tax Incentives). Thirdly, Class of policy instruments (i.e. carbon Tax, electricity specific, energy efficiency, energy security, political measure, regulatory measures, technologies and transport). Fourthly, the Nature the policy instruments (i.e. economic, environmental, institutional, political, regulatory, and technology). Fifthly, the definition of regulatory waves that categorise the specific regulatory compliance measures (i.e. competition, energy security, environmental, generation, ownership, pricing, social, technology, and transport). Sixthly, technology cost effectiveness dates which identified the year at which when specific technologies reached a critical mass of installations (i.e. CCGT, CCGT / CHP, CHP, onshore wind, offshore wind, CCGT / embedded generation, embedded generation, OCGT, FGD, Low Nox burners, Oil, Coal PF & Biomass, and Coal PF & Biomass & Petcoke). Lastly, identification of the regulatory compliance waves (i.e. social political objectives (fuel poverty etc.), technology covering (gas embargo for electricity generation, fuel management, technology development support policy, technology management and control, transport policy).

In all of the above categories, coded energy policy instrument variables were constructed to enable analysis of both the energy policy instruments and energy policy objectives.

6.6.1.2 Energy Policy Objectives Research

Research and reading of the UK Government legislation, Royal Commission on Environmental Pollution (RCEP) published in 2000, and successive Governments' White Papers identified that energy policy over the twenty-year period since privatisation could be framed using five broad policy objectives. The first objective was to maintain competitive energy markets (MCM) i.e. to ensure adequate levels of competition. Second, Protecting Consumers (PC) with particular reference to low income families i.e. in terms of the 'fuel poor' families that spend more than ten per cent of their total household income on energy purchases. Next, the requirement to Protect the Environment (PTE) i.e. by ensuring that energy usage minimised the impact on climate change and that environmental pollution. Then the policy objective of Security of Supply (SOS) i.e. so that the UK's sources or energy did not become too concentrated in terms of fuel types or supply sources. Lastly, maintaining a Sustainable Rate of Economic Growth (SROEG) i.e. so that the general wellbeing of the economy would be enhanced.

Looking at these in the context of electricity it could be argued that the MCM and SROEG objectives were related to enhancing the level of market competition, whereas the PC and SOS objectives were concerned with maintaining or reducing the level of market concentration exhibited in the electricity marketplace. The PTE objective is slightly different because it is primarily concerned with reducing the level of GHG emissions and pollution i.e. it would be a 'control' factor that moderated the level of market competition and market concentration being observed.

To investigate and understand whether these five energy policy objectives were met by the electricity generation industry two different research techniques were adopted.

6.6.1.2.1 FOUNDING AND FAILURE RATES

The first research technique was to utilise the most common technique adopted by organisational ecologists, namely the use of founding and failure rates of entities in the full population. This involved both the founding and failure rates for the generators, as owners of the electricity generating power plants, and the same rates for the power plants that generate electricity. In this case, counts of the number of 'births' and 'deaths' of power plants were recorded by generator, and power plant, so that if a power plant were built by a generator it would be a power plant 'birth' and if the plant were later sold to another generator, or decommissioned, it would be recorded as a 'death'. If all the power plants owned by a generator were purchased collectively this event, would be a generator 'birth', and if they were all sold this event would be recorded as a generator 'death'.

Whilst this approach follows the methods and techniques utilised by organisational ecologists, in terms of its application to the electricity industry it is unique when evaluated by reference to the circa three thousand items of literature used for this research. Furthermore, the use of organisational ecology research and analysis techniques that utilise population-based empirical methods to evaluate the impact of government energy policy is also unique within the scope of the literature evaluated.

6.6.1.2.2 DURATION PERIOD ANALYSIS

The second research technique adopted was to investigate the impact of the energy policy objectives by means of an approach widely used by medical researchers, but only infrequently used by organisational ecologists. I.e. although organisational ecologists make widespread use of founding rates (counts), failure rates (counts), population density (counts) and growth rates to analyse data, they do not typically often use the duration (spell) analysis between vital events in corporate demography[11].

As will be observed below, the limited number of generator and power plants founding and failure events exhibited by the electricity generation industry over the twenty-year period highlighted that it might be beneficial to identify a more granular measure of observing the corporate demography of generators and power plants.

The approach adopted was to attempt to utilise a new and novel technique for the analysis, namely using a lower level of corporate demographic event classification i.e. to allow identification of the specific sub types of birth and death event to be recorded[12]. This information could be used to investigate of how energy policy objectives affected the underlying corporate demography of power plants over the twenty-year period.

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[11] Excepting that of Dussauge et al., 2000, Ingram and Baum, 1997 and Sorensen, 2000 whom have used the duration analysis based technique in specialised settings such as job tenure of CEO's etc.

[12] Power plant vital events were classified as: Corporatisation, Nationalisation, Privatisation, Acquisition, Parent Acquisition, Administration, Demerger, Divestment, Divestment - Regulatory Requirement, Management Buyout, Merger, Reverse Merger, Sale of Share, Change of Company Name, On-going Change, Change of Partner, Build Start, Mothball - Generation Restarted, Generation Start,

This duration-based analysis was undertaken at both the individual energy policy instrument and at the energy policy objective level. To the 'hardened' organisational ecologists this approach may seem strange because it could be asked 'why does the duration between an event such as a power station build announcement and the announcement of first electricity output, of the power station, have any correlation to energy policy instruments or energy policy objectives in the wider economy?'. The rationale for this duration-based approach arise from four broad factors that are set out in the following paragraphs. The results did prove worthwhile, informative and interesting from both a statistical and from an industry analysis perspective.

The text entitled 'The limits of Inference without Theory' (Wolpin, 2013) identified that it is not always necessary to conduct research from a specific theory baseline. The implication is that sometimes with research it is better to let the data 'speak for itself' and to see where that leads. This is very much the underlying premise of using duration based analysis to understand how energy policy instruments and policy objectives affect the day-to-day life of an electricity generating power plant.

The second justification is analogous to that of doctors and medical researchers making extensive use of duration-based analysis to understand the precursors for heart attacks etc. It can be argued that it might be equally valid to use energy policy interventions to understand how power plant owners and managers respond to external environmental changes. This idea arises from the author's many years of business experience during which he observed that as soon as there was some major change driver (or new government policy or regulation) announced, or even rumoured, productivity and investment planning within organisations was impacted as the staff sought to understand the change and determine its impact on the business operation and viability. Therefore, when energy policy changes came about one would anticipate that the management function might respond by extending or reducing the time between the lower level lifecycle vital events of the power plant[13]. The underlying rationale is that external events will cause disruption and instability to the on-going management and co-ordination of the generator company such that this will affect investment of other vital event durations at the power plant level. This could involve investment halts where no new money is spent, investment sprints where certain activities will completed before the new policy takes effect, investment deferrals until new grants or incentives come into effect. Clearly depending upon the nature of the policy one would expect some positive, negative or neutral impacts on the power plants such that durations could be longer, shorter or remain the same until the new policies have been understood, evaluated, appraised and digested.

The third justification for using duration analysis is that the definition of new government policy typically involves a number of different policy development and implementation activities. These range from idea

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Decommissioning Date.

[13] Power plant vital events were classified as: Corporatisation, Nationalisation, Privatisation, Acquisition, Parent Acquisition, Administration, Demerger, Divestment, Divestment - Regulatory Requirement, Management Buyout, Merger, Reverse Merger, Sale of Share, Change of Company Name, On-going Change, Change of Partner, Build Start, Mothball - Generation Restarted, Generation Start,
Decommissioning Date.

generation, idea announcement, drafting of the policy proposals, public / industry consultation on the new policy idea, consideration and refinement of the policy idea based on the consultation, preparing the primary or secondary legislation, enacting the legislation through the Parliament or the regulator, defining the enactment and / or compliance date required by the power plant generator owners (Kingdon, 2011). This process could take between 1 to 5 years from first 'mention' of the policy idea until power plant compliance is required. This means that policy intervention does not take effect instantaneously, and therefore each of these policy implementation events will take time to cause influence and response. This means that policy will have a progressive and dynamic change that can be observed by considering durations between events rather purely than just considering instantaneous founding of failure rates. Typically, organisational ecologists attempt to overcome these factors by using the Year+1, or Year +2 shifts of the key variables. However, in the context of energy policy it is postulated that the number of concurrent environmental interventions preclude such a definitive and prescriptive strategy when considering individual policy instruments.

Another important factor is that electricity power plants are very illiquid financial investments. They have very large price tags, extended build and commissioning times. For example, the build time of a combined cycle gas turbine will be circa eighteen months, a wind farm two years, whereas for a nuclear power plant it will take upwards of ten years. During this time, it is very difficult to sell or divest an investment that is not yet completed. Further, there are relatively few actors in the marketplace and they will take time to complete the due diligence matters associated with either a sale or purchase. Consequently, a new policy may take effect at a specified date but the full impact of this policy will take a lot longer to reach the steady state, even if there are willing buyers or sellers in the marketplace and the other factors associated with tax and financial sourcing are also ignored.

These four factors suggest that instantaneous founding and failure rated counts at defined times may miss a very rich source of inferential data and information. It is therefore hoped and anticipated that the use of duration periods between corporate demographic vital events will provide a rich source of new information and understanding. I.e. by use of inferential techniques to attempt to correlate the perturbation based impact of energy policy instruments and objectives.

Whilst the above has focused on the rational that such an inference-based approach may bring, it is also important to place the above in the context of prior research. In this regard, Dobbin and Dowd's (1997) research into the impact of government policy by analysis of industry behaviour in the US Railroad industry during periods of government and private sector ownership is insightful.

Their work showed that there were four main policy impacts evident when looking at the techniques for conducting this research. Specifically they observed the following when using corporate demography measures and event history analysis shown in table 12:

Impact Factor / Policy Framework	Anti-Trust Policies	Pro-Cartel Policies
Founding Rate	Reduced	Increased
Failure Rate	Increase	Decreased
Market Competition	Increased	Decreased
Market Concentration	Increased	Decreased

Table 12 - Dobbin and Dowd's Policy Impact Findings

This suggests that analysis of market competition, market concentration, founding rates and failure rates will provide the key factors necessary to understand the public policy impact[14].

6.6.2 ENERGY POLICY IMPACT ON MARKET COMPETITION RESEARCH

In addition to corporate demography, Dobbin & Down also considered market competition. Applying this to the analysis of UK energy policy would enable the impact of energy policy to be evaluated by considering market competition.

Attempting to identify the most suitable measurement technique highlights many techniques have been utilised by OE researchers, but the one that has the greatest appeal to long-range population-based studies is 'The Red Queen among Organisations - How Competitiveness Evolves' (Barnett, 2008). This technique:

> 'Questions the idea that large organizations have advantages that make them particularly potent rivals. We argue that the ability of large organizations to ameliorate competitive constraints insulates them from an important source of organizational development and protects them from being selected out if unfit. Consequently, we predict that although large organizations are likely to do well in technology contests, they also are likely to become weak competitors over time compared with small organizations. We specify this prediction in an explicit model of "Red Queen" competition, in which exposure to competition makes organizations both more viable and stronger competitors. We find support for our ideas in empirical estimates of the model obtained using data on hard disk drive manufacturers. Large organizations led the technology race in this market yet failed to develop into stronger competitors through Red Queen competition compared with their small counterparts. We also find evidence that all organizations in this market generated increasingly global competition, regardless of the competitiveness of their home markets. In these ways, our model elucidates important reasons why some organizations are stronger competitors and reveals how strategies that isolate organizations from competition may backfire' (Barnett and McKendrick, 2004).

[14] Albeit that this research also proposes to add duration-based analysis to this work of Dobbin and Down (1997)

Therefore, the research process that will be used to investigate the impact of government policy instruments and policy objectives and how the strength of competition has been affected over the twenty-year period of the study will be a replication of Barnett's framework.

6.6.3 ENERGY POLICY IMPACT ON MARKET CONCENTRATION RESEARCH

The final research framework adopted for this study was to investigate the level of market concentration in the electricity generation market by means of Gini coefficients and Dobrev et al.'s (2002) framework[15].

The detailed analysis technique utilised builds upon a synthesis of the theory base promoted by Boone and Witteloostuijn (2006), and the detailed approach outlined by Dobrev et al. (2002), and summarised thus:

> 'Although the niche figures prominently in contemporary theories of organization, analysts often fail to tie micro processes within the niche to long-term changes in the broader environment. In this paper, we advance arguments about the relationship between an organization's niche and evolution in the structure of its organizational population over time. We focus on the technological niche and processes of positioning and crowding among firms in the niche space, relating them to the level of concentration among all firms in the market. Building on previous empirical studies in organizational ecology, we study the evolution of concentration in the American automobile industry from 1885 to 1981 and estimate models of the hazard of exit of individual producers from the market. The findings show that niche and concentration interact in complex ways, yielding a more unified depiction of organizational evolution than typically described or reported' (Dobrev et al., 2002).M

6.7 METHODOLOGICAL MATTERS SUMMARY

The purpose of this chapter is to outline the high-level research frameworks adopted in subsequent chapters. It has outlined the choice and suitability of the different methods and techniques that will be utilised in the subsequent chapters. The purpose of this discussion was to equip the reader with sufficient background underlying the methods and techniques considered and selected for the subsequent research.

Now, it is worthwhile to orientate the reader to the four research methods that will be used in chapters 8 thru 11. The first method is to use founding and failure rate data associated with generators and power plants, correlating this with successive governments' energy policy instruments and objectives (MCM, PC, PTE, SOS and SROEG). The second method uses the duration periods, i.e. days between successive corporate

[15] The Gini coefficient yields a Gini index or Gini ratio by utilising a statistical measure of dispersion. Typically, this measure is used to represent the income distribution of a country's residents. The technique was published by the Italian sociologist Corrado Gini in his paper entitled 'Variability and Mutability' (1912). A Gini coefficient of zero represents perfect equality, where all values are the same (i.e. everyone in the population has exactly the same level of income), whereas a Gini coefficient of one (or 100%) expresses the maximum inequality among individuals (i.e. one person has all the income).

vital events, to derive period based inferential results from the correlation of energy policy and power plant corporate demography based vital events. The third method investigates the impact of energy policy by looking at how market competition evolves in the twenty-year timeframe of the study using the Red Queen theory. Finally, the level of market concentration exhibited by the EGI after the collective effect of energy policy is observed, using Dobrev et al.'s research techniques (Dobbin and Dowd, 1997, Dobrev et al., 2002).

7. Energy Policy Theory and Testing

7 ENERGY POLICY THEORY AND TESTING BACKGROUND

This chapter provides the reader with an overview of how public energy policy has affected the EGI generator population since the industry's privatisation in 1991. The need for this discussion is to highlight that there is a real paucity of research in this area, and especially so in the field of organisational ecology, where only five relevant sources of prior research could be identified (Diamant, 1960, Dobbin and Dowd, 1997, Russo, 2001, Sine et al., 2005, Wade et al., 1998). These five papers will form an introduction to the framework that will be used to examine UK related EGI energy policy.

The chapter is structured as follows: relevant prior energy policy research, the broad energy policy research question and theory for the research, overview of the data and variables used in the detailed research, and the presentation of the broad model specification and empirical statistical theory.

7.1 PRIOR ENERGY POLICY RESEARCH

The most striking thing about organisational ecology, as a research field, is that there is so little research work relating to public policy and energy policy in the research literature. Arguably, two of the founding fathers of the discipline, Hannan and Carroll, may in part be responsible for this situation with their remarks, cited by Dobbin & Down (1997), that 'regulation is of little theoretical interest' (Hannan and Carroll, 1995: p.540). This coupled with their similar remarks that the 'US economy is a free market, liberal environment that is free of regulation' have left the OE discipline with a shortfall in policy related research.

Despite this apparent oversight, Diamant's 1960 paper, in the Administrative Science Quarterly (ASQ), sets the backdrop to this study by identifying that there are two methods available to evaluate comparative politics. The first is by use of General System Models (GSMs), which conceptualises all societies using a three-staged model (rationalist idealism, material positivism, and realism with vision). Diamant clarifies what this involves in practice by citing David Evanston, 'The political system suggests that systems theory is useful with its sensitivity to input-output exchange between the system and its setting' (Diamant, 1960). Diamant's second approach was to recognise that most political systems can be characterised by Almond's work on culture, which states that policy work must contend with the societies and their political systems which can be classified into one of four structures: Anglo-American (used by the UK, USA, and many former UK Commonwealth countries), Continental European, Pre-industrial & partial industrial economies, and Totalitarian regimes (Almand, cited by Diamant, 1960).

The above suggests that an approach based on the systems model will be of some relevance to this research, and that US-based OE research will extrapolate into the UK culture and setting.

Wade and colleagues whose research (in the American Brewing industry 1840-1918) highlights that 'non-uniform government regulation creates market externalities of two kinds provide the translation of Diamant's work into the context of this research. Firstly, it creates resource flow opportunities that are not directly related to the action, and secondly, it imposes indirect coercive pressures by inflicting cultural norms in the environment of organisations that are not directly affected by the regulations (Wade et al., 1998). Further, their work shows that 'the normative effects of regulation operate non-locally and that these dominate in the jurisdictions not affected by the regulations, and further that at the local level non-uniform regulations affect resource flows and organisations which exhibit connectedness' (Wade et al., 1998).

Translating this into OE research outputs, Dobbin & Dowd identified that public policy 'establishes the ground rules of competition and creates varieties of market behaviour' and that 'most new policies create constraints based on incentives rather than dictating firm behaviour', and that managers construct new business strategies taking those constraints and incentives into account' (Dobbin and Dowd, 1997). Russo, shows that 'state bodies that accepted or rejected new rules for the US Independent Power Plants (IPPs) were predictors in terms of the number of new organisation foundings, such that collective action by IPPs boosted foundings and further, pre-existing relationships between utilities and regulators suppressed new organisation foundings' (Russo, 2001). Sine et al. found that development of regulative and cognitive institutions legitimated the entire Independent Power Producer sector – providing incentives for all sector entrants, with new organisational foundings by all kinds of firms multiplying rapidly, especially amongst those firms that embarked on new and risky technology (Sine et al., 2005). Lastly, Dobbin and Dowd's work also identified that policy regimes in the US Railroad industry (1825-1922) had significant impact on organisational ecology, specifically that when the state intervened in the industry organisational foundings increased, in line with increasing resources, and competition from the industry's incumbents fell. Conversely, when Anti-Trust legislation was enacted organisational foundings were discouraged and reduced, thus stimulating competition and encouraging concentration (mergers). This may appear counter intuitive but the Anti-Trust policy led firms to seek monopolies as the only remaining means of controlling price competition (see Hollingsworth, 1991: 41). The most important observation they made was that 'key organisational ecology findings (the theory fragments) were only valid when policy factors were controlled for' (Dobbin and Dowd, 1997). This gives support to the focus of this thesis, namely that energy policy has a more significant effect on organisations than the use of organisational theory per se.

In specific terms, Dobbin and Dowd's findings, most relevant to this study, are that new policies create constraints and incentives for organisations and that public policy influences the availability and competition for customers. They further remark that regulation can take one of two forms. The first is anti-trust regulation, which increases competition, increases industry concentration, discourages new organisational foundings and increases failures. Secondly, pro-cartel policies, decrease capital, decrease industry concentration, increase foundings and decrease failures. These findings suggest that by classifying the government's policy initiatives it will be possible to make predictive hypotheses usable for testing.

The above also highlights that public energy policy, and especially in the new and emerging IPP sector (similar to that found in the renewables sector in the UK), is of direct relevance to the well-being of firms. The work also brings into question Hannon and Carroll's comments about the relevance of policy and suggests that organisational ecology be subsumed into a role that is below Public Policy. It is this platform and body of research that has encouraged the study into energy policy in the UK EGI of this thesis.

7.2 BROAD ENERGY POLICY RESEARCH QUESTION AND THEORY

The broad context to be investigated is how public energy policy has affected the founding and failure rates and duration of ownership tenure of generators and power plants in the UK EGI since privatisation in 1991. This is especially relevant because of the significant number of policy interventions enacted and enforced in the UK EGI. The purpose of using founding and failure rates (and durations) is that these rates are of interest to researchers and policy makers alike because they can be used as indicators of the success of public policy, and specifically energy policies, in meeting objectives. They may also affect the market concentration ratios, and may affect efficiencies of the producers and the market. These rates also have value in themselves because they reflect how the energy policies have affected survival, longevity, ownership and the other corporate and technical vital events[16], using the form of analysis termed 'Event History Analysis'.

Focusing on the research question and the theory posed in the previous chapter.

Energy Policy Research Question is: How does public energy policy affect generator and power plant founding and failure rates and the length of ownership in the electricity sector?

Energy Policy Research: UK energy policy targets five broad policy groups (maintaining competitive markets, protecting the consumer, protecting the environment, security of energy supply and sustainable rate of economic growth) which are related by policy class, policy nature, macro-economic factors, electricity prices, targeted grants, and government funding stimuli when enacted in a free market environment and measured by the power plant founding, failure and ownership durations of generator companies.

Having outlined the broad energy policy research question and high-level theory proposed it is important to outline the data and variables used for the testing that will be undertaken in the next two chapters.

[16] The corporate vital events recorded were: corporatized, nationalisation, privatisation, acquisition, parent acquisition, administration, demerger, divestment, divestment - regulatory requirement, management buyout, merger, reverse merger, sale of share, change of company name, on-going change, change of partner, build start. The technical vital events recorded were: mothball - generation restarted, generation start, turbine start, downgrade, downgrade - output reduced, upgrade, upgrade - efficiency, upgrade - esp, upgrade - fgd, upgrade - fuel change, upgrade - low nox, upgrade - renovation complete, upgrade - renovation start, upgrade - repowering, upgrade - turbine, mothball - generation cease, mothball - part or all of generation cease, and decommissioning date.

7.3 DATA AND VARIABLES

The independent and control variables used for the energy policy evaluation, in the following two chapters, and the related hypotheses are categorised as follows:

- Dependent Variables
    - Founding and Failure rates for generators in the EGI
    - Founding and failure rates for power plants in the EGI
    - Duration of tenure in the EGI by generators
    - Duration of tenure in the EGI by individual power plants.
- Independent Variables:
    - Energy policy specific variables – which relate to the government's energy policy interventions
    - Grants, Schemes and Incentives (GIS) – this relates to various initiatives implemented by government such as equity investments, grants, subsidies and taxation offsets. The GIS schemes are typical aimed at individual recipient companies or individuals. There were ninety-two schemes announced with a funding of £4 billion in the UK since 1990
    - Funding – in addition to the GIS support mechanisms, the government also implemented a number of major funding schemes announced to stimulate energy policy change. These are aggregate schemes which are worth of millions of pounds and which are targeted at all producers and consumers. The broad schemes (and budgets) included the following: Renewables (£250m), Low Carbon and Renewables Technologies (£500m), Renewable Capital Grants (£60m), Environmental Transformation Fund (£400m), Low Carbon Investment Fund (£350m), and Strategic Investment Fund (£250m)
    - Policy Class – includes variables that summarise the energy policies implemented. They have been summarised for their role in targeting carbon taxes, energy efficiency, regulatory, technology, and transport policy-based measures. These variables were derived from detailed analysis of government commission reports, such as the RCEP, White Papers and government primary and secondary legislation. The information was collated as policies announced per year, accumulated policies and policy years of experience
    - Policy Nature – As a secondary level of analysis the policy class information was re-categorised in terms of the number of policies of economic, environmental, political, regulatory, and technology policy-based measures.
- Control Variables – were collected to ensure that balanced models were well defined. These variables were selected to attempt to ensure that the independent variables were placed into the context of the other factors and variables, that were thought to have some bearing on the dependent variable i.e. to mitigate against the other associated factors that will influence the ownership duration of a power plant:
    - Core Data - using macro-economic factors i.e. bank base rates, price inflation, GDP, and USD:Sterling exchange rates
    - Electricity Price – both domestic and industrial prices
    - Fuel Type – classification of the fuels used by the power plants
    - Fuel Used – which records the amount of fuel used in terms of millions of tonnes of oil equivalent to ensure a normalised comparative mechanism
    - Location - identifies the location of the power plant by county and country
    - Plant Number – each power plant in the UK was given a number to uniquely identify it for the duration of the study
    - Plant Owner – each generating company was also given a unique number to identify the duration of the study
    - Power Plant Fuel Usage – records which fuel is used for the energy conversion
    - Plant Usage – depending on the type of technology power plant can be used for the majority of the day or might be used for short peaks, the plant usage figure records the percentage of time each type of power plant is generating electricity
    - Regulatory Waves - which records the presence or absence of regulatory policy obligations for electricity generators or consumers
    - Tech. Wave – records the year when more than 25% of a power plant type has been achieved
    - Technical Capacity – to record the size of the power plant in terms of its megawatt output
    - Technology Plant Cost – what is the capital cost of building new plant in the year of observation, in terms of its US dollar cost per kilowatt of theoretical output
    - UK Emissions of GHGs – the level of millions of tonnes of CO_2 equivalent emitted for the UK
    - Vital Events – the corporate demography based events related to power plants.

Looking at these in detail.

7.3.1 DEPENDENT VARIABLES

The dependent variable in all models was the power plant holding time between successive corporate demographic events, which were recorded as either founding or failure events. The dependent variable is a parameter called 'daterng' that is the date range between the start and end of the vital event, measured in days. Events are coded according to the start or founding event – this means that a power plant that is acquired is coded as a founding event number '4' and when it is nationalised it is coded with a failure event number '2'. The vital events collected for each power plant are shown in table 13:

Detailed	Detailed Vital Event Code Number	Founding Event	Failure Event	Power Plant Technology Change Event
Corporatized	1	1	1	
Nationalisation	2	1	1	
Privatisation	3	1	1	
Acquisition	4	1	1	
Parent Acquisition	5	1	1	
Administration	6	1	1	
Demerger	8	1	1	
Divestment	9	1	1	
Divestment - Regulatory Requirement	10	1	1	
Management Buyout	11	1	1	
Merger	12	1	1	
Reverse Merger	13	1	1	
Sale of Share	14	1	1	
Change of Company Name	15	1	1	
On-going Change	15	1	1	
Change of Partner	16	1	1	
Build Start	17	1	1	
Mothball - Generation Restarted	18	1	1	
Generation Start	19			1
Turbine Start	20			1
Downgrade	21			1
Downgrade - Output Reduced	22			1
Upgrade	23			1
Upgrade - Efficiency	24			1
Upgrade - ESP	25			1
Upgrade - FGD	26			1
Upgrade - Fuel Change	27			1
Upgrade - Low NOX	28			1
Upgrade - Renovation Complete	29			1
Upgrade - Renovation Start	30			1
Upgrade - Repowering	31			1
Upgrade - Turbine	32			1
Mothball - Generation Cease	33		1	
Mothball - Part or all of Generation Cease	34		1	
Decommissioning Date	35		1	

Table 13 – Dependent Variable Vital Event Type Coding

It should be noted that the events (19 thru 32) are technical upgrade / downgrade events. These have not been used in the research but are available for further research that will look at the impact of energy policy on the generator's technical investment and upgrade policies.

7.3.2 INDEPENDENT AND CONTROL VARIABLES

The full list of independent and control variables used for the testing in the next two chapters is shown in table 14:

Policy	Class	Variable Description	Variable Name	Obs	Mean	Std. Dev.	Min	Max
MCM	GIS	Equity - Equity Investment	giseqinv	14	1.14	1.10	0	3
		Grant - Total Grants, Schemes and Incentives	gisimg	14	1.36	1.28	0	4
		Loan - Loan Incentive	gisloan	14	0.64	0.74	0	2
		Subsidy - Subsidy	gissub	14	1.64	0.50	1	2
		Taxation - Tax Incentive	gistaxoff	14	1.86	1.66	0	4
	Obligations	British Electricity Trading Transmission Arrangements (BETTA)	obegbetta	5	1.00	0.00	1	1
		New Electricity Trading Arrangements (NETA)	obegneta	5	1.00	0.00	1	1
	PI - Class	Regulatory - Policy Count by Cumulative Policy Years of Experience	pcrg	6	10.00	5.93	4	21
		Regulatory - Policy Count by Policy Years of Experience	pcrgyr	6	116.33	97.37	12	231
		Regulatory - Policy Count by Year Policy Announced	pcrgyrcum	6	57.83	36.05	21	108
	PI - Nature	Institutional - Policy Count by Year	pnin	5	4.20	3.11	1	9
		Regulatory - Policy Count by Year	pnrg	5	9.60	10.33	1	27
	Regulatory	Competition - Price & Competition Encouragement	rwcomp	21	1.00	0.00	1	1
		Ownership - Acquisitions, Mergers, and New Player Market Entry	rwownacqp	19	1.00	0.00	1	1
		Ownership - Government Divestment of Remaining Interest	rwowngdp	2	1.00	0.00	1	1
		Ownership - Ownership Total	rwowntotp	21	1.48	0.81	0	3
		Ownership - REC Monopoly Supply, Price Competition and Price Mgt	rwownrecp	10	1.00	0.00	1	1
		Pricing - Price Competition	rwpricpcp	21	1.00	0.00	1	1
		Pricing - Price Management and Control	rwpricpmp	13	1.00	0.00	1	1
		Pricing - Pricing Total	rwprictotp	21	1.62	0.50	1	2
PC	Obligations	Planning and Development Total	obpdtot	21	0.52	0.81	0	2
		Planning Policy Statement 22 (PPS 22)	obpdpps	7	1.00	0.00	1	1
	PI - Class	Political - Policy Count by Cumulative Policy Years of Experience	pcpo	6	10.17	7.00	5	23
		Political - Policy Count by Policy Years of Experience	pcpoyr	6	102.00	123.17	5	345
		Political - Policy Count by Year Policy Announced	pcpoyrcum	6	42.83	29.85	13	85
	PI - Nature	Political - Policy Count by Year	pnpo	6	6.50	4.04	2	11
	Regulatory	Social - Political Objectives (Fuel poverty etc.)	rwsocfpp	9	1.00	0.00	1	1
PTE	Emissions	Hydrofluorocarbons (HFC)	hydrofluorocarbonshfc	21	13.01	2.43	9	19
		Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	21	66.21	20.25	41	97
		Millions of Tonnes of CO2 Equivalent	mtco2e	21	681.28	52.99	573	773
		Net CO2 emissions (emissions minus removals)	netco2emissionsemissionsmin	21	551.28	27.03	478	598
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousoxiden2o	21	49.18	10.97	35	68
		Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	perfluorocarbonspfc	21	0.45	0.31	0	1
		Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	sulphurhexafluoridesf6	21	1.14	0.28	1	2
	Funding	Buildings - Low Carbon Buildings Programme (LCBP)	fundlcbp	5	1.00	0.00	1	1

Policy	Class	Variable Description	Variable Name	Obs	Mean	Std. Dev.	Min	Max
		Environment - Environmental Innovation Fund (EIF)	fundeif	1	1.00	.	1	1
	GIS	Information - Information	gisinfo	14	1.79	1.81	0	5
	Obligations	Carbon Emissions Reduction Target (CERT)	obensucert	9	1.00	0.00	1	1
		Climate Change Levy (CCL)	obeuccl	10	1.00	0.00	1	1
		Community Energy Saving Programme (CESP)	obensucesp	2	1.00	0.00	1	1
		CRC Energy Efficiency Scheme (CRC)	obeucrc	1	1.00	.	1	1
		Electricity Generators Total	obegtot	21	1.24	1.37	0	3
		Electricity Supplier Total	obestot	21	1.43	0.51	1	2
		Electricity Users Total	obeutot	21	0.81	0.98	0	3
		Energy Efficiency Commitment (EEC)	obensueec	7	1.00	0.00	1	1
		Energy Performance Certificates (EPC)	obpdpc	4	1.00	0.00	1	1
		Energy Supplier Total	obensutot	21	0.43	0.51	0	1
		EU Emissions Trading System (EU-ETS) - Generators	obegets	6	1.00	0.00	1	1
		EU Emissions Trading System (EU-ETS) - Users	obeuets	6	1.00	0.00	1	1
		Large Combustion Plant Directive (LCPD)	obeglcpd	10	1.00	0.00	1	1
		Non Fossil Fuel Obligation (NFFO)	obesnffo	21	1.00	0.00	1	1
		Renewables Obligation (RO)	obesro	9	1.00	0.00	1	1
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	pcctyrcum	6	21.50	18.16	5	48
		Carbon Tax - Policy Count by Policy Years of Experience	pcctyr	6	20.83	23.13	2	65
		Carbon Tax - Policy Count by Year Policy Announced	pcct	6	3.67	1.75	1	5
		Electricity - Policy Count by Cumulative Policy Years of Experience	pcelyrcum	3	1.00	0.00	1	1
		Electricity - Policy Count by Policy Years of Experience	pcel	1	1.00	.	1	1
		Electricity - Policy Count by Year Policy Announced	pcelyr	1	1.00	.	1	1
		Energy Efficiency - Policy Count by Cumulative Policy Years of Experience	pcee	6	4.67	5.68	1	16
		Energy Efficiency - Policy Count by Policy Years of Experience	pceeyrcum	6	30.00	19.48	16	64
		Energy Efficiency - Policy Count by Year Policy Announced	pceeyr	6	38.33	49.47	1	128
		Transport - Policy Count by Cumulative Policy Years of Experience	pctr	4	5.75	1.50	4	7
		Transport - Policy Count by Policy Years of Experience	pctryrcum	6	22.50	19.67	7	56
		Transport - Policy Count by Year Policy Announced	pctryr	4	58.25	38.18	16	105
	PI - Nature	Environmental - Policy Count by Year	pnev	6	9.83	4.96	3	17
	Regulatory	Environmental - Carbon Tax Policy	rwcarbonpol	20	1.00	0.00	1	1
		Environmental - Emissions Management	rwenemp	20	1.00	0.00	1	1
		Environmental - Energy Efficiency Policy	rweneep	11	1.00	0.00	1	1
		Environmental - Environmental and Climate Change Control	rwenccp	21	1.00	0.00	1	1
		Environmental - Environmental Total	rwentotp	21	3.86	0.36	3	4
		Environmental - Fuel Management	rwenfmp	9	1.00	0.00	1	1
		Transport - Transport Policy	rwtransp	5	1.00	0.00	1	1
SOS	Funding	Networks - Low Carbon Network Fund (LCNF)	fundlncf	1	1.00	.	1	1
		Products - Market Transformation Programme (MTP)	fundmtp	5	1.00	0.00	1	1

Policy	Class	Variable Description	Variable Name	Obs	Mean	Std. Dev.	Min	Max
		Research - Innovation Funding Incentive (IFI)	fundifi	6	1.00	0.00	1	1
		Technology - High Technology Fund (HTF)	fundhtf	10	1.00	0.00	1	1
		Technology - Marine Renewable Deployment Fund (MRDF)	fundmrdf	1	1.00	.	1	1
	GIS	Grant - Demonstrator Grant	gisdemg	14	6.36	6.30	0	20
	GIS	Grant - Implementation Grant	gisrg	14	3.07	3.97	0	14
	GIS	Grant - Research Grant	gisgrnttot	14	10.79	11.27	0	38
	PI - Class	Energy Security - Policy Count by Cumulative Policy Years of Experience	pcesyrcum	5	11.00	8.25	2	18
		Energy Security - Policy Count by Policy Years of Experience	pcesyr	5	7.20	12.83	0	30
		Energy Security - Policy Count by Year Policy Announced	pces	4	2.25	1.89	1	5
		Technologies - Policy Count by Cumulative Policy Years of Experience	pcte	6	10.17	7.73	4	25
		Technologies - Policy Count by Policy Years of Experience	pcteyr	6	165.83	149.15	16	425
		Technologies - Policy Count by Year Policy Announced	pcteyrcum	6	60.17	30.92	25	105
	PI - Nature	Technology - Policy Count by Year	pnte	6	8.33	5.20	2	16
	Regulatory	Energy Security - Energy Security Policy	rwensecpol	5	1.00	0.00	1	1
		Generation - Electricity Generation Policy	rwelgenp	0				
		Technology - Fuel Management	rwtechfmp	9	1.00	0.00	1	1
		Technology - Gas Embargo for Electricity Generation	rwtechgep	2	1.00	0.00	1	1
		Technology - Technology Development Support Policy	rwtechdevp	9	1.00	0.00	1	1
		Technology - Technology Management and Control	rwtechmgtp	16	1.00	0.00	1	1
		Technology - Technology Total	rwtechtot	21	1.71	0.46	1	2
SROEG	PI - Nature	Economic - Policy Count by Year	pnec	6	8.00	6.26	2	19
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)	biomasscost	21	21.41	3.34	17	28
		CCGT Cost (USDmill/kwh)	ccgtcost	21	4.22	0.66	3	5
		Coal Cost (USDmill/kwh)	coalcost	21	9.37	1.46	7	12
		Conventional Thermal Cost (USDmill/kwh)	ctcost	21	12.68	1.98	10	16
		Fuel Cell Cost (USDmill/kwh)	fuelcellcost	21	40.88	6.38	32	53
		Geothermal Cost (USDmill/kwh)	geothermalcost	21	39.51	6.17	31	51
		Hydro Cost (USDmill/kwh)	hydropowercost	21	6.50	1.02	5	8
		IGCC Cost (USDmill/kwh)	igcccost	21	11.52	1.80	9	15
		MSW Landfill Cost (USDmill/kwh)	mswlandfillcost	21	29.49	4.61	23	38
		Nuclear Cost (USDmill/kwh)	nuclearcost	21	13.27	2.07	10	17
		Solar PV Cost (USDmill/kwh)	solarpvcost	21	2.60	0.41	2	3
		Solar Thermal Cost (USDmill/kwh)	solarthemcost	21	8.07	1.26	6	10
		Wind Cost (USDmill/kwh)	windcost	21	7.56	1.18	6	10
		Wind Offshore Cost (USDmill/kwh)	windooffcost	21	20.67	3.23	16	27
FUEL	Fuel Usage	Coal Used MTOE	coalmtoe	21	34.23	7.97	25	53
		Natural Gas Used MTOE	naturalgasmtoe	21	20.08	10.96	0	32
		Nuclear Used MTOE	nuclearmtoe	21	18.64	3.27	12	23
		Oil Used MTOE	oilmtoe	21	2.54	1.78	1	7
		Other Renewables Used MTOE	otherrenmtoe	12	2.92	0.95	1	4
		Other Technologies Used MTOE	othermtoe	21	1.30	0.29	1	2
		Hydro Used MTOE	hydromtoe	21	0.39	0.06	0	0
		Imports Electricity MTOE	importsmtoe	21	0.96	0.44	0	1
		Wind Used MTOE	windmtoe	6	0.56	0.25	0	1
MACRO	Core	BoE Base Rate	baserate	21	5.45	2.94	1	14
		Brent Crude Oil Price	oilprice	21	35.53	25.60	11	94
		Escalator / Deflator (US CPI)	cpiescdefl	21	1.19	0.19	1	2

Policy	Class	Variable Description	Variable Name	Obs	Mean	Std. Dev.	Min	Max
		GDP Billions (£)	gdp	21	972.61	356.48	66	1458
		Households in Fuel Poverty %	fuelpoor	8	11.76	4.96	6	18
		Implied Investment Deflator	investd	21	0.92	0.07	1	1
		US $ to Sterling Spot Exchange Rate	spotrate	21	1.67	0.17	1	2
PRICE	Electricity Price	Industrial Price Per Pence KwH	indprce	21	4.83	1.61	3	9
		Retail Price of Electricity Pence per KwH	pencekwh	21	8.54	2.09	7	13
TECH	Capacity	CCGT Capacity (MW)	ccgtmw	21	17041.81	11232.78	76	34099
		Hydro Natural Flow Capacity (MW)	hydronatmw	21	1383.12	319.89	1	1526
		Hydro Pumped Capacity (MW)	hydropumpmw	21	2709.52	302.35	1393	2787
		New Plant Commissioned (MW)	newplantmw	21	885.19	2379.26	-3029	5494
		Nuclear Capacity (MW)	nuclearmw	21	11823.48	771.02	10585	12956
		Other Technologies Capacity (MW)	othermw	21	1791.08	786.17	289	3356
		Thermal Capacity (MW)	thermalmw	21	40593.38	6681.00	33772	55712
	Tech. Cap.	All Technologies Capacity (MW)	allmw	21	74846.40	6436.77	64960	88648
		Maximum Output (MW s.o)	maxoutputmw	21	57593.24	3351.67	51663	61717
		Other Renewables Capacity (MW)	otherrenmw	21	910.62	602.57	125	1960
		Total Installed Capacity (MW)	totcapmw	21	76637.48	5958.92	67499	88937
		Wind Capacity (MW)	windmw	6	1345.67	624.07	658	2260
UTILISATION	Plant Usage	All Plant Load Factor (%)	loadfactor	21	75.29	3.10	68	81
		CCGT Load Factor	ccgtlf	19	64.78	9.96	35	81
		Hydro Natural Flow Load Factor	hydronatlf	20	33.24	4.64	23	40
		Hydro Pumped Load Factor	hydropumlf	21	9.81	3.71	6	17
		Nuclear Load Factor	nuclearlf	21	70.69	7.99	49	80
		Other Technology Load Factor	otherslf	21	9.51	3.51	3	15
		Thermal Plant Load Factor	thermallf	21	44.07	4.93	33	50
WAVE	Tech. Wave	CCGT / CHP >25% of Total Installed CCGT / CHP	teccgtchp	1	1.00	.	1	1
		CCGT / Embed. Gen. >25% of Total Installed CCGT / Embed. Gen	teccgtem	1	1.00	.	1	1
		CCGT >25% of Total Installed CCGT	teccgt	1	1.00	.	1	1
		CHP >25% of Total Installed CHP	techp	1	1.00	.	1	1
		Coal PF & Biomass & Petcoke >25% of Total Installed Coal Pet	tecoalbiopet	1	1.00	.	1	1
		Coal PF & Biomass >25% of Total Installed Coal PF Bio.	tecoalbio	1	1.00	.	1	1
		Embedded Generation >25% of Total Installed Embed. Gen	teeg	1	1.00	.	1	1
		OCGT, FGD, Low Nox burners >25% of Total Installed OCGT	teocgt	1	1.00	.	1	1
		Offshore >25% of Total Installed Offshore	teonwind	1	1.00	.	1	1
		Oil >25% of Total Installed Oil	teoil	1	1.00	.	1	1
		Onshore >25% of Total Installed Onshore	teoffwind	1	1.00	.	1	1
VIT	VIT	Year of Observation	year	21	2000.00	6.20	1990	2010

Table 14 - Independent and Control Variables

These are summarised in table 15:

Variable Category	Variable Description	Both	Founding Only	Failure Only	Total Used	Collected but Unused	Total Variables
Policy Class	Count of Policy Interventions by Instrument	9	4	1	14	10	24
Policy Nature	Count of Policy Interventions by Instrument target	1	3	1	5	1	6
Regulatory Obligations	Count of Regulatory Obligations					18	18
Regulatory Waves	Regulatory Intervention Phases	1		2	3	20	23
Technology Waves	Technical Adoption & Usage Phases					11	11
Electricity Price	Consumer and Industrial Price	1		1	2		2
GIS	Government funded Incentives	2	4		6	3	9
Broad Funding Programmes	Major Government Expenditure Plans					7	7
Power Plant Capacity	MW Generating capacity	4	2	1	7	5	12
Power Plant Fuel Usage	Millions of Tonnes of Oil Equivalent used	1	5	1	7	2	9
Power Plant Usage	Load Factor - % Used	2	1	1	4	3	7
Technology Plant Cost	Capital Build Cost by Technology	14			14		14
UK Emissions of GHGs	Volume of GHGs emitted by UK	4	2	6		1	7
Vital Events	Power Plant demographic data	8		3	11	12	13
Core Data	Control data	1	2	1	4	4	8
Totals		48	23	12	83	100	183

Table 15 - Collected Data Analysis by Variable Category

The classification of the detailed variables and their purpose in the energy policy hypotheses are shown in table 16:

Variable Category	Government Policy	Variable Description	Variable Name	Variable Usage
Core Data	MACRO	BoE Base Rate	baserate	All
		Escalator / Deflator (US CPI)	cpiescdefl	All
		GDP Billions (£)	gdp	All
		US $ to Sterling Spot Exchange Rate	spotrate	All
Electricity Price	PRICE	Industrial Price Per Pence KwH	indprce	All
		Retail Price of Electricity Pence per KwH	pencekwh	All
Grants, Incentives and Schemes	MCM	Equity - Equity Investment	giseqinv	Policy
	SOS	Grant - Research Grant	gisgrnttot	Policy
	GIS	Grant - Total Grants, Schemes and Incentives	gisimg	All
	SOS	Grant - Implementation Grant	gisrg	Policy
	MCM	Subsidy - Subsidy	gissub	Policy
	MCM	Taxation - Tax Incentive	gistaxoff	Policy
Policy Class	MCM	Regulatory - Policy Count by Cumulative Policy Years of Experience	pcrg	Policy
		Regulatory - Policy Count by Policy Years of Experience	pcrgyr	Policy
		Regulatory - Policy Count by Year Policy Announced	pcrgyrcum	Policy
	PTE	Carbon Tax - Policy Count by Policy Years of Experience	pcctyr	Policy
		Carbon Tax - Policy Count by Cumulative Policy Years of Experience	pcctyrcum	Policy
		Energy Efficiency - Policy Count by Cumulative Policy Years of Experience	pcee	Policy
		Energy Efficiency - Policy Count by Year Policy Announced	pceeyr	Policy
		Energy Efficiency - Policy Count by Policy Years of Experience	pceeyrcum	Policy
		Transport - Policy Count by Cumulative Policy Years of Experience	pctr	Policy
		Transport - Policy Count by Policy Years of Experience	pctryrcum	Policy
	PC	Political - Policy Count by Year Policy Announced	pcpoyrcum	Policy
	SOS	Technologies - Policy Count by Cumulative Policy Years of Experience	pcte	Policy
		Technologies - Policy Count by Policy Years of Experience	pcteyr	Policy
		Technologies - Policy Count by Year Policy Announced	pcteyrcum	Policy
Policy Nature	MCM	Regulatory - Policy Count by Year	pnrg	Policy

Variable Category	Government Policy	Variable Description	Variable Name	Variable Usage
	PTE	Environmental - Policy Count by Year	pnev	Policy
	PC	Political - Policy Count by Year	pnpo	Policy
	SOS	Technology - Policy Count by Year	pnte	Policy
	SROEG	Economic - Policy Count by Year	pnec	Policy
Power Plant Capacity	TECH	CCGT Capacity (MW)	ccgtmw	All
		Hydro Natural Flow Capacity (MW)	hydronatmw	All
		Hydro Pumped Capacity (MW)	hydropumpmw	All
		New Plant Commissioned (MW)	newplantmw	All
		Nuclear Capacity (MW)	nuclearmw	All
		Other Technologies Capacity (MW)	othermw	All
		Thermal Capacity (MW)	thermalmw	All
Power Plant Fuel Usage	FUEL	Coal Used MTOE	coalmtoe	All
		Hydro Used MTOE	hydromtoe	All
		Natural Gas Used MTOE	naturalgas~e	All
		Nuclear Used MTOE	nuclearmtoe	All
		Oil Used MTOE	oilmtoe	All
		Other Technologies Used MTOE	othermtoe	All
		Other Renewables Used MTOE	otherrenmtoe	All
Power Plant Usage	UTILISATION	CCGT Load Factor	ccgtlf	All
		Hydro Natural Flow Load Factor	hydronatlf	All
		Nuclear Load Factor	nuclearlf	All
		Thermal Plant Load Factor	thermallf	All
Regulatory Waves	PTE	Environmental - Environmental Total	rwentotp	Policy
	MCM	Ownership - Ownership Total	rwowntotp	Policy
	SOS	Technology - Technology Total	rwtechtot	Policy
	PTE	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	Policy
		Millions of Tonnes of CO2 Equivalent	mtco2e	Policy
		Net CO2 emissions (emissions minus removals)	netco2emis~n	Policy
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousox~2o	Policy
		Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	perfluoroc~c	Policy
		Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	sulphurhex~6	Policy
Technology Plant Cost	CAPITAL	Biomass Cost (USDmill/khw)	biomasscost	All
		CCGT Cost (USDmill/kwh)	ccgtcost	All
		Coal Cost (USDmill/kwh)	coalcost	All
		Conventional Thermal Cost (USDmill/kwh)	ctcost	All
		Fuel Cell Cost (USDmill/kwh)	fuelcellcost	All
		Geothermal Cost (USDmill/kwh)	geothermal~t	All
		Hydro Cost (USDmill/kwh)	hydropower~t	All
		IGCC Cost (USDmill/kwh)	igcccost	All
		MSW Landfill Cost (USDmill/kwh)	mswlandfil~t	All
		Nuclear Cost (USDmill/kwh)	nuclearcost	All
		Solar PV Cost (USDmill/kwh)	solarpvcost	All
		Solar Thermal Cost (USDmill/kwh)	solarthemc~t	All
		Wind Cost (USDmill/kwh)	windcost	All
		Wind Offshore Cost (USDmill/kwh)	windooffcost	All
Vital Events	EVENT	Vital Event Detailed Number	evtdetnos	All
		Vital Event High-Level Group Number	evgrtnos	All
		Vital Event Summary Number	evtsumnos	All
	FUEL	Co-fired Fuel used in Power Plant	cofire	All
		Detailed Fuel Number of Power Plant	fuelnos	All
		Primary Fuel Number of Power Plant	primnos	All
	LOCATION	Country Number Where Power Plant is Located	countrynos	All
	MW	MW Generating Capacity of Power Plant	mw	All
	TECH	Technology Number of Power Plant	technos	All
	VIT	End Date of Power Plant Record	date1	Control
		End Date of Power Plant Record (XXXX)	dateyr0	Control
		First Year of Power Plant Record	firstyr	Control
		First Year of Power Plant Record (XXXX)	date1yr	Control
		Last Data of Power Plant Vital Event Recorded	lastnorcevt	Control
		Number of Days Recorded for All Vital Events on Power Plant	fslstdate	Control
		Power Plant Vital Event is Left Censored	lc	Control
		Power Plant Vital Event Record is Right Censored	rc	Control
		Sequence Number of Power Plant Vital Event	seq	Control
		Start Date of Power Plant Vital Event Record	date0	Control

Table 16 - List of Variables

Taking each category in turn. The policy class identifies the number of policy interventions announced in the Energy Review, White Papers and the RCEP report. The counts have been accumulated by year, and further broken down into policy counts by year (raw data), policy years of experience of that type of policy since announcement (to illustrate the government's experience with a specific type of policy intervention), and also cumulative policies based on years of experience multiplied by policy count (to show the accumulated basis of experience and policy density). The policies are further categorised by policy instrument intervention types (carbon taxes, energy efficiency measure, political social objectives [such as targeting the fuel poor], regulatory interventions [such as the EU-ETS], measures targeted at encouraging / curbing preferred technologies, and policies aimed at transportation [which have an indirect impact of fuel costs etc. for electricity producers].

A different perspective on the policy backdrop can be seen from considering the nature of the policy nature interventions, as opposed to the policy class above that was directed more at the user's perspective. The policy count data used for this analysis are the same as those used above but the policies are defined in terms of their public policy intervention, namely: economic, environmental, institutional (government body establishment etc.), political, regulatory and technology based. The policy nature analysis was made only in policy count terms with regard to the year of announcement because a more detailed, but different categorisation, framework was adopted for the Policy Class variables.

The regulatory obligations classification was made using a series of categorical (1 or 0) measures to record the start date of the major obligations that have been enacted. These include the: Carbon Emissions Reduction Target (CERT), Community Energy Saving Programme (CESP), Energy Efficiency Commitment (EEC), Climate Change Levy (CCL), CRC Energy Efficiency Scheme (CRC), EU Emissions Trading System (EU-ETS), Non Fossil Fuel Obligation (NFFO), Renewables Obligation (RO), Energy Performance Certificates (EPC), Planning Policy Statement 22 (PPS 22), Large Combustion Plant Directive (LCPD), EU Emissions Trading System (EU-ETS), New Electricity Trading Arrangements (NETA), British Electricity Trading Transmission Arrangements (BETTA).

The regulatory waves were based upon the distinct periods of regulatory intervention that were observed by the author in the course of the research. Nineteen regulatory waves were observed, which were summarised into nine sub groups (and four totals) which have been used when more than one variable was present in each sub group.

The measures collated were made as categorical observations during each year of the study. The full range of parameters used is shown in table 17:

Regulatory Wave Groups	Regulatory Wave
Competition	Price & Competition Encouragement
Energy Security	Energy Security Policy
Environmental	Carbon Tax Policy
	Emissions Management
	Energy Efficiency Policy
	Environmental and Climate Change Control
	Fuel Management
Environmental Total	
Generation	Electricity Generation Policy
Ownership	Acquisitions, Mergers, and New Player Market Entry
	Government Divestment of Remaining Interest
	REC Monopoly Supply, Price Competition and Price Management
Ownership Total	
Pricing	Price Competition
	Price Management and Control
Pricing Total	
Social	Political Objectives (Fuel poverty etc.)
Technology	Gas Embargo for Electricity Generation
	Fuel Management
	Technology Development Support Policy
	Technology Management and Control
Technology Total	
Transport	Transport Policy

Table 17 - Regulatory Waves

Technology Waves are a means of identifying whether or not technology adoption was a factor in the founding and failure rates of the EGI power plants. An analysis of these was undertaken to determine the year in which the installed base of a specific generation technology achieved 25% of the 2011 total base (measured in MW generating capacity terms). This gave rise to eleven technology adoption waves between 1990 and 2005. These waves were recorded using categorical variables by year to identify that time period at which the technology was deemed to be 'legitimised' in density terms.

The electricity price data for domestic and industrial consumers was collected and bivariately modelled with the founding and failure durations in common with all the testing in this section.

The Grants, Incentives and Schemes (GIS) developed and implemented by the UK government cover some 91 different forms of project or investment-based funding that utilise funds from the 'Broad Funding Programmes' that will be discussed below. The GIS schemes were all collated, researched and recorded by GIS scheme counts by year.

Broad Funding Programmes relate to the major funding programmes, (HM_Government, 2001, HM_Government, 2001-2009, HM_Government, 2001-2010, HM_Government, 2002, HM_Government, 2003, HM_Government, 2004, HM_Government, 2005, HM_Government, 2006, HM_Government, 2007, HM_Government, 2008, HM_Government, 2009, HM_Treasury, 1997, HM_Treasury, 2002), to stimulate and encourage the uptake of renewable and climate change programmes and technology, albeit that frequently the headline numbers announced by the government were not fully expended in practice. These are summarised in table 18:

Announced Date	Broad Funding Scheme / Purpose	Announced Funding £M	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
2001	Renewables Support	£250m	63	63	63	63					
2002	Low Carbon and Renewables Technologies	£500m	83	83	83	83	83	83			
2003	Renewable Capital Grants	£60m	10	10	10	10	10	10			
2007	Environmental Transformation Fund	£400m						100	100	100	100
2009	Low Carbon Investment Fund	£350m							117	117	117
2009	Strategic Investment Fund	£250m							83	83	83
Total Funding (£m per Annum)			156	156	156	156	93	193	300	300	300
Grand Total Funding (£M)											**1,810**

Table 18 - Announced Broad Funding by Government

Technology choice by the power plants is considered from a number of dimensions: power plant generating capacity, the amount of fuel used by the plants, the proportion of time that the power plants were active in each year, and the costs of power plant technologies.

Power plant capacity was collated using twelve measures in terms of the power plant capacity (all were measured in terms of megawatt capacity), of which seven were found to be statistically significantly ($p<0.05$) when correlated with the dependent variable of power plant founding and failure rates. The seven variables were hydro natural flow capacity, new plant commissioned, other technologies capacity and thermal capacity. All technology capacities showed positive impact on founding rates. The impact on failure rates was positive for new plant commissioned, whereas the impact was negative for the remainder. This suggests that owners view these technologies positively from an investment perspective, but once installed they wish to retain their investments and not make new investments. The relevant regressions can be found in chapter 9 and 10.

Power plant fuel usage reveals a number of interesting factors about the fuels that power plant owners prefer to use. In part, this reflects the cost of the fuels and the 'order-of-merit' utilisation in terms of 'baseload' generation preference. The data was collated on a unified basis of millions of tonnes of oil equivalent used by the plants each year.

Power plant usage reflects the amount of time that each generation type was actually used in each year. Unsurprisingly the four fuels that were key to founding and failure durations were nuclear, thermal, CCGT and Hydroelectric natural flow power plants.

Lastly, under the technology category, technology plant capital build costs were recorded for thirteen technologies.

UK Emissions of GHGs records the level of GHGs emitted within the UK government's GHG regulatory policies.

In addition to the independent variables, there were a number of control variables recorded which included twenty-three demographic vital events related to the power plant and owner details, and a further eight measures such as Price escalator / deflator, GDP, BoE Base Rate, and US $ to Sterling Spot Exchange Rate were also recorded.

7.4 BROAD MODEL SPECIFICATION UTILISED

The first approach in determining the validity of the energy policy research theory was to test the contribution of the individual variables against the underlying holding founding and failure events (and durations) for their significance. The purpose of this initial testing was to undertake a 'first pass' to identify which variables were significant enough to be used for the detailed energy policy testing that will be performed in this chapter. The results from this testing saw the initial set of 183 variables being reduced to 92 independent and control variables deemed to be significant enough to warrant inclusion in the subsequent testing (using Bivariate stcox tests to model the individual variables with the founding and failure rates).

The energy policy testing undertaken using a multivariate regression technique to undertake the detailed analysis of the impact of each energy policy instruments and the five energy policy objectives (i.e. the MCM, PC, PTE SOS and SROEG)[17].

[17] Policy Objectives are: MCM – Maintaining Competitive Markets, PC – Protecting Consumers, PTE – Protecting the Environment, SOS – Security of Supply, SROEG - Sustainable Rate of Economic Growth.

The broad formulation of energy policy objectives analysis underpinning the testing in the next two chapters is presented by the following hypotheses:

- MCM Energy Policy Hypothesis – Generator and Power plant ownership founding & failures rates and durations will increase if the government policy objective to maintain competitive markets (MCM) is supported by use of policy interventions which are based upon Equity Investment grants, Subsidy grants, Tax Incentives, Regulatory Policy Counts (Cumulative Policy Years of Experience, Policy Years of Experience, Year Policy Announced, and Cumulative Policies by Year)
- MCM Energy Policy Alternate Hypothesis – When MCM policies are absent, or reduced, founding durations and founding durations will decrease or remain static.
- PC Energy Policy Hypothesis – Generator and Power plant ownership founding & failures rates and durations will decrease if government policy objective of protecting consumers (PC) can be equated to the political and planning / development policies implemented by government
- PC Energy Policy Alternate Hypothesis – When PC policies are absent, or reduced, founding and failure durations will increase or remain static.
- PTE Energy Policy Hypothesis – Generator and Power plant ownership founding & failures rates and durations will decrease if government policy objective to Protect the environment (PTE) can be equated to policies of carbon taxes and GHG emissions restrictions (i.e. using taxes and correcting negative externalities
- PTE Energy Policy Alternate Hypothesis – When PTE policies are absent, or reduced, generator and Power plant ownership founding & failures rates and durations will increase or remain static.
- SOS Energy Policy Hypothesis – Power plant ownership durations (founding event and failure event initiated) will increase if the government policy objective to implement security of supply (SOS) policies which adopt research and implementation grants, and policies that encourage technological innovation in electricity generation
- SOS Energy Policy Alternate Hypothesis – When SOS policies are absent, or reduced, generator and Power plant ownership founding & failures rates and durations will decrease or remain static.
- SROEG Energy Policy Hypothesis – Generator and Power plant ownership founding & failures rates and durations will increase if the government policy objective to maintain sustainable rate of economic growth (SROEG) policies which adopt use of economic instruments
- SROEG Energy Policy Alternate Hypothesis – When SROEG policies are absent, or reduced, founding and founding durations will decrease or remain static.

In summary, table 19 shows what can be expected:

Hypothesis	Policy Instruments	Founding Durations	Failure Durations
MCM Energy Policy Hypothesis	Increased	Increased	Increased
MCM Energy Policy Alternate Hypothesis	Decreased, or static	Decreased	Decreased
PC Energy Policy Hypothesis	Increased	Decreased	Decreased
PC Energy Policy Alternate Hypothesis	Decreased, or static	Increased	Increased
PTE Energy Policy Hypothesis	Increased	Decreased	Decreased
PTE Energy Policy Alternate Hypothesis	Decreased, or static	Increased	Increased
SOS Energy Policy Hypothesis	Increased	Increased	Increased
SOS Energy Policy Alternate Hypothesis	Decreased, or static	Decreased	Decreased
SROEG Energy Policy Hypothesis	Increased	Increased	Increased
SROEG Energy Policy Alternate Hypothesis	Decreased, or static	Decreased	Decreased
Complete Energy Policy Hypothesis	Increased	Each policy objective will follow the relevant EnPol1 thru 5	Each policy objective will follow the relevant EnPol1 thru 5
Complete Energy Policy Alternate Hypothesis	Decreased, or static	Each policy objective will follow the relevant EnPol1 thru 5	Each policy objective will follow the relevant EnPol1 thru 5

Table 19 – Summary of Hypotheses and Expected Results

7.4.1 MODEL THEORY

The models developed are all based upon event history analysis (EHA) techniques. Like most fields of scientific endeavour, there are many different techniques within the EHA approach. The key choice is to decide which survival analysis technique to adopt, i.e. semi-parametric or parametric models.

Semi parametric and parametric models both are able to handle the same problems – time varying covariates (such as policy changes over successive years), and delayed entry, gaps and right censoring of the data. This means that any data that are suitable for Cox-based modelling (STATA stcox) are also suitable for parametric regression modelling (STATA streg). The main benefit of a parametric model is that it allows for better estimates to be made of the model constant, β_x. Additionally, the role of the 'origin' (i.e. the definition of t=0) in a Cox regression has no real purpose, whereas with parametric regression it is vital. Further, both models are invariate to multiplicative transforms of time and are unconcerned whether time is measured in minutes, hours, days or years (Cleves, 2010).

There are many different forms of the parametric model (which use either the proportional hazards or accelerated failure-time formulations).

The most simple of these is the exponential PH model that assumes that the baseline hazard is constant:

$$h(t|x_j) = h_{=}(t)exp(x_j\beta_x)$$

$$h(t|x_j) = exp(\beta_0)exp(x_j\beta_x)$$

$$h(t|x_j) = exp(\beta_0 + x_j\beta_x)$$

For the core constant β_0, which may be thought of as an intercept term (Cleves, 2010 p.129).

The role of the survival and hazard functions are inversely related to one another:

$$H(t|x_j) = exp(\beta_0 + x_j\beta_x)t$$

$$S(t|x_j) = exp[-exp(\beta_0 + x_j\beta_x)t]$$

If a model is fitted to the regression coefficients (using streg), then the intercept term, β_x, is given by the STATA (Cons) results (Cleves, 2010). The way that time varying data is handled, by the STATA streg command, is to break the data that has the time varying covariates into 'splits', so that the data within each split are time constant. This can be handled either using the STATA stplit command, or alternatively, Sorensen's STATA stpiece command may be used. A further technique is to code time varying parameters into the covariate data – which is the technique that has been adopted for the policy-based parametric regression in chapter 10[18].

The last consideration is to decide which of the time dependent transition rate models to use. In STATA, there are eight different variants possible (Exponential, Weibull, Gompertz, Lognormal, Log-Logistic, and Gamma). Each of these models is suited to particular time-dependence data. For the policy analysis, the Gompertz model was chosen, because the covariate data being modelled followed a linear transition rate throughout the period of the study. This also accords with previous studies (Freedman et al., 1983, Carroll and Hannan, 2000, Lomi, 1995) involving the lifetimes of organisations. Further, during the early testing the Gompertz distribution was found to yield the most informative and most significant results. In each of the models that developed the format was the same. Four variants of each model were estimated using Stata. These were founding and failure rate, both of which were used firstly with the key policy based independent variables, and secondly modelling to include the control variables.

7.5 CHAPTER SUMMARY

The purpose of this chapter was to review prior energy policy literature, outline the broad energy policy research question and theory for the research, present an overview of the data and variables collected and to present of the broad model specification and empirical statistical theory that will be used for the four research methods.

[18] The central issue with parametric tests is whether the raw data are of a type appropriate for parametric tests and normally distributed

8. ENERGY POLICY IMPACT ON GENERATOR AND POWER PLANT FOUNDING AND FAILINGS

8 GENERATOR AND POWER PLANT FOUNDING AND FAILURE RATES

This chapter presents the results from the policy instrument and policy objective analysis of the founding and failure corporate demography based vital event rates. Specifically, it examines the impact of energy policy instruments and energy policy objectives on electricity generators and power plant vital events.

The chapter adopts the following headings: founding and failure rate data and variables, founding and failure rate research context, founding and failure rates model specification, founding and failure rates results, founding and failure rates discussion, and founding and failure rates summary.

8.1 FOUNDING AND FAILURE RATES - DATA AND VARIABLES

The independent variables collected for this analysis were described in the previous chapter. However, the dependent variables used for generator and power plant foundings & failings are shown in table 20:

Year	Generator Founding Events	Generator Failure Events	Power Plant Founding Events	Power Plant Failure Events
1990	10	0	5	1
1991	11	1	9	6
1992	9	0	13	1
1993	3	0	8	7
1994	3	1	5	4
1995	4	1	6	4
1996	10	1	10	0
1997	6	2	10	1
1998	14	1	13	0
1999	5	0	14	5
2000	10	0	22	0
2001	6	6	16	2
2002	11	5	18	3
2003	5	3	19	3
2004	16	6	24	0
2005	10	2	22	2
2006	15	0	35	4
2007	9	9	38	0
2008	17	2	43	0
2009	13	4	35	0
2010	11	4	32	0
Total Events	**198**	**48**	**397**	**43**
Mean Number of Events Per Annum	**9.00**	**2.18**	**18.05**	**1.95**

Table 20 - Generator and Power Plant Vital Events

This shows that over the twenty-year timeframe the number of annualised (and censored) vital events was actually quite small (e.g., this will give rise to 21 events when one considers the founding rates of generators each year). Clearly, this has implications for the statistical analysis that can be undertaken.

8.2 FOUNDING AND FAILURE RATES RESEARCH CONTEXT

Now that the variables have been identified, it is important to present the research question, research theory, and hypotheses that will be used to conduct the detailed analyses.

Research Question – Using Generator and Power Plant vital events over the twenty-year period since electricity privatisation, can the impact of successive Governments' energy policies be understood using policy instrument (i.e. the individual policy interventions been enacted) and policy objective analysis (i.e. using the five broad policy objectives adopted by successive Governments' – MCM, PC, PTE, SOS, and SROEG[19]).

Research Theory – The impact and action of energy policy can be defined and understood, in the electricity generation industry, by means of event history analysis of the corporate demographic events (dependent variables), energy policy explanatory variables (for both the individual policy instruments and the grouping of these policy instruments[20] to form energy policy objectives), and control variables that act to baseline the dependent and independent variables (i.e. capital cost of generating plant, fuel type used, technology used, year in which technology critical mass was achieved, power plant utilisation, macro-economic variables and corporate demography data such as the location etc.).

Hypotheses – there are four hypotheses posited for this research endeavour:

> **Generator Founding Rate hypothesis** – It is possible to identify level impact (direction and magnitude) of the specific energy policy instruments on new electricity generator founding rates in the electricity industry since 1990 Further, it is also possible to correlate and explain the results of the energy policy interventions using to Dobbin and Dowd's (1997) research findings[21].
>
> **Generator Failure Rate hypothesis** – It is possible to identify the level of impact (direction and magnitude) of specific energy policy instruments on new electricity generator founding rates in the electricity industry since 1990 Further, it is also possible to correlate and explain the results of the energy policy interventions using Dobbin and Dowd's (1997) research findings.
>
> **Power Plant Founding Rate hypothesis** – It is possible to identify the specific energy policy instruments and their impact (direction and magnitude) on new electricity generator founding rates

[19] Policy Objectives are: MCM – Maintaining Competitive Markets, PC – Protecting Consumers, PTE – Protecting the Environment, SOS – Security of Supply, SROEG - Sustainable Rate of Economic Growth.
[20] Policy Instruments type are: Emissions controls, Government major funding schemes, investor or user based Grants, Incentives and other Schemes (GIS), Obligations, Policy instrument class of action, Policy Instrument nature of action, Regulatory compliance obligations.
[21] Dobbin and Dowd's research identified that government intervention could be categorised as Anti-Trust (which increased competition, industrial concentration, company failure rates and reduced company founding rates), or Pro-Cartel (which reduced competition, industrial concentration, company failure rates and increased company founding rates).

in the electricity industry since 1990 Further, it is also possible to correlate and explain the results of the energy policy interventions using Dobbin and Dowd's (1997) research findings.

Power Plant Failure Rate hypothesis – It is possible to identify the specific energy policy instruments and their impact (direction and magnitude) on new electricity generator failure rates in the electricity industry since 1990 Further, it is also possible to correlate and explain the results of the energy policy interventions using Dobbin and Dowd's (1997) research findings.

8.3 FOUNDING AND FAILURE RATES - MODEL SPECIFICATION

In each founding and failure case (generator founding & failing, and Power Plant founding and failing i.e. the dependent variables), the cox proportional hazards model was used to undertake the regressions.

The models were built in two steps. Firstly, a bivariate analysis of the approximately 200 independent and control variables was performed against each of the four dependent variables. This showed the level of influence that each of the independent and control variables has on the dependent variable. The results from this are presented in a combined table (Table 21) that shows all regression results (coefficient and standard errors) for the four dependent variables.

Next, the dependent variables were considered individually in terms of three elements. The first element was to provide a summary of the bivariate regression for the most significant independent variables (i.e. the energy policy instruments). The second element took these variables and multiplied the coefficient of the policy instrument variable by its mean value to provide an average magnitude of impact. This allowed the relative impact of each policy instrument to be compared in both scale and direction of influence on the dependent variable. This table was supplemented by a narrative to enable the reader to understand how the policy instruments operated. The third element was to undertake a combined regression that showed the build-up of the policy variables in a regression that utilised all of the independent and control variables. This last element provided a model that showed the impact of all of the variables on the dependent variable i.e. to build a complete model showing how each dependent variable was impacted by all of the policy instruments.

This framework was used to confirm the validity of the generator and power plant founding and failure hypotheses i.e. four models sets were tested.

8.4 FOUNDING AND FAILURE RATES - RESULTS

The bivariate analysis of the key variables[22] for the founding and failure analysis were the four dependent variables (i.e. generator company founding & failing events, and power plant founding & failure events) in each case the dependent variable was regressed with independent and control variables using a bivariate cox regression in STATA. The results are shown in table 21:

Policy	Class	Variable Description	Variable Name	Generator Foundings	Generator Failings	Power Plant Foundings	Power Plant Failings	Obs	Mean
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)	biomasscost	0.127*	0.297**	0.612***	-0.0791	21	21
CAPITAL	Plant Cost			(0.0665)	(0.13)	(0.141)	(0.107)		
CAPITAL	Plant Cost	CCGT Cost (USDmill/kwh)	ccgtcost	0.649*	1.504**	3.114***	-0.403	21	4
CAPITAL	Plant Cost			(0.338)	(0.661)	(0.719)	(0.543)		
CAPITAL	Plant Cost	Coal Cost (USDmill/kwh)	coalcost	0.291*	0.679**	1.396***	-0.181	21	9
CAPITAL	Plant Cost			(0.152)	(0.297)	(0.322)	(0.244)		
CAPITAL	Plant Cost	Conventional Thermal Cost (USDmill/kwh)	ctcost	0.214*	0.501**	1.030***	-0.133	21	13
CAPITAL	Plant Cost			(0.112)	(0.219)	(0.238)	(0.181)		
CAPITAL	Plant Cost	Fuel Cell Cost (USDmill/kwh)	fuelcellcost	0.0666*	0.155**	0.320***	-0.0414	21	41
CAPITAL	Plant Cost			(0.0348)	(0.0681)	(0.0738)	(0.056)		
CAPITAL	Plant Cost	Geothermal Cost (USDmill/kwh)	geothermalcost	0.0689*	0.161**	0.331***	-0.0428	21	40
CAPITAL	Plant Cost			(0.036)	(0.0705)	(0.0763)	(0.058)		
CAPITAL	Plant Cost	Hydro Cost (USDmill/kwh)	hydropowercost	0.420*	0.975**	2.008***	-0.26	21	7
CAPITAL	Plant Cost			(0.219)	(0.428)	(0.463)	(0.352)		
CAPITAL	Plant Cost	IGCC Cost (USDmill/kwh)	igcccost	0.237*	0.552**	1.137***	-0.148	21	12
CAPITAL	Plant Cost			(0.124)	(0.242)	(0.262)	(0.199)		
CAPITAL	Plant Cost	MSW Landfill Cost (USDmill/kwh)	mswlandfillcost	0.0923*	0.215**	0.443***	-0.0573	21	29
CAPITAL	Plant Cost			(0.0482)	(0.0943)	(0.102)	(0.0777)		
CAPITAL	Plant Cost	Nuclear Cost (USDmill/kwh)	nuclearcost	0.205*	0.480**	0.985***	-0.127	21	13
CAPITAL	Plant Cost			(0.107)	(0.21)	(0.227)	(0.173)		
CAPITAL	Plant Cost	Solar PV Cost (USDmill/kwh)	solarpvcost	1.038*	2.433**	4.972***	-0.656	21	3
CAPITAL	Plant Cost			(0.545)	(1.066)	(1.146)	(0.881)		
CAPITAL	Plant Cost	Solar Thermal Cost (USDmill/kwh)	solarthemcost	0.338*	0.788**	1.622***	-0.21	21	8
CAPITAL	Plant Cost			(0.176)	(0.345)	(0.374)	(0.284)		
CAPITAL	Plant Cost	Wind Cost (USDmill/kwh)	windcost	0.360*	0.838**	1.729***	-0.224	21	8
CAPITAL	Plant Cost			(0.188)	(0.367)	(0.399)	(0.303)		
CAPITAL	Plant Cost	Wind Offshore Cost (USDmill/kwh)	windooffcost	0.132*	0.307**	0.633***	-0.0817	21	21
CAPITAL	Plant Cost			(0.0688)	(0.135)	(0.146)	(0.111)		
FUEL	Fuel Usage	Coal Used MTOE	coalmtoe	1.76E-02	0.0587	0.0909***	-0.0138	21	34
FUEL	Fuel Usage			(0.0266)	(0.048)	(0.0351)	(0.0371)		
FUEL	Fuel Usage	Natural Gas Used MTOE	naturalgasmtoe	-0.0351*	-0.0866**	-0.121***	0.0233	21	20
FUEL	Fuel Usage			(0.0198)	(0.0369)	(0.03)	(0.0305)		
FUEL	Fuel Usage	Nuclear Used MTOE	nuclearmtoe	0.141**	0.113	0.359***	-0.0277	21	19
FUEL	Fuel Usage			(0.0709)	(0.0926)	(0.116)	(0.134)		
FUEL	Fuel Usage	Oil Used MTOE	oilmtoe	0.149	0.585**	0.644***	-0.129	21	3
FUEL	Fuel Usage			(0.12)	(0.244)	(0.178)	(0.184)		
FUEL	Fuel Usage	Other Technologies Used MTOE	othermtoe	-0.0763	0.376	0.549	-0.00389	21	1
FUEL	Fuel Usage			(0.738)	(0.922)	(0.772)	(1.079)		
FUEL	Fuel Usage	Other Renewables Used MTOE	otherrenmtoe	-0.641	0.209	-1.253**	0.393	12	3
FUEL	Fuel Usage			(0.41)	(0.462)	(0.499)	(0.582)		
FUEL	Fuel Used	Hydro Used MTOE	hydromtoe	-5.069	-2.946	-6.37	3.057	21	0
FUEL	Fuel Used			(4.337)	(4.669)	(3.9)	(4.978)		
FUEL	Fuel Used	Imports Electricity MTOE	importsmtoe	0.915	1.806**	2.126***	-0.849	21	1
FUEL	Fuel Used			(0.643)	(0.858)	(0.742)	(0.75)		
FUEL	Fuel Used	Wind Used MTOE	windmtoe	-0.686	-0.45	-0.537	-289.3	6	1
FUEL	Fuel Used			(2.253)	(2.371)	(2.604)	(110000000)		
MACRO	Core	BoE Base Rate	baserate	0.0725	0.139	0.354***	0.0248	21	5

[22] The variables used above are not collinear with the dependent variable, have observations and also have a p-value of less than 0.20. This is used because If the regression has a p-value greater than 0.20 in a bivariate analysis it is highly deemed unlikely that it will be able to contribute anything to multivariate model.

Policy	Class	Variable Description	Variable Name	Generator Foundings	Generator Failings	Power Plant Foundings	Power Plant Failings	Obs	Mean
MACRO	Core			(0.0681)	(0.136)	(0.111)	(0.126)		
MACRO	Core	Escalator / Deflator (US CPI)	cpiescdefl	2.288*	5.337**	10.98***	-1.421	21	1
MACRO	Core			(1.195)	(2.338)	(2.534)	(1.924)		
MACRO	Core	Households in Fuel Poverty %	fuelpoor	-0.0447	-0.0195	-0.258*	-0.41	8	12
MACRO	Core			(0.0826)	(0.0853)	(0.141)	(0.474)		
MACRO	Core	GDP Billions (£)	gdp	-0.00135**	-0.00290**	-0.00270***	0.000296	21	973
MACRO	Core			(0.000636)	(0.00137)	(0.000681)	(0.00113)		
MACRO	Core	Implied Investment Deflator	investd	-8.191**	-8.439	-25.25***	4.809	21	1
MACRO	Core			(3.629)	(5.277)	(5.882)	(5.142)		
MACRO	Core	Brent Crude Oil Price	oilprice	-0.0107	-0.0188	-0.0334***	0.014	21	36
MACRO	Core			(0.0105)	(0.012)	(0.013)	(0.0186)		
MACRO	Core	US $ to Sterling Spot Exchange Rate	spotrate	-0.644	-1.475	-0.354	0.549	21	2
MACRO	Core			(1.223)	(1.494)	(1.149)	(1.686)		
MCM	GIS	Equity - Equity Investment	giseqinv	-0.395	-0.145	-1.285***	-0.112	14	1
MCM	GIS			(0.304)	(0.328)	(0.471)	(0.544)		
MCM	GIS	Grant - Total Grants, Schemes and Incentives	gisimg	-0.312	-0.238	-0.906**	-0.0809	14	1
MCM	GIS			(0.283)	(0.265)	(0.364)	(0.476)		
MCM	GIS	Loan - Loan Incentive	gisloan	-0.653	-0.167	-1.536**	0.0372	14	1
MCM	GIS			(0.48)	(0.456)	(0.664)	(0.881)		
MCM	GIS	Subsidy - Subsidy	gissub	-0.947	-0.391	-2.079***	0.0732	14	2
MCM	GIS			(0.619)	(0.7)	(0.757)	(0.882)		
MCM	GIS	Taxation - Tax Incentive	gistaxoff	-0.313	-0.239	-1.076***	0.0257	14	2
MCM	GIS			(0.195)	(0.242)	(0.347)	(0.366)		
MCM	PI - Class	Regulatory - Policy Count by Cumulative Policy Years of Experience	pcrg	0.0086	-0.0448	-0.0267	-0.397	6	10
MCM	PI - Class			(0.0944)	(0.211)	(0.119)	(0.467)		
MCM	PI - Class	Regulatory - Policy Count by Policy Years of Experience	pcrgyr	-0.00484	-0.0139	-0.006	-0.0286	6	116
MCM	PI - Class			(0.00561)	(0.0139)	(0.00671)	(0.0892)		
MCM	PI - Class	Regulatory - Policy Count by Year Policy Announced	pcrgyrcum	-0.0125	-0.00838	-0.0382	-0.0822	6	58
MCM	PI - Class			(0.0156)	(0.0176)	(0.0242)	(0.116)		
MCM	PI - Nature	Institutional - Policy Count by Year	pnin	-0.137	-19.07	-0.0348	-5.072	5	4
MCM	PI - Nature			(0.176)	0)	(0.167)	(7320000)		
MCM	PI - Nature	Regulatory - Policy Count by Year	pnrg	0.0257	0.22	0.0615	5.578	5	10
MCM	PI - Nature			(0.0521)	(0.28)	(0.0611)	(2970000)		
MCM	Regulatory	Ownership - Ownership Total	rwowntotp	0.321		1.898***	-0.415	21	1
MCM	Regulatory			(0.264)	)	(0.522)	(0.49)		
MCM	Regulatory	Pricing - Pricing Total	rwprictotp	1.102**	0.701	2.697***	-0.371	21	2
MCM	Regulatory			(0.542)	(0.553)	(0.801)	(0.695)		
PC	Obligations	Planning and Development Total	obpdtot	-0.766**	-0.449	-1.993***	0.265	21	1
PC	Obligations			(0.366)	(0.339)	(0.604)	(0.793)		
PC	PI - Class	Political - Policy Count by Cumulative Policy Years of Experience	pcpo	0.0951	-0.164	-0.162	-31.98	6	10
PC	PI - Class			(0.089)	(0.166)	(0.133)	0)		
PC	PI - Class	Political - Policy Count by Policy Years of Experience	pcpoyr	0.0038	-0.00831	-0.0445	-0.0303	6	102
PC	PI - Class			(0.00488)	(0.00872)	(0.0311)	(0.0354)		
PC	PI - Class	Political - Policy Count by Year Policy Announced	pcpoyrcum	-0.00884	-0.0105	-0.0403	-0.0984	6	43
PC	PI - Class			(0.0179)	(0.0206)	(0.0257)	(0.117)		
PC	PI - Nature	Political - Policy Count by Year	pnpo	-0.0256	-6.632	-0.0888	-0.27	6	7
PC	PI - Nature			(0.131)	0)	(0.118)	(0.319)		
PRICE	Electricity Price	Industrial Price Per Pence KwH	indprce	-0.225	-0.0606	-0.606***	-0.322	21	5
PRICE	Electricity Price			(0.146)	(0.152)	(0.225)	(0.472)		
PRICE	Electricity Price	Retail Price of Electricity Pence per KwH	pencekwh	-0.188	-0.0655	-0.575***	-0.173	21	9
PRICE	Electricity Price			(0.119)	(0.123)	(0.21)	(0.393)		
PTE	Emissions	Hydrofluorocarbons (HFC)	hydrofluorocarbonshfc	0.00279	0.203*	0.0584	0.0454	21	13
PTE	Emissions			(0.104)	(0.116)	(0.118)	(0.164)		

Policy	Class	Variable Description	Variable Name	Generator Foundings	Generator Failings	Power Plant Foundings	Power Plant Failings	Obs	Mean
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	0.0230**	0.0526**	0.0998***	-0.0156	21	66
PTE	Emissions			(0.0115)	(0.0217)	(0.0241)	(0.0168)		
PTE	Emissions	Millions of Tonnes of CO2 Equivalent	mtco2e	0.00627	0.0131*	0.0297***	-0.00481	21	681
PTE	Emissions			(0.0042)	(0.00749)	(0.00775)	(0.00763)		
PTE	Emissions	Net CO2 emissions (emissions minus removals)	netco2emissionsemissionsmin	0.00829	0.00803	0.0346**	-0.00489	21	551
PTE	Emissions			(0.00837)	(0.0117)	(0.0138)	(0.0177)		
PTE	Emissions	Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousoxiden2o	0.0314	0.0945**	0.193***	-0.0183	21	49
PTE	Emissions			(0.0199)	(0.0378)	(0.0498)	(0.031)		
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	perfluorocarbonspfc	0.498	2.015*	3.659***	-0.211	21	0
PTE	Emissions			(0.626)	(1.09)	(1.007)	(0.985)		
PTE	Emissions	Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	sulphurhexafluoridesf6	1.231	0.541	1.642**	0.024	21	1
PTE	Emissions			(0.75)	(0.975)	(0.727)	(1.897)		
PTE	GIS	Information - Information	gisinfo	-0.208	-0.0673	-0.697**	0.191	14	2
PTE	GIS			(0.178)	(0.209)	(0.272)	(0.54)		
PTE	Obligations	Electricity Generators Total	obegtot	-0.364**	-0.737**	-0.958***	0.232	21	1
PTE	Obligations			(0.184)	(0.313)	(0.257)	(0.245)		
PTE	Obligations	Energy Supplier Total	obensutot	-1.123**	-0.881	-2.409***	0.476	21	0
PTE	Obligations			(0.516)	(0.561)	(0.689)	(0.662)		
PTE	Obligations	Electricity Supplier Total	obestot	-1.123**	-0.881	-2.409***	0.476	21	1
PTE	Obligations			(0.516)	(0.561)	(0.689)	(0.662)		
PTE	Obligations	Electricity Users Total	obeutot	-0.485*	-0.712*	-1.422***	0.316	21	1
PTE	Obligations			(0.268)	(0.411)	(0.408)	(0.379)		
PTE	PI - Class	Carbon Tax - Policy Count by Year Policy Announced	pcct	0.0228	-0.188	-0.29	-0.273	6	4
PTE	PI - Class			(0.269)	(0.352)	(0.297)	(0.408)		
PTE	PI - Class	Carbon Tax - Policy Count by Policy Years of Experience	pcctyr	0.00779	-0.0357	-0.125	-0.0812	6	21
PTE	PI - Class			(0.0273)	(0.0366)	(0.0858)	(0.0963)		
PTE	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	pcctyrcum	-0.00812	-0.0173	-0.0581	-0.193	6	22
PTE	PI - Class			(0.0278)	(0.0337)	(0.0393)	(0.226)		
PTE	PI - Class	Energy Efficiency - Policy Count by Cumulative Policy Years of Experience	pcee	0.018	-0.47	0.0191	-11.72	6	5
PTE	PI - Class			(0.0982)	(0.62)	(0.101)	(14300000)		
PTE	PI - Class	Energy Efficiency - Policy Count by Year Policy Announced	pceeyr	0.00146	0.0029	0.00017	-2.406	6	38
PTE	PI - Class			(0.011)	(0.0261)	(0.0119)	(4570000)		
PTE	PI - Class	Energy Efficiency - Policy Count by Policy Years of Experience	pceeyrcum	-0.00618	-0.00867	-0.0377	-0.599	6	30
PTE	PI - Class			(0.0238)	(0.0337)	(0.0332)	(0.755)		
PTE	PI - Class	Transport - Policy Count by Cumulative Policy Years of Experience	pctr	-0.0232	11.05	0.584	-1.784	4	6
PTE	PI - Class			(0.527)	(5930000)	(0.533)	(2800000)		
PTE	PI - Class	Transport - Policy Count by Year Policy Announced	pctryr	-0.0339	0.377	0.0087		4	58
PTE	PI - Class			(0.0306)	(234469)	(0.0172)	)		
PTE	PI - Class	Transport - Policy Count by Policy Years of Experience	pctryrcum	-0.025	-0.00594	-0.0559		6	23
PTE	PI - Class			(0.0292)	(0.033)	(0.0431)	)		
PTE	PI - Nature	Environmental - Policy Count by Year	pnev	-4.56E-02	-0.088	-4.443	-0.25	6	10
PTE	PI - Nature			(0.114)	(0.106)		(0.292)		
PTE	Regulatory	Environmental - Environmental Total	rwentotp	0.0545	1.014**	-0.108	-0.0349	21	4
PTE	Regulatory			(0.635)	(0.485)	(0.635)	(0.682)		

Policy	Class	Variable Description	Variable Name	Generator Foundings	Generator Failings	Power Plant Foundings	Power Plant Failings	Obs	Mean
SOS	GIS	Grant - Demonstrator Grant	gisdemg	-0.0591	-0.0121	-0.203**	0.0276	14	6
SOS	GIS			(0.0549)	(0.0583)	(0.0876)	(0.131)		
SOS	GIS	Grant - Research Grant	gisgrnttot	-0.0336	-0.00729	-0.114**	0.00646	14	11
SOS	GIS			(0.0318)	(0.032)	(0.0502)	(0.0815)		
SOS	GIS	Grant - Implementation Grant	gisrg	-0.0893	-0.0015	-0.259*	-0.0336	14	3
SOS	GIS			(0.095)	(0.0851)	(0.144)	(0.342)		
SOS	PI - Class	Energy Security - Policy Count by Year Policy Announced	pces	-0.697	0.347	0.104	-11.47	4	2
SOS	PI - Class			(0.691)	(1.435)	(0.303)	(9310000)		
SOS	PI - Class	Energy Security - Policy Count by Policy Years of Experience	pcesyr	-0.169	0.116	-0.00233	-1.377	5	7
SOS	PI - Class			(0.224)	(0.478)	(0.0393)	(1820000)		
SOS	PI - Class	Energy Security - Policy Count by Cumulative Policy Years of Experience	pcesyrcum	-0.0884	-0.0571	-0.336	-2.617	5	11
SOS	PI - Class			(0.0809)	(0.08)	(0.361)	(6340000)		
SOS	PI - Class	Technologies - Policy Count by Cumulative Policy Years of Experience	pcte	0.0511	0.273	0.0408	0.0302	6	10
SOS	PI - Class			(0.0628)	(0.292)	(0.0679)	(0.212)		
SOS	PI - Class	Technologies - Policy Count by Policy Years of Experience	pcteyr	0.00361	0.0108	0.00218	0.002	6	166
SOS	PI - Class			(0.0034)	(0.0108)	(0.00381)	(0.00675)		
SOS	PI - Class	Technologies - Policy Count by Year Policy Announced	pcteyrcum	-0.0092	-0.00381	-0.0339	-0.0384	6	60
SOS	PI - Class			(0.0165)	(0.0198)	(0.0227)	(0.0505)		
SOS	PI - Nature	Technology - Policy Count by Year	pnte	2.14E-01	-0.0802	0.0112	0.14	6	8
SOS	PI - Nature			(0.131)	(0.206)	(0.0976)	(0.193)		
SOS	Regulatory	Technology - Technology Total	rwtechtot	-1.506***	0.204	-0.888*	0.497	21	2
SOS	Regulatory			(0.576)	(0.779)	(0.539)	(0.621)		
SROEG	PI - Nature	Economic - Policy Count by Year	pnec	-0.0344	-0.103	-0.0498	-5.052	6	8
SROEG	PI - Nature			(0.101)	(0.207)	(0.121)	(7150000)		
TECH	Capacity	CCGT Capacity (MW)	ccgtmw	-4.04e-05*	-9.94e-05**	- 0.000166***	3.33E-05	21	17,042
TECH	Capacity			(0.0000207)	(0.0000413)	(0.0000424)	(0.0000312)		
TECH	Capacity	Hydro Natural Flow Capacity (MW)	hydronatmw	0.000598	0.000516	6.87E-05	0.00305	21	1,383
TECH	Capacity			(0.000651)	(0.000695)	(0.000642)	(0.00951)		
TECH	Capacity	Hydro Pumped Capacity (MW)	hydropumpmw	-1.04E-05	-0.000322	0.000318	-0.000698	21	2,710
TECH	Capacity			(0.000803)	(0.000796)	(0.00085)	(0.000808)		
TECH	Capacity	New Plant Commissioned (MW)	newplantmw	-3.34E-05	-1.03E-05	-6.78E-05	0.000370*	21	885
TECH	Capacity			(0.000106)	(0.000141)	(0.000114)	(0.000208)		
TECH	Capacity	Nuclear Capacity (MW)	nuclearmw	0.000366	0.000333	0.000910**	0.000337	21	11,823
TECH	Capacity			(0.000289)	(0.000379)	(0.000389)	(0.000462)		
TECH	Capacity	Other Technologies Capacity (MW)	othermw	0.000225	0.000736	0.000744**	-0.000128	21	1,791
TECH	Capacity			(0.000285)	(0.00047)	(0.000333)	(0.000481)		
TECH	Capacity	Thermal Capacity (MW)	thermalmw	3.90E-05	0.000111**	0.000171***	-3.30E-05	21	40,593
TECH	Capacity			(0.0000308)	(0.0000552)	(0.0000465)	(0.000048)		
TECH	Tech. Cap.	All Technologies Capacity (MW)	allmw	- 0.000105**	- 0.000158**	- 0.000376***	7.28E-05	21	74,846
TECH	Tech. Cap.			(0.0000456)	(0.000072)	(0.0000981)	(0.0000569)		
TECH	Tech. Cap.	Maximum Output (MW s.o)	maxoutputmw	- 0.000177**	- 0.000307**	- 0.000393***	8.35E-05	21	57,593
TECH	Tech. Cap.			(0.0000802)	(0.000123)	(0.000101)	(0.000101)		
TECH	Tech. Cap.	Other Renewables Capacity (MW)	otherrenmw	- 0.000837**	-0.00150**	-0.00378***	0.000603	21	911
TECH	Tech. Cap.			(0.000408)	(0.000678)	(0.000948)	(0.000641)		
TECH	Tech. Cap.	Total Installed Capacity (MW)	totcapmw	- 0.000118**	- 0.000159**	- 0.000413***	7.81E-05	21	76,637
TECH	Tech. Cap.			(0.0000492)	(0.0000735)	(0.000108)	(0.0000599)		
TECH	Tech. Cap.	Wind Capacity (MW)	windmw	-0.000162	-0.000113	-1.96E-06	-0.196	6	1,346
TECH	Tech. Cap.			(0.000899)	(0.000925)	(0.00103)	(53510)		
UTILISATION	Plant Usage	CCGT Load Factor	ccgtlf	-0.0154	0.0564	-0.00162	-0.0302	19	65

Policy	Class	Variable Description	Variable Name	Generator Foundings	Generator Failings	Power Plant Foundings	Power Plant Failings	Obs	Mean
UTILISATION	Plant Usage			(0.0245)	(0.0626)	(0.0303)	(0.0385)		
UTILISATION	Plant Usage	Hydro Natural Flow Load Factor	hydronatlf	-0.0602	-0.0262	-0.0464	-0.0869	20	33
UTILISATION	Plant Usage			(0.0665)	(0.0569)	(0.0547)	(0.0612)		
UTILISATION	Plant Usage	Hydro Pumped Load Factor	hydropumlf	-0.154**	-0.206*	-0.956***	0.0422	21	10
UTILISATION	Plant Usage			(0.0693)	(0.107)	(0.298)	(0.0975)		
UTILISATION	Plant Usage	All Plant Load Factor (%)	loadfactor	0.107	0.0622	0.227**	-0.12	21	75
UTILISATION	Plant Usage			(0.0754)	(0.093)	(0.0956)	(0.111)		
UTILISATION	Plant Usage	Nuclear Load Factor	nuclearlf	0.0623*	0.0256	0.152***	0.028	21	71
UTILISATION	Plant Usage			(0.0325)	(0.0376)	(0.0512)	(0.0534)		
UTILISATION	Plant Usage	Other Technology Load Factor	otherslf	0.095	0.0904	0.236***	-0.0704	21	10
UTILISATION	Plant Usage			(0.0632)	(0.0786)	(0.0794)	(0.0814)		
UTILISATION	Plant Usage	Thermal Plant Load Factor	thermallf	0.0646	0.0371	0.0779*	-0.038	21	44
UTILISATION	Plant Usage			(0.0486)	(0.0647)	(0.047)	(0.0885)		
Standard errors in parentheses									
*** p<0.01, ** p<0.05, * p<0.1									

Table 21 - Generator and Power Plant Founding and Failure Rate Cox Regression[23]

8.4.1 GENERATOR FOUNDINGS

The Generator founding events are shown graphically in figure 27:

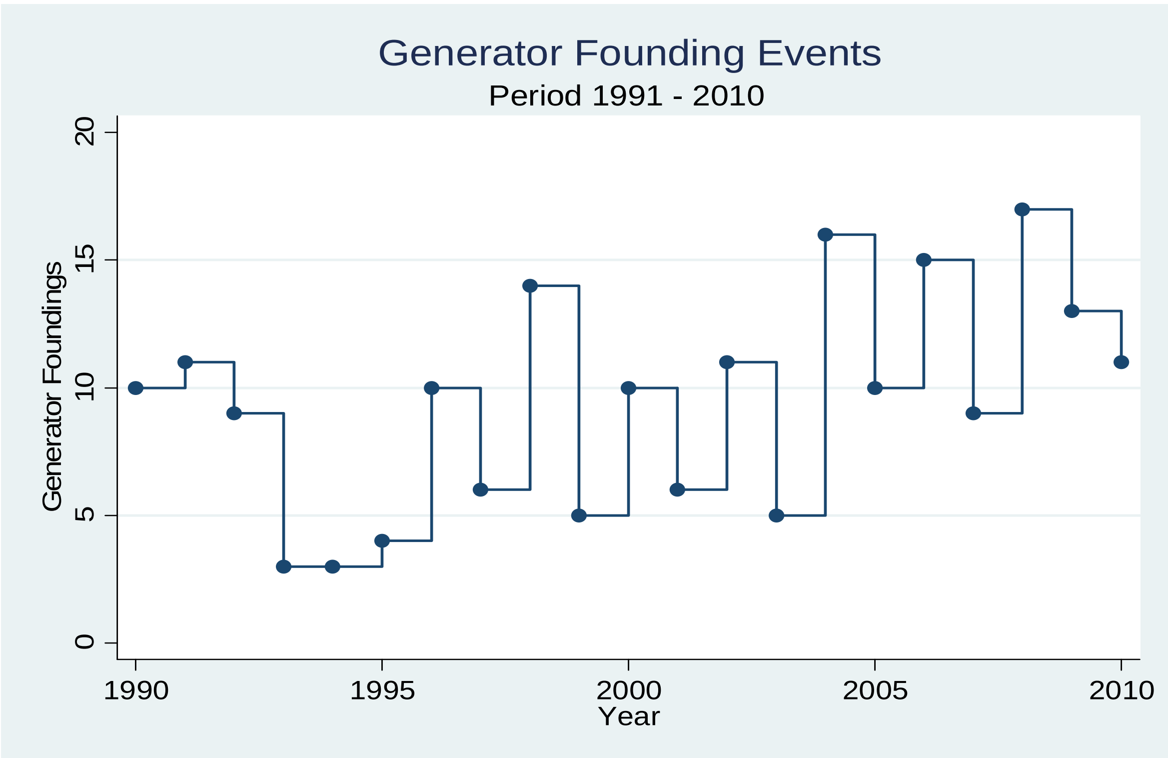

Figure 27 –Generator Founding Events (1991 – 2010)

[23] Note: the independent variables are those termed MCM, PC, PTE, SOS or SROEG, the reminder are the control variables used in the multivariate regressions.

If we consider the statistics surrounding the most significant generator founding variables, and specifically those that are significant at the 95% or 99% level these are presented in table 22:

Policy	Class	Variable Description	Variable Name	Coefficient	Obs	Mean	Magnitude
MCM	Regulatory	Pricing - Pricing Total	rwprictotp	1.102**	21	1	1.79
PC	Obligations	Planning and Development Total	obpdtot	-0.766**	21	66	-0.40
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	0.0230**	21	1	1.52
PTE	Obligations	Electricity Generators Total	obegtot	-0.364**	21	0	-0.45
PTE	Obligations	Energy Supplier Total	obensutot	-1.123**	21	1	-0.48
PTE	Obligations	Electricity Supplier Total	obestot	-1.123**	21	2	-1.61
SOS	Regulatory	Technology - Technology Total	rwtechtot	-1.506***	21	19	-2.58
FUEL	Fuel Usage	Nuclear Used MTOE	nuclearmtoe	0.141**	21	973	2.63
MACRO	Core	GDP Billions (£)	gdp	-0.00135**	21	1	-1.31
MACRO	Core	Implied Investment Deflator	investd	-8.191**	21	2	-7.54
TECH	Tech. Cap.	Maximum Output (MW s.o)	maxoutputmw	-0.000177**	21	57,593	-10.19
TECH	Tech. Cap.	Other Renewables Capacity (MW)	otherrenmw	-0.000837**	21	911	-0.76
TECH	Tech. Cap.	Total Installed Capacity (MW)	totcapmw	-0.000118**	21	76,637	-9.04
UTILISATION	Plant Usage	Hydro Pumped Load Factor	hydropumlf	-0.154**	21	10	-1.51
*** p<0.01, ** p<0.05							

Table 22 – Most Statistically Significant Variables for Generator Foundings (Bivariate Analysis)[24]

This is very interesting because it highlights the energy policy and other independent variables that have the greatest significance in terms of new generator founding rates. This shows that with the exception of Regulatory Pricing obligations and Methane emissions all the policy interventions have reduced the founding rate for new generators. It is further interesting to note that of the 83 policy variables researched only seven were significant and that four of these relate to protecting the environment, but all of the policies are of a compliance, obligatory or regulatory nature. This is shows that the incentive and information instruments have had no apparent effect on generator behaviour, clearly show use of the policy 'stick' rather than the 'carrot' or 'sermon' as defined by Bemelmans-videc et al. (2003).

Looking at the other variables is also informative and showed that if more Nuclear energy is used this is positive for generator foundings, this will arise because Nuclear is used for baseload generation and when it increased this indicates greater wider electricity demand (other factors being controlled for). The economic measures of GDP and Invest Deflator showed a negative impact for new generator foundings, which is contrary to that expected for increases of GDP expansion. The Technology capacity measures are in-line with what could be expected i.e. as productive capacity increases the number of new generator entrants is curtailed due to increased competition. The same is the case with increases in pumped storage, which shows that increased electricity storage negatively affects generator foundings, this confirms what industry insiders believe, and namely that pumped storage can have a significant impact on the dynamics of the electricity market, and especially with the Peak-Load generation facilities. As might be anticipated the mean magnitude of the policies is quite small.

[24] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

If the significant variables are modelled in a multi-variate Cox regression, we can see the following:

No. of subjects	21 (with 198 generator foundings)
Number of obs	21
No. of failures	21
Time at risk	0.5420944559 (Years)
LR chi2(13)	20.28
Log likelihood	-36.462568
Prob > chi2	0.0884
Incidence rate	38.73864

With the detailed regression results shown in table 23:

Policy	Class	Variable Description	Coefficient	Std. Err.	z	P>z	[Min 95% CI]	[Max 95% CI]
MCM	Regulatory	Pricing - Pricing Total	.0152077	1.825499	0.01	0.993	-3.562705	3.59312
PC	Obligations	Planning and Development Total	-.1896074	2.522038	-0.08	0.940	-5.13271	4.753495
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	.3057397	.1768824	1.73	0.084	-.0409435	.6524229
	Obligations	Electricity Generators Total	1.347243	.8280939	1.63	0.104	-.2757917	2.970277
		Energy Supplier Total	2.789658	3.252442	0.86	0.391	-3.585012	9.164327
		Electricity Supplier Total	(omitted)					
SOS	Regulatory	Technology - Technology Total	-4.035718	1.813424	-2.23	0.026	-7.589963	-.4814723
FUEL	Fuel Usage	Nuclear Used MTOE	.3722551	.5759528	0.65	0.518	-.7565917	1.501102
MACRO	Core	GDP Billions (£)	.0081519	.0043024	1.89	0.058	-.0002806	.0165843
		Implied Investment Deflator	6.44475	33.76218	0.19	0.849	-59.7279	72.6174
TECH	Tech. Cap.	Maximum Output (MW s.o)	-.0002909	.0003662	-0.79	0.427	-.0010087	.0004269
		Other Renewables Capacity (MW)	.0035905	.0044411	0.81	0.419	-.0051139	.0122948
		Total Installed Capacity (MW)	-.0000971	.0003226	-0.30	0.764	-.0007293	.0005352
UTIL.	Plant Usage	Hydro Pumped Load Factor	-.1707481	.355864	-0.48	0.631	-.8682287	.5267325

Table 23 - Generator Founding Regression[25]

The combined founding policy regression illustrates that only seven policy variables remain in the regression model. As before, these are predominantly associated with PTE. However, what is interesting is that the actions of some of the instruments in combined policy sense have changed the nature of their influence e.g. those shown in Red text. This is important because it shows that combined policy actions can have rather different effects when compared to their individual policy action. This highlights how CBA and other policy evaluations, which undertake policy-by-policy appraisal, should be treated with caution.

As with the generator foundings, the combined failure policy regression illustrated that only the PTE policy variables remain. Once again, the actions of some of the instruments in a combined policy sense have changed the nature of their influence from a bivariate model into the full multivariate regression e.g. those shown in Red text.

[25] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

The mean magnitude of the factors is shown in table 24:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	Mean	Magnitude	Group Magnitude	Policy vs Rest
MCM	Regulatory	Pricing - Pricing Total	0.0152	1.83	0.993	1.62	0.02	**0.02**	
PC	Obligations	Planning and Development Total	-0.1896	2.52	0.94	0.52	-0.10	**-0.10**	
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	0.3057	0.18	0.084	66.21	20.24		
	Obligations	Electricity Generators Total	1.3472	0.83	0.104	1.24	1.67		
		Energy Supplier Total	2.7897	3.25	0.391	0.43	1.20	**23.11**	
SOS	Regulatory	Technology - Technology Total	-4.0357	1.81	0.026	1.71	-6.90	**-6.90**	**16.14**
FUEL	Fuel Usage	Nuclear Used MTOE	0.3723	0.58	0.518	18.64	6.94	**6.94**	
MACRO	Core	GDP Billions (£)	0.0082	0.00	0.058	972.61	7.93		
		Implied Investment Deflator	6.4448	33.76	0.849	0.92	5.93	**13.86**	
TECH	Tech. Cap.	Maximum Output (MW s.o)	-0.0003	0.00	0.427	57593.24	-16.75		
		Other Renewables Capacity (MW)	0.0036	0.00	0.419	910.62	3.27		
		Total Installed Capacity (MW)	-0.0001	0.00	0.764	76637.48	-7.44	**-20.93**	
UTIL.	Plant Usage	Hydro Pumped Load Factor	-0.1707	0.36	0.631	9.81	-1.68	**-1.68**	**-1.80**

Table 24 - Generator Founding Summary Impact Analysis[26]

In summary, at the combined policy level, the model is able to define the factors underlying generator foundings in the EGI. Firstly, the breakdown of the policies showed that MCM and PTE policy objectives have been positive for foundings and PC and SOS policy objectives have been negative for foundings, whilst the net effect of the policies have been positive on foundings.

Secondly, looking at the other factors additional nuclear baseload output encouraged generator foundings, indicating that steady consistent demand for electricity is growing. The macro-economic factors showed that increasing GDP and investment deflation encouraged new generators, suggesting that a growing economy with high inflation provided encouragement for generators. Interestingly, and as expected increased Generation capacity will reduce foundings. The increased use of pumped hydro indicates increased energy storage usage and in common with other countries (such as Norway), use of these facilities has had a significant effect on generators.

It clearly shows that PTE policies have encouraged more generator foundings and that the influence of the other variables have reduced generator foundings (albeit that the policy factors are almost ten times the magnitude in impact). This shows how important energy policy is with respect to a healthy and vibrant Generation marketplace.

[26] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

8.4.2 GENERATOR FAILURES

The generator failure events are shown graphically in figure 28:

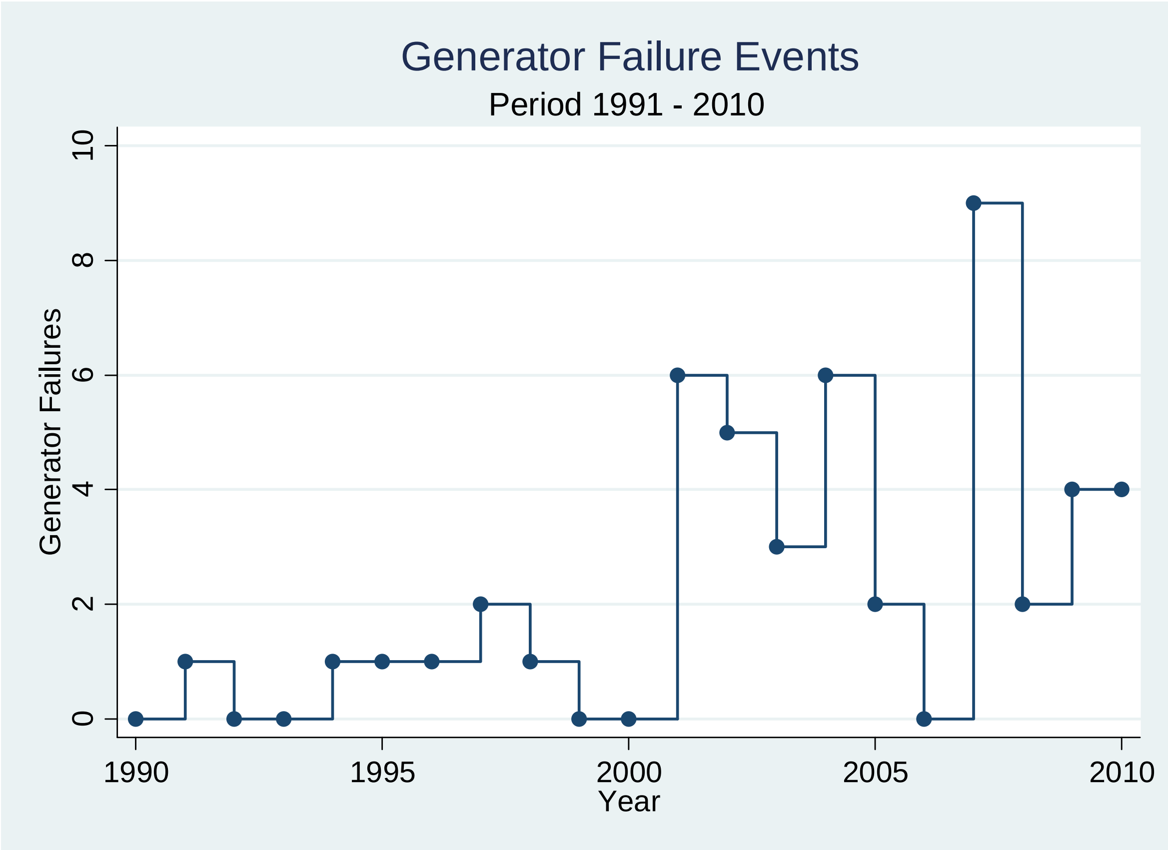

Figure 28 - Generator Failure Events (1991 – 2010)

Looking at the statistics surrounding the most significant generator failure variables significant at the 95% level (since none were significant at the 99% level) can be seen in table 25:

Policy	Class	Variable Description	Variable Name	Coefficient	Obs	Mean	Magnitude
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	0.0526**	21	66	3.482646
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousoxiden2o	0.0945**	21	49	4.64751
	Obligations	Electricity Generators Total	obegtot	-0.737**	21	1	-0.91388
	Regulatory	Environmental - Environmental Total	rwentotp	1.014**	21	4	3.91404
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)	biomasscost	0.297**	21	21	6.35877
		CCGT Cost (USDmill/kwh)	ccgtcost	1.504**	21	4	6.34688
		Coal Cost (USDmill/kwh)	coalcost	0.679**	21	9	6.36223
		Conventional Thermal Cost (USDmill/kwh)	ctcost	0.501**	21	13	6.35268
		Fuel Cell Cost (USDmill/kwh)	fuelcellcost	0.155**	21	41	6.3364
		Geothermal Cost (USDmill/kwh)	geothermalcost	0.161**	21	40	6.36111
		Hydro Cost (USDmill/kwh)	hydropowercost	0.975**	21	7	6.3375
		IGCC Cost (USDmill/kwh)	igcccost	0.552**	21	12	6.35904
		MSW Landfill Cost (USDmill/kwh)	mswlandfillcost	0.215**	21	29	6.34035
		Nuclear Cost (USDmill/kwh)	nuclearcost	0.480**	21	13	6.3696
		Solar PV Cost (USDmill/kwh)	solarpvcost	2.433**	21	3	6.3258
		Solar Thermal Cost (USDmill/kwh)	solarthemcost	0.788**	21	8	6.35916
		Wind Cost (USDmill/kwh)	windcost	0.838**	21	8	6.33528
		Wind Offshore Cost (USDmill/kwh)	windooffcost	0.307**	21	21	6.34569
FUEL	Fuel Usage	Natural Gas Used MTOE	naturalgasmtoe	-0.0866**	21	20	-1.738928
		Oil Used MTOE	oilmtoe	0.585**	21	3	1.4859
	Fuel Used	Imports Electricity MTOE	importsmtoe	1.806**	21	1	1.73376
MACRO	Core	Escalator / Deflator (US CPI)	cpiescdefl	5.337**	21	1	6.35103
		GDP Billions (£)	gdp	-0.00290**	21	973	-2.820569
TECH	Capacity	CCGT Capacity (MW)	ccgtmw	-9.94e-05**	21	17,042	-1.693955914
		Thermal Capacity (MW)	thermalmw	0.000111**	21	40,593	4.50586518
	Tech. Cap.	All Technologies Capacity (MW)	allmw	-0.000158**	21	74,846	-11.8257312
		Maximum Output (MW s.o)	maxoutputmw	-0.000307**	21	57,593	-17.68112468
		Other Renewables Capacity (MW)	otherrenmw	-0.00150**	21	911	-1.36593
		Total Installed Capacity (MW)	totcapmw	-0.000159**	21	76,637	-12.18535932
***** p<0.01, ** p<0.05**							

Table 25 – Most Statistically Significant Variables for Generator Failures (Bivariate Analysis)[27]

Looking at the policy instruments above highlights that the only policies significant to generator failure relate to PTE. Further, it is interesting that the increased obligations on generators reduced the failure rate. This suggests that a greater number of obligations might restrict new entrants and provides existing players with the confidence to remain in marketplace by anticipating that new competition will be stifled, albeit that this effect is small in relation to the others.

Focusing on the other elements of the model highlights that increased plant costs increase foundings, with all plant costs being of similar impact to generator failings. The fuel usage variables show that when CCGTs are producing more electricity generator failures are reduced, whilst increases in Oil and imported electricity are the least cost effective sources of electricity. Hence, if these factors are observed this encourages generators to remain in the market i.e. they signal shortfalls in generation facilities.

The technical capacity variables are all negative meaning that increased electricity production reduced the generator exits from the market, as above. The only exception to this is the thermal capacity, which showed that the use of this technology discouraged exits because coal is a baseload facility, and the LCPD forced

[27] Note: the independent variables are those termed PTE, the reminder are the control variables.

withdrawal encouraged many new technologies and generator foundings. Therefore, the LCPD has increased the coal usage ahead of the embargo on coal-fired plants at the end of 2015.

If these are modelled using a multi-variate Cox regression we can see the following:

No. of subjects	15
Number of obs	15 (48 over the 21 years)
No. of failures	15
Time at risk	0.1314168378 (Years)
LR chi2(13)	30.77
Log likelihood	-14.173716
Prob > chi2	0.0036
Incidence rate	114.1406

With the detailed regression results shown in table 26:

Policy	Class	Variable Description	Coefficient	Std. Err.	z	P>z	[Min 95% CI]	[Max 95% CI]
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	-2.614993	1.705764	-1.53	0.125	-5.958229	0.7282437
	Emissions	Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	3.906992	3.3441	1.17	0.243	-2.647324	10.46131
	Obligations	Electricity Generators Total	18.86174	8.892937	2.12	0.034	1.4319	36.29157
CAPITAL	Plant Cost	CCGT Cost (USDmill/kwh)	-4427.907	1722.419	-2.57	0.01	-7803.785	1052.029
		Coal Cost (USDmill/kwh)	-700.5077	1196.517	-0.59	0.558	-3045.639	1644.623
		Conventional Thermal Cost (USDmill/kwh)	-115.3138	755.6444	-0.15	0.879	-1596.35	1365.722
		Fuel Cell Cost (USDmill/kwh)	-2362.083	1575.555	-1.5	0.134	-5450.114	725.949
		Geothermal Cost (USDmill/kwh)	-5148.815	1428.406	-3.6	0	-7948.439	-2349.19
		Hydro Cost (USDmill/kwh)	1871.626	1931.235	0.97	0.332	-1913.526	5656.778
		IGCC Cost (USDmill/kwh)	132.9563	624.0131	0.21	0.831	-1090.087	1355.999
		MSW Landfill Cost (USDmill/kwh)	2401.231	1730.857	1.39	0.165	-991.1873	5793.649
		Nuclear Cost (USDmill/kwh)	4775.281	1361.992	3.51	0	2105.826	7444.736
		Solar PV Cost (USDmill/kwh)	5441.143	914.0708	5.95	0	3649.597	7232.689

Table 26 - Generator Failure Regression[28]

As with the generator foundings, the combined failure policy regression illustrated that only the PTE policy variables remained. Once again, the actions of some of the instruments, in combined policy sense, have changed the nature of their influence e.g. those shown in Red text.

[28] Note: the independent variables are those termed PTE, the reminder are the control variables.

Looking at the combined model in summary, with the mean magnitude of the factors, is shown in table 27:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	Mean	Magnitude	Group Magnitude	Policy vs Rest
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	-2.6150	1.71	0.125	66.21	-173.15		
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	3.9070	3.34	0.243	49.18	192.15		
	Obligations	Electricity Generators Total	18.8617	8.89	0.034	1.24	23.35	**42.35**	**42.35**
CAPITAL	Plant Cost	CCGT Cost (USDmill/kwh)	-4427.9070	1722.42	0.01	4.22	-18671.01		
		Coal Cost (USDmill/kwh)	-700.5077	1196.52	0.558	9.37	-6563.76		
		Conventional Thermal Cost (USDmill/kwh)	-115.3138	755.64	0.879	12.68	-1462.18		
		Fuel Cell Cost (USDmill/kwh)	-2362.0830	1575.56	0.134	40.88	-96561.95		
		Geothermal Cost (USDmill/kwh)	-5148.8150	1428.41	0	39.51	-203429.68		
		Hydro Cost (USDmill/kwh)	1871.6260	1931.24	0.332	6.50	12165.57		
		IGCC Cost (USDmill/kwh)	132.9563	624.01	0.831	11.52	1531.66		
		MSW Landfill Cost (USDmill/kwh)	2401.2310	1730.86	0.165	29.49	70812.30		
		Nuclear Cost (USDmill/kwh)	4775.2810	1361.99	0	13.27	63367.98		
		Solar PV Cost (USDmill/kwh)	5441.1430	914.07	0	2.60	14146.97	**-164664.10**	**-164664.10**

Table 27 - Generator Tenure Summary Impact Analysis[29]

In summary, at the combined policy level, the model was able to define the factors underlying Generator failure in the EGI. Firstly, the breakdown of the policies showed that only PTE policy objectives have positive effect for generator failures (i.e. more fail with these policies).

Secondly, looking at the other factors it can been seen that the non-policy influences on generator failures were all associated with the hourly cost of electricity production. This is in-line with a market in which wholesale electricity costs are only based on price i.e. through the BETTA system. Looking in detail showed that generator failures were increased when Hydroelectric, IGCC, MSW landfill, Nuclear and Solar costs increase. Conversely, generator failures reduced when CCGT, Coal, Thermal, Fuel Cell and Geothermal costs were reduced (demonstrating generators preference for thermal or chemical based technologies).

Lastly, the influence of policy on foundings was very small compared to the other factors, suggesting that the Generation business has great inertia and once generation businesses have been acquired the owners will accept policy interventions and will continue with their investments if the price of new plant continues to rise, as might be expected.

[29] Note: the independent variables are those termed PTE, the reminder are the control variables.

8.4.3 POWER PLANT FOUNDINGS

The Power Plant vital events are shown graphically in figure 29:

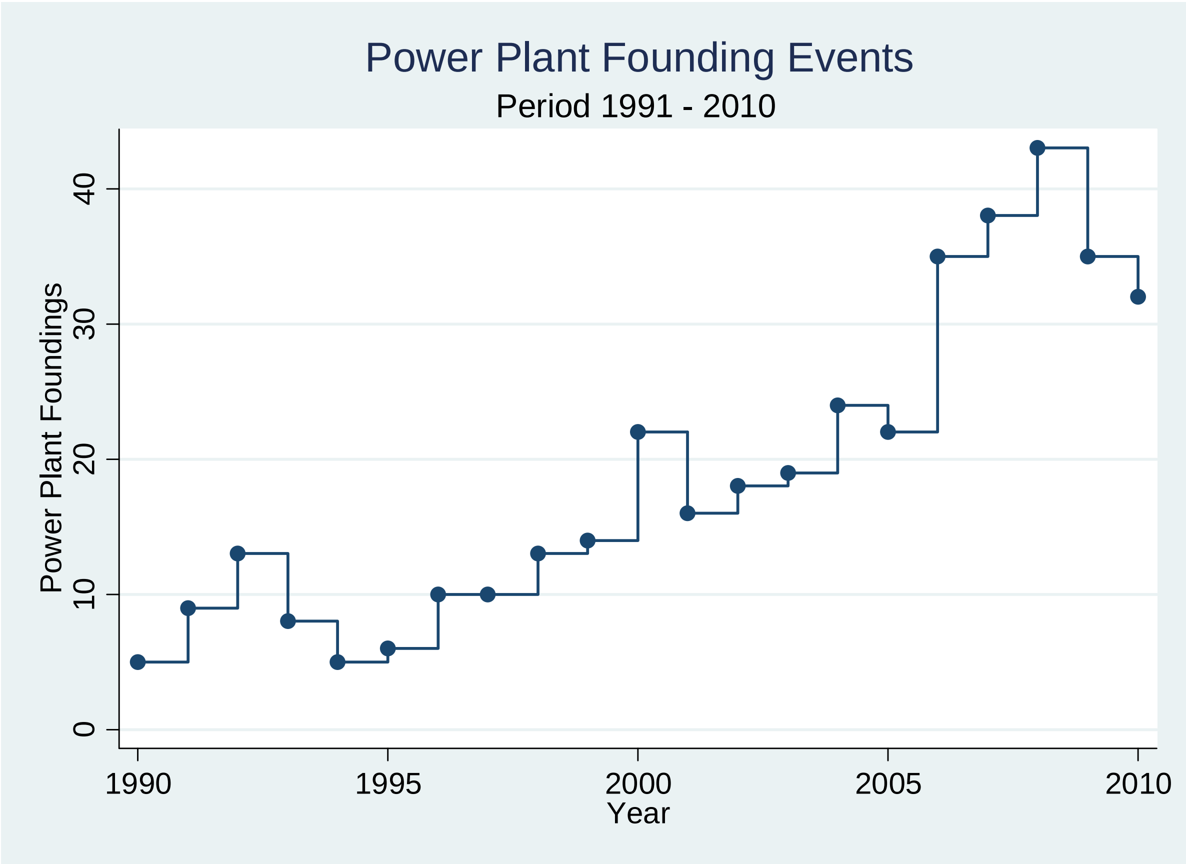

Figure 29 - Power Plant Vital Events (1991 - 2010)

If we now look at the statistics surrounding the most significant power plant variables, and specifically those that are significant at the 95% or 99% level this is shown in table 28:

Policy	Class	Variable Description	Variable Name	Coefficient	Obs	Mean
MCM	GIS	Equity - Equity Investment	giseqinv	-1.285	1	-0.12768
		Grant - Total Grants, Schemes and Incentives	gisimg	-0.906	1	-0.110024
		Loan - Loan Incentive	gisloan	-1.536	1	0.023808
		Subsidy - Subsidy	gissub	-2.079	2	0.120048
		Taxation - Tax Incentive	gistaxoff	-1.076	2	0.047802
	Regulatory	Pricing - Pricing Total	rwprictotp	2.697	2	-0.60102
PC	Obligations	Planning and Development Total	obpdtot	-1.993	1	0.1378
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	0.0998	66	-1.032876
		Millions of Tonnes of CO2 Equivalent	mtco2e	0.0297	681	-3.2769568
		Net CO2 emissions (emissions minus removals)	netco2emissionsemissionsmin	0.0346	551	-2.6957592
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousoxiden2o	0.193	49	-0.899994
		Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	perfluorocarbonspfc	3.659	0	-0.09495
		Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	sulphurhexafluoridesf6	1.642	1	0.02736
	GIS	Information - Information	gisinfo	-0.697	2	0.34189
	Obligations	Electricity Generators Total	obegtot	-0.958	1	0.28768
		Energy Supplier Total	obensutot	-2.409	0	0.20468
		Electricity Supplier Total	obestot	-2.409	1	0.68068
		Electricity Users Total	obeutot	-1.422	1	0.25596

SOS	GIS	Grant - Demonstrator Grant	gisdemg	-0.203	6	0.175536
		Grant - Research Grant	gisgrnttot	-0.114	11	0.0697034
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)	biomasscost	0.612	21	-1.693531
		CCGT Cost (USDmill/kwh)	ccgtcost	3.114	4	-1.70066
		Coal Cost (USDmill/kwh)	coalcost	1.396	9	-1.69597
		Conventional Thermal Cost (USDmill/kwh)	ctcost	1.03	13	-1.68644
		Fuel Cell Cost (USDmill/kwh)	fuelcellcost	0.32	41	-1.692432
		Geothermal Cost (USDmill/kwh)	geothermalcost	0.331	40	-1.691028
		Hydro Cost (USDmill/kwh)	hydropowercost	2.008	7	-1.69
		IGCC Cost (USDmill/kwh)	igcccost	1.137	12	-1.70496
		MSW Landfill Cost (USDmill/kwh)	mswlandfillcost	0.443	29	-1.689777
		Nuclear Cost (USDmill/kwh)	nuclearcost	0.985	13	-1.68529
		Solar PV Cost (USDmill/kwh)	solarpvcost	4.972	3	-1.7056
		Solar Thermal Cost (USDmill/kwh)	solarthemcost	1.622	8	-1.6947
		Wind Cost (USDmill/kwh)	windcost	1.729	8	-1.69344
		Wind Offshore Cost (USDmill/kwh)	windooffcost	0.633	21	-1.688739
FUEL	Fuel Usage	Coal Used MTOE	coalmtoe	0.0909	34	-0.472374
		Natural Gas Used MTOE	naturalgasmtoe	-0.121	20	0.467864
		Nuclear Used MTOE	nuclearmtoe	0.359	19	-0.516328
		Oil Used MTOE	oilmtoe	0.644	3	-0.32766
		Other Renewables Used MTOE	otherrenmtoe	-1.253	3	1.14756
	Fuel Used	Imports Electricity MTOE	importsmtoe	2.126	1	-0.81504
MACRO	Core	BoE Base Rate	baserate	0.354	5	0.13516
		Escalator / Deflator (US CPI)	cpiescdefl	10.98	1	-1.69099
		GDP Billions (£)	gdp	-0.0027	973	0.28789256
		Implied Investment Deflator	investd	-25.25	1	4.42428
		Brent Crude Oil Price	oilprice	-0.0334	36	0.49742
PRICE	Electricity Price	Industrial Price Per Pence KwH	indprce	-0.606	5	-1.55526
		Retail Price of Electricity Pence per KwH	pencekwh	-0.575	9	-1.47742
TECH	Capacity	CCGT Capacity (MW)	ccgtmw	-0.000166	17,042	5.67E-01
		Nuclear Capacity (MW)	nuclearmw	0.00091	11,823	3.98451276
		Other Technologies Capacity (MW)	othermw	0.000744	1,791	-0.22925824
		Thermal Capacity (MW)	thermalmw	0.000171	40,593	-1.33958154
	Tech. Cap.	All Technologies Capacity (MW)	allmw	-0.000376	74,846	5.44881792
		Maximum Output (MW s.o)	maxoutputmw	-0.000393	57,593	4.80903554
		Other Renewables Capacity (MW)	otherrenmw	-0.00378	911	0.54910386
		Total Installed Capacity (MW)	totcapmw	-0.000413	76,637	5.985387188
UTILISATION	Plant Usage	Hydro Pumped Load Factor	hydropumlf	-0.956	10	0.413982
		All Plant Load Factor (%)	loadfactor	0.227	75	-9.0348
		Nuclear Load Factor	nuclearlf	0.152	71	1.97932
		Other Technology Load Factor	otherslf	0.236	10	-0.669504

Table 28 – Most Statistically Significant Variables for Power Plant Foundings (Bivariate Analysis)[30]

This table shows that the number of policy and other significance influences, in terms of variables, was much greater than was the case with the Generator level of analysis. It also showed that all of the successive Governments' policy objectives except SREOEG had some impact on power plant foundings.

The main policy instruments having influence were associated with the MCM policy object were grants and incentives and regulatory price controls. This is interesting because most of the grants involved only provide small monetary values but these have clearly had an effect. However, as Dobbin and Dowd suggest these have all been viewed as 'Pro-Cartel' and have therefore reduced the number of new Power Plant foundings, with the exception of the price controls which have been Anti-Trust in nature and encouraged new power plant investments.

[30] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

The only PC policy relates to planning control and as could be expected this reduced the number of new power plants.

PTE policies include emissions, grants and incentives, and obligations on electricity players. The emissions policies all encouraged new power plants (it is thought that these have encouraged new renewables plants). Whilst the use of information and obligations have reduced the number of power plants being developed.

The SOS policies observed were associated with new technology development grants and incentives, both of which reduced the number of power plant foundings. Perhaps encouraging new technologies might mean that investors will wait for new technology before investing.

The capital cost variables are all positive, and as they increase this tends to encourage new power plant foundings. The exact nature of this operation cannot be determined from the data, for example it might be that increased costs make old plant redundant as more efficient new technology enters the marketplace.

The fuel usage showed that Gas and Renewables discourage foundings, whilst this also increased usage of the other fuels encourage new power plant builds. This suggests that investors prefer traditional technologies for electricity generation (see Market Concentration analysis for further comment).

The macro-economic factors showed that higher interest rates and price inflation encourage foundings, whilst GDP, investment deflator and increased crude oil prices discourage new power plants.

The table also shows that Increases in electricity prices reduce the level of power plant foundings.

Increases in capacity i.e. CCGT capacity reduce foundings and those in Nuclear, Other and Thermal plants encourage foundings. This observation indicates the nature of the power plant outputs i.e. new power plants are encouraged by baseload facilities, whilst peak and intermediate load capacities reduce foundings. Knowledge of the UK EGI shows that this is correct because it is the baseload facilities that are short in the UK EGI at present.

Despite the above, power plants foundings are lower when market power plant capacity is high, obviously companies do not want to over invest.

The last significant variables relate to power plant utilisation and these showed that, with the exception of pumped storage, increased load factors indicate power plant shortages and encourage foundings.

When the 48 variables with a 99% significance (from the bivariate regression) are collectively modelled in a multi-variate Cox regression the model suffers from a ‘flat region’. Looking at the Stata support literature highlights that the Cox regressions should be specified with the ‘Efron, or exactp, or exactm’ options when the regression has many tied failure times. This problem arises because of what is termed the 'mono-tone' likelihood. Unfortunately, the ‘Firth method’, which can help overcome this, is not yet implemented in Stata for Cox models. Therefore, it was necessary to be selective with the variables to test models to see if the 'flat region' issue was overcome.

After extensive testing, using the 99% significant policy variables (since these are core to the research context) a policy model could be used (albeit that six of the twelve significant variables were omitted from the model). This is shown below:

No. of subjects	14
Number of obs	14
No. of failures	14
Time at risk	0.9336071184 (Years)
LR chi2(13)	44.75
Log likelihood	-1.4318631
Prob > chi2	0.0000
Incidence rate	19.32053

With the detailed regression results are shown in table 29:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	[Min 95% CI]	[Max 95% CI]
MCM	GIS	Equity - Equity Investment	-9.950914	2.980746	0.001	-15.79307	-4.10876
		Taxation - Tax Incentive	10.57415	5.899322	0.073	-0.988307	22.13661
		Subsidy - Subsidy	0	(omitted)			
	Regulatory	Pricing - Pricing Total	-3.955544	.	.	.	.
PC	Obligations	Planning and Development Total	-21.23039	5.142262	0	-31.30904	-11.15175
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	-92.00678	.	.	.	
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	4.85889	.	.	.	.
		Methane (CH4), Millions of Tonnes of CO2 Equivalent	0.4198714	.	.	.	.
		Millions of Tonnes of CO2 Equivalent	-0.2714278	.	.	.	.
	Obligations	Electricity Generators Total	-4.985301	4.562841	0.275	-13.9283	3.957702
		Energy Supplier Total	2.858214	3.962922	0.471	-4.908969	10.6254
		Electricity Supplier Total	0	(omitted)			
		Electricity Users Total	14.14673	2.720934	0	8.813801	19.47967

Table 29 – Power Plant Founding Regression[31]

This showed that a broader range of policy objectives influences the power plant foundings, albeit that SOS and SROEG objectives are absent. Once again, the actions of some of the instruments in combined policy sense have changed the nature of their influence e.g. those shown in Red text.

[31] Note: the independent variables are those termed MCM, PC and PTE, the reminder are the control variables.

Looking at the combined model in summary along with the mean magnitude of the factors remaining in table 30:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	Mean	Magnitude	Sub Group Magnitude	Group Magnitude
MCM	GIS	Equity - Equity Investment	-9.950914	2.980746	0.001	1.14	-11.34		
		Taxation - Tax Incentive	10.57415	5.899322	0.073	1.86	19.67	**8.32**	**8.32**
PC	Obligations	Planning and Development Total	-21.23039	5.142262	0	0.52	-11.04	**-11.04**	**-11.04**
PTE	Obligations	Electricity Generators Total	-4.985301	4.562841	0.275	1.24	-6.18		
		Energy Supplier Total	2.858214	3.962922	0.471	0.43	1.23		
		Electricity Users Total	14.14673	2.720934	0	0.81	11.46	**6.51**	**6.51**

Table 30 - Generator Failure Summary Impact Analysis[32]

This table is interesting because it provides information on the combined impact of government policy. This showed that for the MCM policy object Equity investment schemes were detrimental to power plant foundings (i.e. they are Pro Cartel in nature) and Tax Incentives encouraged power plant foundings.

The PC policy once again showed that planning obligations are a constraint to power plant foundings. This is especially the case with the current public backlash to onshore wind turbines.

The PTE policy showed a number of similarities in terms of the instruments to the models presented before.

Overall, if the mean impact of the policy objectives was considered net impact of MCM and PTE policies have been positive to power plant foundings, whilst the PC policy has been negative. Summating these shows that the net impact has been slightly positive.

In stating the above, one must be mindful of the fact that due to data / statistical limitations some 42 other significant variables had to be omitted. This means that the above mode is therefore not complete. Despite this it does provide and insight into the key policy instruments and their impact.

[32] Note: the independent variables are those termed MCM, PC and PTE, the reminder are the control variables.

8.4.4 POWER PLANT FAILINGS

The total number of power plant failures in the data set was forty-three (compared to forty-eight generator failings). All variables were statistically insignificant at the 95% and 99% levels. Therefore, no combined policy model regressions could be undertaken to analyse the power plant failings.

The Power Plant failing vital events are presented in figure 30:

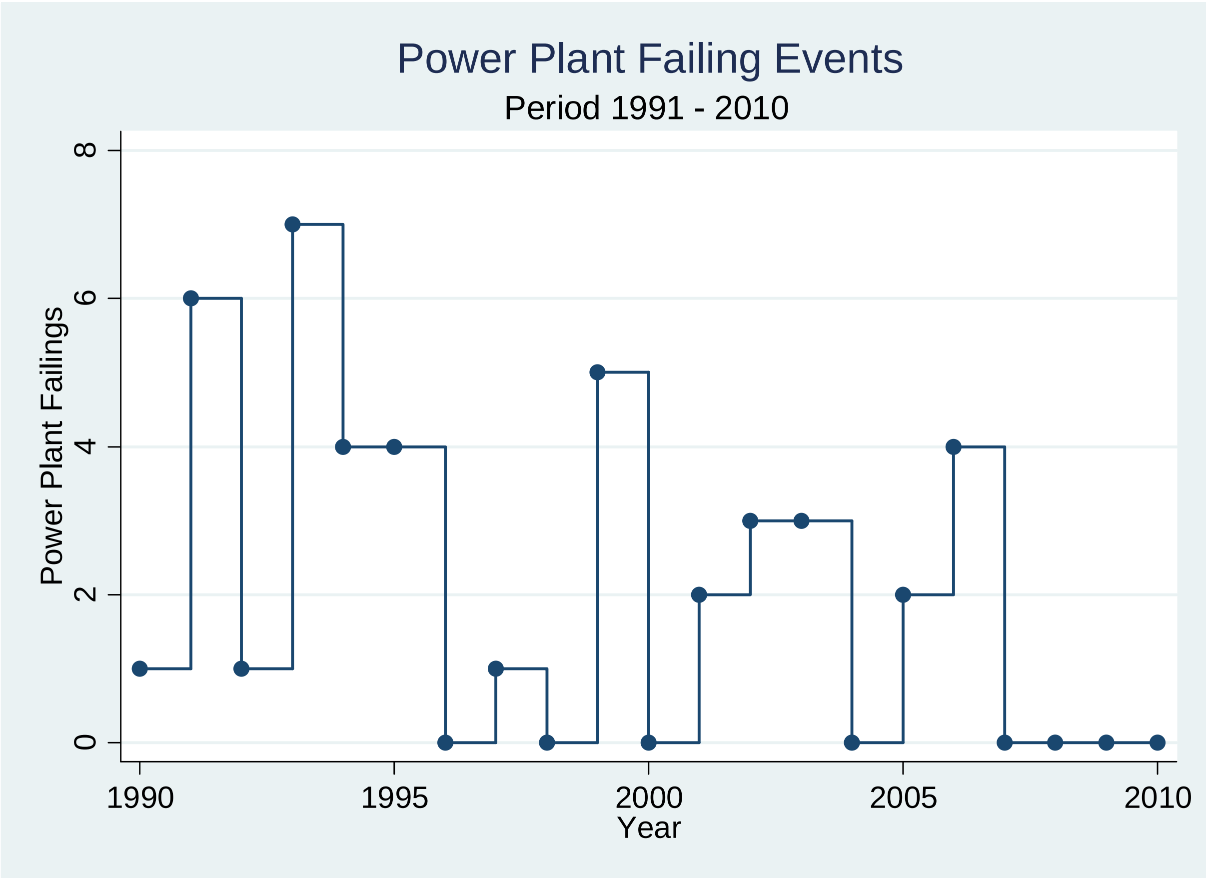

Figure 30 - Power Plant Failing Vital Events (1990 - 2010)

8.5 FOUNDING AND FAILURE RATES - DISCUSSION

Table 31 shows the results from above collated to illustrate the distribution of policy objectives and instruments for generators (foundings and failures) and power plant foundings:

Policy Objective	Policy Class	Policy Instrument	Gen Fail	Gen Found	PP Found	Grand Total
MCM	GIS	Equity - Equity Investment			1	1
	GIS	Grant - Total Grants, Schemes and Incentives			1	1
	GIS	Loan - Loan Incentive			1	1
	GIS	Subsidy - Subsidy			1	1
	GIS	Taxation - Tax Incentive			1	1
	Regulatory	Pricing - Pricing Total	1		1	2
		MCM TOTAL	**1**	**0**	**6**	**7**
PC	Obligations	Planning and Development Total	1		1	2
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	1	1	1	3
	Emissions	Millions of Tonnes of CO2 Equivalent			1	1
	Emissions	Net CO2 emissions (emissions minus removals)			1	1
	Emissions	Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent		1	1	2
	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent			1	1
	Emissions	Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent			1	1
	GIS	Information - Information			1	1
	Obligations	Electricity Generators Total	1	1	1	3
	Obligations	Electricity Supplier Total	1		1	2
	Obligations	Electricity Users Total			1	1
	Obligations	Energy Supplier Total	1		1	2
		PTE TOTAL	**5**	**3**	**12**	**20**
SOS	GIS	Grant - Demonstrator Grant			1	1
	GIS	Grant - Research Grant			1	1
		SOS TOTAL				**2**
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)		1	1	2
	Plant Cost	CCGT Cost (USDmill/kwh)		1	1	2
	Plant Cost	Coal Cost (USDmill/kwh)		1	1	2
	Plant Cost	Conventional Thermal Cost (USDmill/kwh)		1	1	2
	Plant Cost	Fuel Cell Cost (USDmill/kwh)		1	1	2
	Plant Cost	Geothermal Cost (USDmill/kwh)		1	1	2
	Plant Cost	Hydro Cost (USDmill/kwh)		1	1	2
	Plant Cost	IGCC Cost (USDmill/kwh)		1	1	2
	Plant Cost	MSW Landfill Cost (USDmill/kwh)		1	1	2
	Plant Cost	Nuclear Cost (USDmill/kwh)		1	1	2
	Plant Cost	Solar PV Cost (USDmill/kwh)		1	1	2
	Plant Cost	Solar Thermal Cost (USDmill/kwh)		1	1	2
	Plant Cost	Wind Cost (USDmill/kwh)		1	1	2
	Plant Cost	Wind Offshore Cost (USDmill/kwh)		1	1	2
		CAPITAL TOTAL	**0**	**14**	**14**	**28**
FUEL	Fuel Usage	Coal Used MTOE			1	1
	Fuel Usage	Natural Gas Used MTOE		1	1	2
	Fuel Usage	Nuclear Used MTOE	1		1	2
	Fuel Usage	Oil Used MTOE		1	1	2
	Fuel Usage	Other Renewables Used MTOE			1	1
	Fuel Used	Imports Electricity MTOE		1	1	2
		FUEL TOTAL	**1**	**3**	**6**	**10**
MACRO	Core	BoE Base Rate			1	1
	Core	Brent Crude Oil Price			1	1
	Core	Escalator / Deflator (US CPI)		1	1	2
	Core	GDP Billions (£)	1	1	1	3
	Core	Implied Investment Deflator	1		1	2
		MACRO TOTAL	**2**	**2**	**5**	**9**
PRICE	Electricity Price	Industrial Price Per Pence KwH			1	1
	Electricity Price	Retail Price of Electricity Pence per KwH			1	1
		PRICE TOTAL	**0**	**0**	**2**	**2**
TECH	Capacity	CCGT Capacity (MW)		1	1	2
	Capacity	Nuclear Capacity (MW)			1	1
	Capacity	Other Technologies Capacity (MW)			1	1
	Capacity	Thermal Capacity (MW)		1	1	2
	Tech. Cap.	All Technologies Capacity (MW)		1	1	2
	Tech. Cap.	Maximum Output (MW s.o)	1	1	1	3
	Tech. Cap.	Other Renewables Capacity (MW)	1	1	1	3
	Tech. Cap.	Total Installed Capacity (MW)	1	1	1	3
		TECH TOTAL	**3**	**6**	**8**	**17**

Policy Objective	Policy Class	Policy Instrument	Gen Fail	Gen Found	PP Found	Grand Total
UTILISATION	Plant Usage	All Plant Load Factor (%)			1	1
	Plant Usage	Hydro Pumped Load Factor	1		1	2
	Plant Usage	Nuclear Load Factor			1	1
	Plant Usage	Other Technology Load Factor			1	1
		UTILISATION TOTAL	**1**	**0**	**4**	**5**
		GRAND TOTAL	**13**	**28**	**57**	**98**

Table 31 - Count of Instruments Found to be Significant in all Regressed Models

The detailed summary of regression results suggests that Dobbin and Dowd's (1997) research may have some direct relevance to this study. Their work considered the effects of policy on markets and competition by looking at the effects of three common policy regimes - public capitalisation, pro-cartel and antitrust policies relating to competition on the founding of new firms in the railroad sector in the USA between 1825 and 1922 (Dobbin and Dowd, 1997). Their key findings are shown in table 32:

Impact Factor / Policy Framework	Anti-Trust Policies	Pro-Cartel Policies
Founding Rate	Reduced	Increased
Failure Rate	Increased	Decreased
Market Competition	Increased	Decreased
Market Concentration	Increased	Decreased

Table 32 - Dobbin and Dowd's Policy Impact Findings

In order to compare this with the findings from this research a further bivariate coefficient regression Generator and power plant analysis of the results was undertaken and is shown in table 33:

Policy	Class	Variable Description	Action	Founding Impact Expected	Magnitude Gen. Found	Magnitude Power Plant Found
MCM	GIS	Equity - Equity Investment	Anti-Trust	Reduced	-0.395	-1.285***
		Taxation - Tax Incentive	Anti-Trust	Reduced	-0.313	-1.076***
	Regulatory	Pricing - Pricing Total	Pro-Cartel	Increased	1.102**	2.697***
PC	Obligations	Planning and Development Total	Anti-Trust	Reduced	-0.766**	-1.993***
		Planning and Development Total	Anti-Trust	Reduced	-0.766**	-1.993***
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	0.0230**	0.0998***
		Methane (CH4), Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	0.0230**	0.0998***
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	0.0314	0.193***
	Obligations	Electricity Generators Total	Anti-Trust	Reduced	-0.364**	-0.958***
		Electricity Generators Total	Anti-Trust	Reduced	-0.364**	-0.958***
		Electricity Generators Total	Anti-Trust	Reduced	-0.364**	-0.958***
		Electricity Users Total	Anti-Trust	Reduced	-0.485*	-1.422***
		Energy Supplier Total	Anti-Trust	Reduced	-1.123**	-2.409***
		Energy Supplier Total	Anti-Trust	Reduced	-1.123**	-2.409***
SOS	Regulatory	Technology - Technology Total	Anti-Trust	Reduced	-1.506***	-0.888*

Table 33 - Dobbin and Dowd's Policy Correlation

This shows the type of action and the expected observation when considering Dobbin and Dowd's work and the results from the analysis of the founding and failure rates.

The last factor arising from the combined results is whether the research questions have been answered and the theory and hypotheses have been confirmed. These results show that it is possible to identify the policy instruments and policy objectives and their impact on the founding and failure rates for generators and founding rates for power plants.

The above is even more interesting when one considers that Dobbin and Dowd's analysis was undertaken by looking at ownership at the whole population level i.e. whether or not the railroad industry was nationalised or privatised, whereas this research looks at vital rates for generators and power plants and the impact of policy objectives and the individual policy instruments on them.

8.6 FOUNDING AND FAILURE RATES SUMMARY

This chapter set out to present the results from the policy instrument and policy objective analysis of the founding and failure corporate demography based vital event rates for generator and power plants. The main objective was to examine the impact of energy policy instruments and energy policy objectives on electricity generators and power plant by means of their vital events. In summary, the chapter presented the data and variables used, research context, model specifications, results and supplemented this with a discussion of what the results showed.

As can be seen from the above, this research has shown that population based measures can be used to undertake empirical analysis of the electricity generation industry in a period during which intense government policy making and intervention has been undertaken in the UK and European Union.

The most pleasing aspect of this research component is that despite the relatively short timeframe of the study (21 years), and the relatively small number of vital events, the research questions, have been addressed and that the theory and hypotheses have all been confirmed. Albeit that this recognises that power plant failures could not be computer by virtue of the limited number of valid events. Lastly, the results also confirm that it is possible to extend Dobbin and Dowd's findings to the UK electricity industry.

9. Energy Policy Impact on Generator and Power Plant Duration of Tenure

9 GENERATOR AND POWER PLANT TENURE

This chapter presents the results from the policy instrument and policy objective generator and power plant duration of tenure analysis. Specifically, it examines the impact of energy policy instruments and energy policy objectives on the time duration that individual generators and their power plants were present in the electricity generation business and the duration of time that power plants produced electricity.

The chapter is structured under the headings of generator and power plant tenure data & variables, generator and power plant tenure research context, generator and power plant tenure model specification, generator and power plant tenure results, generator and power plant tenure discussion, and generator and power plant tenure summary.

9.1 GENERATOR AND POWER PLANT TENURE DATA AND VARIABLES

The independent variables collected for this analysis were the same as those described in chapter 8 entitled 'Data and Bivariate Testing'. However, the dependent variables are different. These are the number of years of tenure that a generator had in the electricity generation business and the number of years that an individual power plant produced electricity.

The structure of the data on generator years of ownership tenure is presented in table 34:

Variable	Obs	Mean	Std. Dev.	Min	Max
As At Owner Number of the Power Plant	210			3	224
Year of Observation	210			1991	2011
Number of Years Generator was Present in the Marketplace	210	9.1	5.59	1	21
Censoring Indicator	210			0	1

Table 34 - Generator Operational Duration Events Data

Analysis of this data highlighted that out of two hundred and ten generator companies, one hundred and fifty four were right censored i.e. they continued their operations up to and after the end timeframe of this study. This showed that over the twenty-year timeframe the remaining number of vital events available for analysis was actually quite small. Clearly, this has implications for the statistical analysis that can be undertaken.

Power plant operational service years of tenure are presented in table 35:

Description	Variable	Obs	Mean	Std. Dev.	Min	Max
Station Number of the Power Plant	statnos	570			1	582
Year of Observation	dateyr0	210			1991	2011
Number of Years Generator was Present in the Marketplace	yrcount	210	11.3	7.4	1	21
Censoring Indicator	cens	210			0	1

Table 35 – Power Plant Operational Duration Events Data

Analysis of the power plant data highlights that out of five hundred and seventy generator companies there were one hundred and eighty two left censored (i.e. they started producing electricity before the start of the study) and five hundred and twenty eight were right censored. Once again, this shows that over the twenty-year timeframe the number of vital events available for analysis was actually quite small. Clearly, this also has implications for the statistical analysis that can be undertaken.

9.2 GENERATOR AND POWER PLANT TENURE RESEARCH CONTEXT

Now that the dependent variables have been discussed, it is important to present the research questions, theory, and hypotheses for the detailed analyses.

Research Question – Using generator tenure and Power Plant production (in years) over the twenty-year period since electricity privatisation, is it possible to evaluate the impact of successive Governments' energy policies using policy instruments (i.e. the individual policy interventions enacted) and policy objective analysis (i.e. using the five broad policy objectives adopted by successive Governments' – MCM, PC, PTE, SOS, and SROEG[33]) at the aggregate level?

Research Theory – The impact and action of energy policy can be defined and understood, in the electricity generation industry, by means of event history analysis relating to: the duration of ownership, or the duration that a power plant produced data, (dependent variables), energy policy explanatory variables (for both the individual policy instruments and the grouping of these policy instruments[34] to form energy policy objectives), and control variables that act to baseline the dependent and independent variables (i.e. capital cost of generating plant, fuel type used, technology used, year in which technology critical mass was achieved, power plant utilisation, macro-economic variables and corporate demography data such as the location etc.).

Hypotheses – there are two hypotheses posited for this research endeavour:

> **Generator Tenure hypothesis** – The impact (direction and magnitude) of the specific energy policy instruments on electricity generator tenure duration, in the electricity industry since 1990, can be understood by use of Dobbin and Dowd's (1997) anti-trust and pro-cartel policy classification[35].
>
> **Power Plant Production Duration hypothesis** – The impact (direction and magnitude) of the specific energy policy instruments on electricity power plant duration, lifespan in the electricity industry since 1990, can be understood by use of Dobbin and Dowd's (1997) anti-trust and pro-cartel policy classification.

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[33] Policy Objectives are: MCM – Maintaining Competitive Markets, PC – Protecting Consumers, PTE – Protecting the Environment, SOS – Security of Supply, SROEG - Sustainable Rate of Economic Growth.

[34] Policy Instruments type are: Emissions controls, Government major funding schemes, investor or user based Grants, Incentives and other Schemes (GIS), Obligations, Policy instrument class of action, Policy Instrument nature of action, Regulatory compliance obligations.

[35] Dobbin and Dowd's research identified that government intervention could be categorised as Anti-Trust (which increased competition, industrial concentration, company failure rates and reduced company founding rates), or Pro-Cartel (which reduced competition, industrial concentration, company failure rates and increased company founding rates).

9.3 GENERATOR AND POWER PLANT TENURE MODEL SPECIFICATION

Two sets of models were constructed for this analysis. The first was the development of a table that recorded the first-year (that the generator was active) and the total number of calendar years that each electricity generator was active in the electricity industry. The second was the development of a table that recorded the first year that a power plant was operational and the total number of years that the power plant was active in the EGI. In order to conduct the statistical analysis both tables were merged with the independent policy instrument, policy objective and control variables.

In both cases, analysis of the regressions utilised the semi parametric cox proportional hazards formulation to undertake the model building that would enable each of the significant policy instruments and policy objectives to be regressed together.

Two models built, firstly, a Cox-based bivariate analysis of the 183 independent and control variables was performed against the two dependent variables. This showed the level of influence that each of the independent and control variables has on the dependent variable. The results from this analysis are in a combined table that shows all regression results (coefficient and standard errors) for the two dependent variables.

Next, the dependent variables were evaluated by considering three elements. The first element was to provide a summary of the bivariate regression for the most significant independent variables (i.e. the energy policy instruments). The second element took these variables and multiplied the coefficient of the policy instrument variable by its mean value to provide an average magnitude of impact, this allowed the relative impact of each policy instrument to be compared in both scale and direction of influence on the dependent variable. This table was supplemented by use of a narrative to allow the reader to understand how the policy instruments are working. The last element undertook a multivariate regression utilising all of the independent and control variables.

This framework was used to confirm the validity or otherwise of the generator and power plant tenure hypotheses i.e. two models sets were tested.

9.4 GENERATOR AND POWER PLANT TENURE RESULTS

9.4.1 OVERALL BIVARIATE ANALYSIS

The key variables for the duration analysis were the two dependent variables (i.e. generator company tenure in the electricity generation industry and the number of years that each power plant produced electricity within the period of the study) in each case the dependent variable were regressed with independent and control variables using a bivariate cox regression in STATA. Due to the limited number of non-censored observations for the power plant duration, only the generator duration regression could be performed. The statistically significant results are shown in table 36:

Policy	Class	Description	coef	se	pval	N	mean	ci high	ci low
MCM	Regulatory	Ownership - Ownership Total	0.408**	(0.185)	0.0274	211	1.531	0.77	0.0455
		Pricing - Pricing Total	1.090**	(0.489)	0.0259	211	1.54	2.048	0.131
PC	Obligations	Planning and Development Total	-0.752*	(0.416)	0.0708	211	0.645	0.0637	-1.568
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	0.0233***	(0.0089)	0.00885	210	66.94	0.0407	0.00585
		Millions of Tonnes of CO2 Equivalent	0.00942***	(0.00341)	0.00574	210	687.5	0.0161	0.00274
		Net CO2 emissions (emissions minus removals)	0.0203***	(0.00738)	0.00583	210	555.8	0.0348	0.00588
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	0.0389**	(0.0153)	0.0108	210	50.28	0.0688	0.00897
		Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	0.681**	(0.289)	0.0184	210	0.547	1.248	0.115
	GIS	Information - Information	-0.544*	(0.282)	0.0541	146	2.041	0.00962	-1.097
	Obligations	Electricity Generators Total	-0.358**	(0.162)	0.0271	211	1.412	-0.0404	-0.676
		Energy Supplier Total	-0.817*	(0.428)	0.0561	211	0.483	0.0212	-1.655
		Electricity Supplier Total	-0.817*	(0.428)	0.0561	211	1.483	0.0212	-1.655
		Electricity Users Total	-0.633**	(0.277)	0.0223	211	0.938	-0.0903	-1.176
SOS	GIS	Grant - Demonstrator Grant	-0.136*	(0.0759)	0.0722	146	7	0.0123	-0.285
		Grant - Research Grant	-0.0793*	(0.0448)	0.077	146	11.99	0.00858	-0.167
		Grant - Implementation Grant	-0.297*	(0.177)	0.0938	146	3.486	0.0503	-0.643
CAPITAL	Plant Cost	Biomass Cost (USDmill/khw)	0.122***	(0.0464)	0.00853	210	21.74	0.213	0.0311
		CCGT Cost (USDmill/kwh)	0.620***	(0.236)	0.00853	210	4.283	1.081	0.158
		Coal Cost (USDmill/kwh)	0.279***	(0.106)	0.00853	210	9.514	0.487	0.0711
		Conventional Thermal Cost (USDmill/kwh)	0.206***	(0.0783)	0.00853	210	12.88	0.359	0.0525
		Fuel Cell Cost (USDmill/kwh)	0.0639***	(0.0243)	0.00853	210	41.52	0.112	0.0163
		Geothermal Cost (USDmill/kwh)	0.0661***	(0.0251)	0.00853	210	40.13	0.115	0.0169
		Hydro Cost (USDmill/kwh)	0.402***	(0.153)	0.00853	210	6.605	0.701	0.102
		IGCC Cost (USDmill/kwh)	0.227***	(0.0862)	0.00853	210	11.7	0.396	0.0578
		MSW Landfill Cost (USDmill/kwh)	0.0886***	(0.0337)	0.00853	210	29.96	0.155	0.0226
		Nuclear Cost (USDmill/kwh)	0.197***	(0.0749)	0.00853	210	13.48	0.344	0.0502
		Solar PV Cost (USDmill/kwh)	1.004***	(0.382)	0.00853	210	2.643	1.752	0.256
		Solar Thermal Cost (USDmill/kwh)	0.324***	(0.123)	0.00853	210	8.197	0.565	0.0825
		Wind Cost (USDmill/kwh)	0.346***	(0.131)	0.00853	210	7.676	0.603	0.0881
		Wind Offshore Cost (USDmill/kwh)	0.126***	(0.048)	0.00853	210	21	0.221	0.0322
FUEL	Fuel Usage	Coal Used MTOE	0.0333**	(0.0136)	0.0148	210	36.13	0.06	0.00653
		Natural Gas Used MTOE	-0.0343***	(0.0131)	0.00884	210	19.08	-0.00863	-0.06
		Oil Used MTOE	0.156**	(0.0616)	0.0115	210	2.827	0.276	0.0349
MACRO	Core	BoE Base Rate	0.0667*	(0.0349)	0.0558	210	6.585	0.135	-0.00165
		Escalator / Deflator (US CPI)	2.194***	(0.834)	0.00853	210	1.209	3.83	0.559
		GDP Billions (£)	-0.00119**	(0.000519)	0.0214	210	983	-0.000177	-0.00221
		Implied Investment Deflator	-7.360**	(3.197)	0.0213	210	0.924	-1.093	-13.63
PRICE	Electricity Price	Retail Price of Electricity Pence per KwH	-0.342*	(0.197)	0.0819	210	8.345	0.0433	-0.728
TECH	Capacity	CCGT Capacity (MW)	-4.09e-05**	(1.60E-05)	0.0103	210	16,425	-9.64E-06	-7.22E-05
		Other Technologies Capacity (MW)	0.000363**	(0.00017)	0.0331	210	1,996	0.000696	2.92E-05
		Thermal Capacity (MW)	3.99e-05**	(1.76E-05)	0.0231	210	41,613	7.43E-05	5.49E-06
TECH	Tech. Cap.	All Technologies Capacity (MW)	-8.28e-05**	(3.74E-05)	0.0268	210	75,048	-9.53E-06	-0.000156
		Maximum Output (MW s.o)	-0.000152***	(5.42E-05)	0.00504	210	57,835	-4.58E-05	-0.000258
		Other Renewables Capacity (MW)	-0.000955***	(0.000368)	0.00941	210	887.7	-0.000234	-0.00168

Policy	Class	Description	coef	se	pval	N	mean	ci high	ci low
		Total Installed Capacity (MW)	-6.94e-05*	(3.74E-05)	0.0636	210	77,044	3.94E-06	-0.000143
UTILISATION	Plant Usage	Hydro Pumped Load Factor	-0.118*	(0.0684)	0.084	210	10.11	0.0159	-0.252
		Thermal Plant Load Factor	0.0929*	(0.0489)	0.0574	210	44.5	0.189	-0.00294
Standard errors in parentheses									
*** p<0.01, ** p<0.05, * p<0.1									

Table 36 – Generator Tenure Duration Stcox Bivariate Analysis to the Independent Variable[36]

9.4.2 GENERATOR TENURE

The generator tenure in terms of the number of vital events being recorded (tenure measurements) is presented in figure 31:

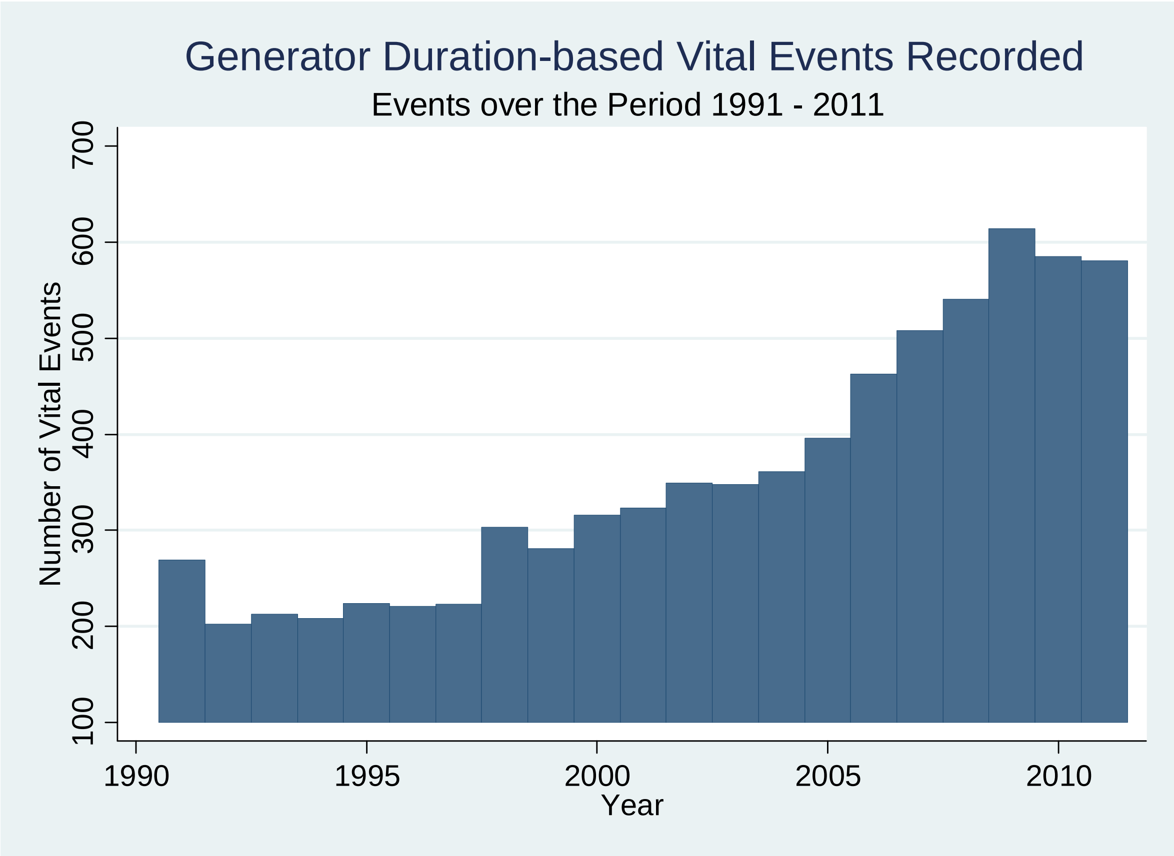

Figure 31 - Generator Duration-based Vital Events

[36] Note: the independent variables are those termed MCM, PC, PTE,SOS and SROEG, the reminder are the control variables.

The results from the multivariate regression of the generator companies in table 36:

No. of subjects	146
Number of obs	146
No. of failures	18
Time at risk	2.85284052 (Years)
LR chi2(13)	21.78
Log likelihood	-70.339524
Prob > chi2	0.0006
Incidence rate	10.6977

With the detailed regression results are shown in table 37[37]:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	P>z	[Min 95% CI]	[Max 95% CI]
MCM	Regulatory	Pricing - Pricing Total	17.13064	12182.48	0	0.999	-23860.09	23894.35
PC	Obligations	Planning and Development Total	-26.94489	9482.727	0	0.998	-18612.75	18558.86
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	-3.917595	4215.39	0	0.999	-8265.93	8258.095
		Millions of Tonnes of CO2 Equivalent	0.1175087	5133.488	0	1	-10061.33	10061.57
		Net CO2 emissions (emissions minus removals)	1.46782	5345.537	0	1	-10475.59	10478.53
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	-2.087537	8560.343	0	1	-16780.05	16775.88
	Obligations	Electricity Generators Total	3.501084	1804.77	0	0.998	-3533.783	3540.785
SOS	GIS	Grant - Research Grant	8.524698	1548.864	0.01	0.996	-3027.194	3044.243

Table 37 - Significant Policy Instruments that Impact Generator Tenure

Looking at the combined model in summary with the mean magnitude of the factors remaining in table 38:

Policy	Class	Variable Description	Coefficient	Std. Err.	P>z	Mean	Magnitude	Group Magnitude	Group Magnitude
MCM	Regulatory	Pricing - Pricing Total	17.13064	12182.48	0.999	1.62	27.75	27.75	27.75
PC	Obligations	Planning and Development Total	-26.94489	9482.727	0.998	0.52	-14.01	-14.01	-14.01
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	-3.917595	4215.39	0.999	66.21	-259.38	527.19	531.53
		Millions of Tonnes of CO2 Equivalent	0.1175087	5133.488	1	681.28	80.06		
		Net CO2 emissions (emissions minus removals)	1.46782	5345.537	1	551.28	809.18		
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	-2.087537	8560.343	1	49.18	-102.67		
	Obligations	Electricity Generators Total	3.501084	1804.77	0.998	1.24	4.34	4.34	
SOS	GIS	Grant - Research Grant	8.524698	1548.864	0.996	10.79	91.98	91.98	91.98

Table 38 - Generator Failure Summary Impact Analysis

These two tables show that all of the policy objectives except SROEG were present in the multi-variate regression. Once again, they show that the PTE policy objective has the greatest number of significant policy instruments in the model, and that the mean magnitude of effect was greatest for these.

Following Dobbin and Dowd, the MCM price control policies yield increased generator tenure in the industry, whilst the PC planning obligation reduces generator industry tenure as before. The PTE policies relating to

[37] Those that were found to be significant at the 90%, 95% and 95% significance in the bivariate model regressions.

emissions management significantly increase generator tenure, whilst the obligations on generators increase it in minor way. Lastly, SOS research grants also increase industry tenure in a medium level.

9.4.3 POWER PLANT TENURE

The total number of power plant failures in the dataset is forty-four (compared to forty-eight generator failing). This number was found to be too small when trying to undertake the regressions, and therefore no results could be obtained from the analysis of the power plant tenure analysis.

9.5 GENERATOR AND POWER PLANT TENURE DISCUSSION

Looking at the summary of regression results in detail, suggests that Dobbin and Dowd's (1997) research may have some direct relevance to this study. As stated before, their work considered the effects of policy on markets and competition by looking at the effects of three common policy regimes-public capitalization, pro-cartel, and antitrust-on competition and the founding of new firms in the railroad sector in the USA between 1825 and 1922 (Dobbin and Dowd, 1997). Their key findings are shown in table 39:

Impact Factor / Policy Framework	Anti-Trust Policies	Pro-Cartel Policies
Founding Rate	Reduced	Increased
Failure Rate	Increased	Decreased
Market Competition	Increased	Decreased
Market Concentration	Increased	Decreased

Table 39 - Dobbin and Dowd's Policy Impact Findings

If the author extends Dobbin and Dowd's work, it could be argued that a model including tenure duration would be expected to show that anti-trust policies would shorten tenure whereas pro-cartel policies would increase tenure.

The research theory and hypotheses posited above suggests that it would be possible to assess the impact of energy policy by use of duration-based analysis of generators and power plants in the electricity generation industry, and specifically by reference to Dobbin and Dowd's (1997) research findings.

The application of the regression findings above in the context of the extended Dobbin and Dowd model is shown in table 40:

Policy	Class	Variable Description	Action	Duration of Tenure Expected	Magnitude
MCM	Regulatory	Pricing - Pricing Total	Pro-Cartel	Increased	27.75
PC	Obligations	Planning and Development Total	Anti-Trust	Reduced	-14.01
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	-259.38
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	-102.67
		Millions of Tonnes of CO2 Equivalent	Pro-Cartel	Increased	80.06
		Net CO2 emissions (emissions minus removals)	Pro-Cartel	Increased	809.18
	Obligations	Electricity Generators Total	Pro-Cartel	Increased	4.34
SOS	GIS	Grant - Research Grant	Anti-Trust	Reduced	91.98

Table 40 - Generator Tenure Magnitude of Impact (Individual Instrument)

This is interesting because it shows that Dobbin and Dowd's model does not hold for tenure. This may be because they have correctly recognised that tenure is not a valid measure of organisational dynamics or that other factors are at work.

Looking at the differences from what would be expected it could be seen that the emissions categories that do not follow the model relate to Methane and Nitrous Oxide. These are whole economy measures i.e. UK total outputs and for this reason they do not reflect the generators' own outputs. Further, it could be argued that Research Grants are not usually paid to generators, but to Universities and Research institutes and for this reason this is also not a valid measure in terms of Dobbin and Dowd's model, albeit that there is a statistical relationship with tenure. However, statistical significance does not always mean causation.

Despite the above, the results have shown that the theory and hypotheses have been all been confirmed. The results also show the distribution of policy objectives and instruments on generator tenure in the industry, and if one understands that a generator has a mean tenure of 11 years, it can be observed that the impact of energy policy is small and is likely to have little real bearing on the length of generator tenure when aggregated together.

9.6 GENERATOR AND POWER PLANT TENURE SUMMARY

In summary, this chapter presented the results from the policy instrument and objectives related to generator and power plant duration of tenure analysis. Specifically, it examined the impact of energy policy instruments and energy policy objectives on the time duration that individual generators and their power plants were present in the electricity generation business and the duration of time that power plants produced electricity. The information was structured under the headings of data and variables used, research context, model specifications, results and supplemented this with a discussion of what the results showed.

In concluding this research, once again it must be recognised that although a twenty-year analysis period was used, the actual number of uncensored events was small and that when looking at power plant lifespans some of the intended statistical analyses could not be undertaken. Despite these limitations, the research and analysis has confirmed that duration of tenure can applied to policy analysis in a manner that broadly concurs with Dobbin and Dowd's research (when the valid measures are evaluated).

In terms of the opportunities for further research, one extension of this work is to consider the effects of energy policy on the management and organisation of the electricity generators at a lower level of detail. This would make use of the corporate demography of electricity generators that occurs during the tenure of one owner. I.e. this would consider the impact of corporate vital events that occur whilst a company is under the same ownership structure but recognise that events such corporate actions, dividends, actions affecting shareholding, restructuring, change of name etc. would be studied. This might show the impact of government policy on the corporate actions undertaken by a company i.e. did the company pay more in dividends when certain policies were undertaken.

Finally, whilst most organisational ecologists only adopt the traditional founding, growth and failure rate measures this research has identified that there is another toolset and approach that is worthy of use in analysing population based events.

10. MARKET COMPETITION IN THE EGI

10 MARKET COMPETITION

The chapter presents the analysis of market competition within the EGI under the following headings: Market competition relevant research literature, market competition data and variables, market competition research context, market competition model specification, market competition results, market competition discussion, and market competition summary.

As will be observed, this is the third research method that seeks to understand how energy policy has affected the level of competition within the EGI since the industry's privatisation in 1991. There are many different academic disciplines and techniques used to measure competition, and the contrast between these has been the subject of discussion in earlier chapters. However, in-line with the focus on the use of organisational ecology techniques and methods to underpin this research, it was decided to use William P. Barnett's framework and method as presented in his 'Red Queen Amongst Organisations' text (Barnett, 2008). This text outlines the research techniques used to investigate how competition operated, at the county level, in the Illinois banking industry 1900 – 1993, and the Computer manufacturing industry relating to mainframe, midrange computer and microcomputers in the USA 1951 – 1994.

Application of the techniques and methods, outlined by Barnett, has resonance with the EGI study because the electricity industry has also exhibited both regulatory and technological change factors. Specifically, Barnett's research had the benefit of a long-range dataset spanning 93 years in the banking research and 43 years in the computer industry.

However, the dataset used in the EGI study has been restricted to the period between 1991 and 2011, reflecting the period when the industry returned to the private sector. Before this time, the EGI was controlled, operated and managed by the CEGB as a government controlled entity.

The chapter structure is relevant research, data and variables, research context, model specification, results, discussion and conclusion.

10.1 MARKET COMPETITION RELEVANT RESEARCH LITERATURE

Within the organisational ecology literature, arguably the most relevant research to the assessment of competition is Barnett's text 'Red Queen Amongst Organisations – How Competition Evolves' (Barnett, 2008). The story is based upon Lewis Carroll's book 'Through the Looking Glass' wherein the Red Queen remarks to Alice:

> 'In this place it takes all the running you can do, (just) to keep in the same place.'
>
> 'Running the Red Queen went so fast that Alice had trouble to keep up with her ….Curiously, however fast they went, they never seemed to pass anything... 'Here it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!'

Building upon this story, Leigh Van Valen: proposed a "A New Evolutionary Law", (Van-Valen, 1973) as an explanatory tangent to the 'Law of extinction'. His "Law of Extinction" identified the apparent constant probability (as opposed to rate) of extinction observed in families of related organisms. Barnett's research used data compiled from the then current literature relating to fossil record data. Van Valen proposed his Red Queen's Hypothesis (1973), as an explanatory tangent to the Law of Extinction. His Red Queen's hypothesis captured the idea that there is a 'constant arms race between co-evolving species to out compete one another (Van-Valen. 1973).

Van Valen's hypothesis makes reference to the Red Queen's race from the book entitled 'Alice Through the Looking Glass', (Carroll, 1872) in which the chess board moves in space such that Alice must continue running just to stay in the same place.

Barnett, used Van Valen's work to define how organisations compete and competitiveness evolves (Barnett, 2008). His book identifies how: 'Species improvement gives it selective advantage, variation yields an increase in fitness and co-evolving species means competitive advantage, and capturing a larger share of environmental resources. Increasing fitness in one evolutionary system leads to fitness decrease in another, and species that are involved in a competition maintain their fitness (relative to the others) by improving their design' (Barnett, 2008).

The key proposition is that as organisations encounter competition, they experiment to improve, but the competition also improves. This organisational learning resulting stops organisations from developing sustainable advantage by exhibiting the 'Red Queen of Evolution' phenomenon which proposes that organisations appear to 'stand still', as other organisations pull ahead, but this sows the seeds for their rival competitors' improvements. This results in the fact that the competitive advantage is repeatedly lost. The Red Queen theory suggests that 'competitiveness is not a property of markets (as most management theories suggest), but varies from organisation to organisation. If viability is used as a proxy for competition the key is that some organisations are more viable than others. This is called the Beta $\boldsymbol{\beta}$ effect, and it generates stronger competitive intensity, the Omega $\boldsymbol{\omega}$ effect' (Barnett, 2008), see figure 32:

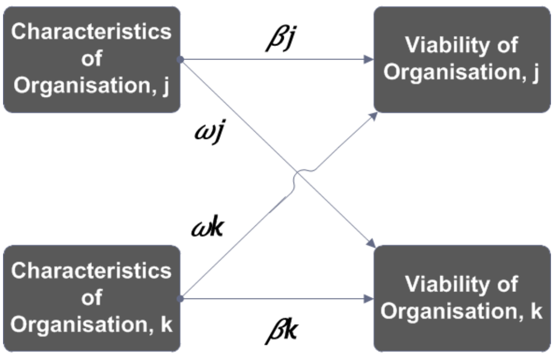

Figure 32 - Characteristics and Viability of Organisations

The key finding is that what it takes to win is defined by the Logics of Competition, (LoCs):

> **'A system of principles in a given context that determines who can compete, how they compete, on what criteria they succeed or fail, and what are the consequences of success or failure'.** Represented by: technology, organisational form, market environment, social & political, meta-competition among alternative logics, and Institutional logics (Barnett, 2008).

The theory of the Red Queen Amongst Organisations is summarised by the following statements: the LoCs vary over time and across contexts, alternative LoCs contend for prominence in a given context, organisations sometimes follow a logic of predation, organisations sample their LoCs by competing and alternative Logics of Competition contend for prominence in a given context.

The Red Queen model is specified by the following four elements. Firstly, Hysteretic Competition – (current-time effects of competing in the past). This involves two theories: the Competitive Hysteresis Hypothesis that states that 'Recent competition makes organisations more viable and generates stronger competition', and the Competency Trap Hypothesis that states that 'Distant history of competition makes organisations less viable and generates weaker competition'. The second factor is the spatial constraint, organisations forget the right lessons that involves the Costly Adaptation Hypothesis – 'An organisation's viability falls with the number of distinct historical rivals it has faced'. The third factor is constrained sampling which proposes that there is myopic learning in the Red Queen Evolution, where the Myopic Learning Hypothesis states that 'the greater the dispersion of historical exposure to competition, the more viable the organisation'. Lastly, the predation and the learning process gives rise to the costly predation hypothesis: 'An organisation's viability falls with the number of rivals it has acquired' (Barnett, 2008).

In terms of applying the Red Queen Amongst Organisations to a practical study, the key analysis required involves modelling organisational founding, failure and survival rates. Barnett's organisational viability model is presented thus:

$$\boldsymbol{v_j(t) = v_j(t)^* exp\left[aK_j + b_D T_{Dj} + b_R T_{Rj} + nN + c\sum_k T_k\right]}$$

Where:

$\boldsymbol{v_j(t)^*}$ = Baseline viability exponential

$\boldsymbol{aK_j} =$ Number of historical rivals faced

$\boldsymbol{b_D T_{Dj}}$ = Number of org.-years of rivalry * Distant competitive experience (organisation-years of rivalry)

$\boldsymbol{b_R T_{Rj}}$ = Recent competitive experience (organization-years of rivalry)

$\boldsymbol{nN}$ = Coefficient of probability * Density of organisational population

$\boldsymbol{c\sum_k T_k}$ = Effect historical exposure to competition on current-time strength * probability organisations compete * aggregate strength of competition generated against any given rival as a linear function of its history of having competed.

10.1.1 RED QUEEN MODEL OF COMPETITION

In common with much of the theory used by organisational ecologists, Barnett's work utilised Founding Rates and Failure Rates from industry vital event data and survival analysis techniques. The use of statistically based survival theory, unlike more typical linear regression techniques, is applicable where survey data is non-normally distributed and right censored. This is the case with the generators in the EGI, because many of the EGI generators existing ahead of privatisation remain active – albeit that the three major players at privatisation (British Energy, National Power and PowerGen) have morphed into members of the Big Six by virtue of takeovers by the utility companies based in continental Western Europe.

Looking in detail at the Red Queen model reveals two component models, one based on founding and the other based on failure rates. Each of these has seven sub models that can be used to investigate competition in an industry.

10.1.2 RED QUEEN MODEL EMBEDDED THEORY

The Red Queen Theory is predicated and underpinned by five hypotheses:

> 'The Competitive Hysteresis Hypothesis proposes that the Red Queen competition depends on the historical timing of experience in that: 'organisations with more exposure to a recent history of competition are more viable and generate stronger competition. The Competency Trap Hypothesis, proposes that if an organisation's Logics of Competition (LoC) change over time, as is likely, then its habits of responding to challenges with established routines becomes increasingly dysfunctional, despite the fact that these solutions were effective in the past, therefore organisations with more exposure to competition in the distant past are less viable and generate weaker competition. The third hypothesis, the Costly Adaptation Hypothesis, suggests that the process of responding to competition by searching and implementing changes in an organisations is costly - to develop and implement new products, services, and routines, as well as the costs involved in the process of change per se, such that if a given amount of historical competition, an organisation's viability falls with the number of distinct historical rivals it has faced. The Myopic Learning Hypothesis proposes that for learning to be adaptive, an organisation's accumulation from its lessons needs to be represented within the prevailing LoC. Myopia usually develops because the organisation's experience is too limited or restricted to provide organisations with unbiased lessons. Therefore, myopia can arise for a variety of reasons such as negative feedback, responding to recent problems or responding to limited competition, and the greater the dispersion of historical exposure to competition, the more viable the organisation. The last hypothesis, the Costly Predation Hypothesis – proposes that acquiring one's rivals carries harmful compositional and process effects, although this strategy also has clear benefits in terms of lessened competition and increased scale. Therefore by controlling for the current-time position of an organisation, an organisation's viability falls with the number of distinct historical rivals it has acquired' (Barnett, 2008).

10.1.3 RED QUEEN MODEL HIGH LEVEL CONSTRUCT

The high-level construct of the Red Queen model, prepared by the author is presented in figure 33:

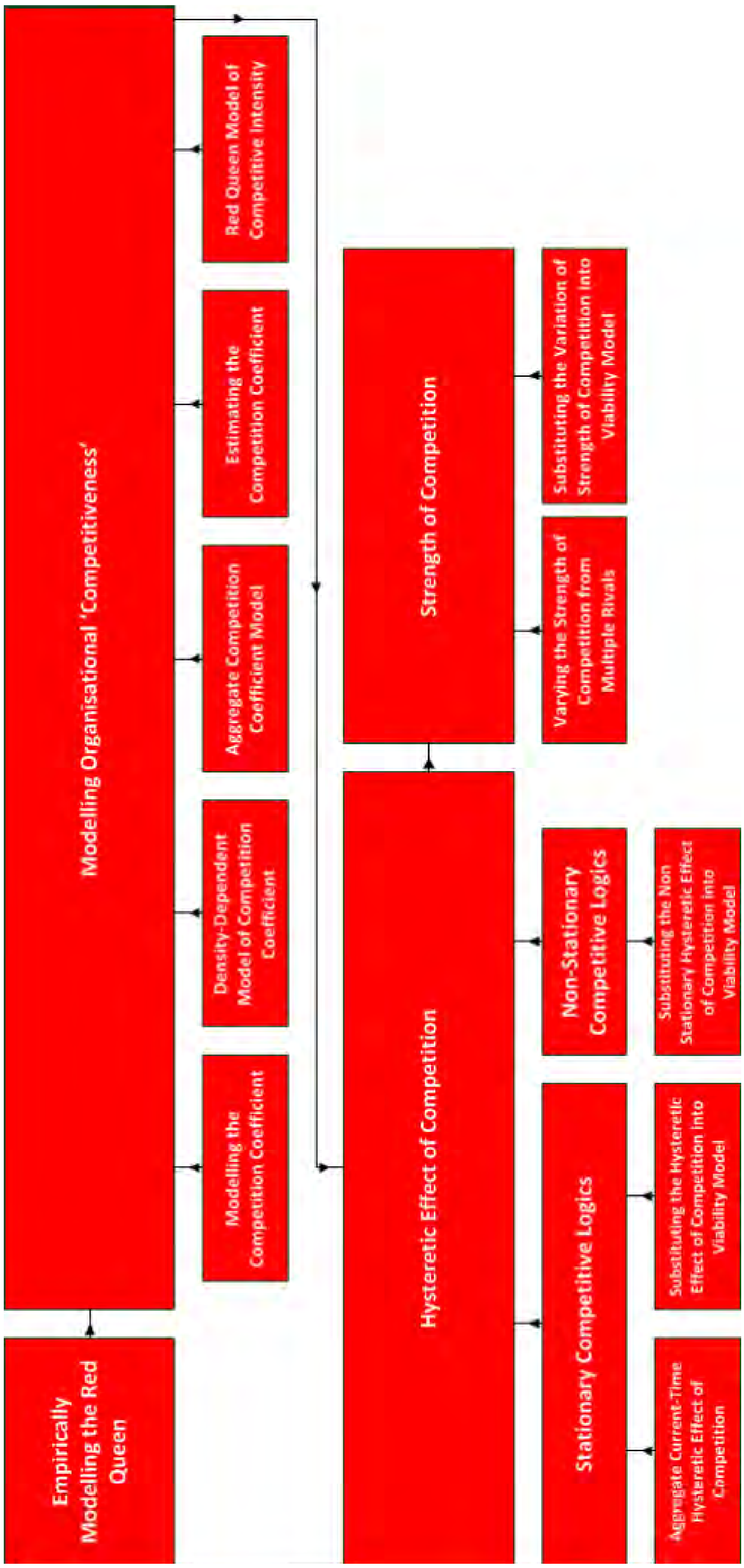

Figure 33 - Red Queen Model - High Level Construct

10.1.4 RED QUEEN MODEL DETAILED STRUCTURE

The Red Queen model, prepared by the author, is shown in figure 34:

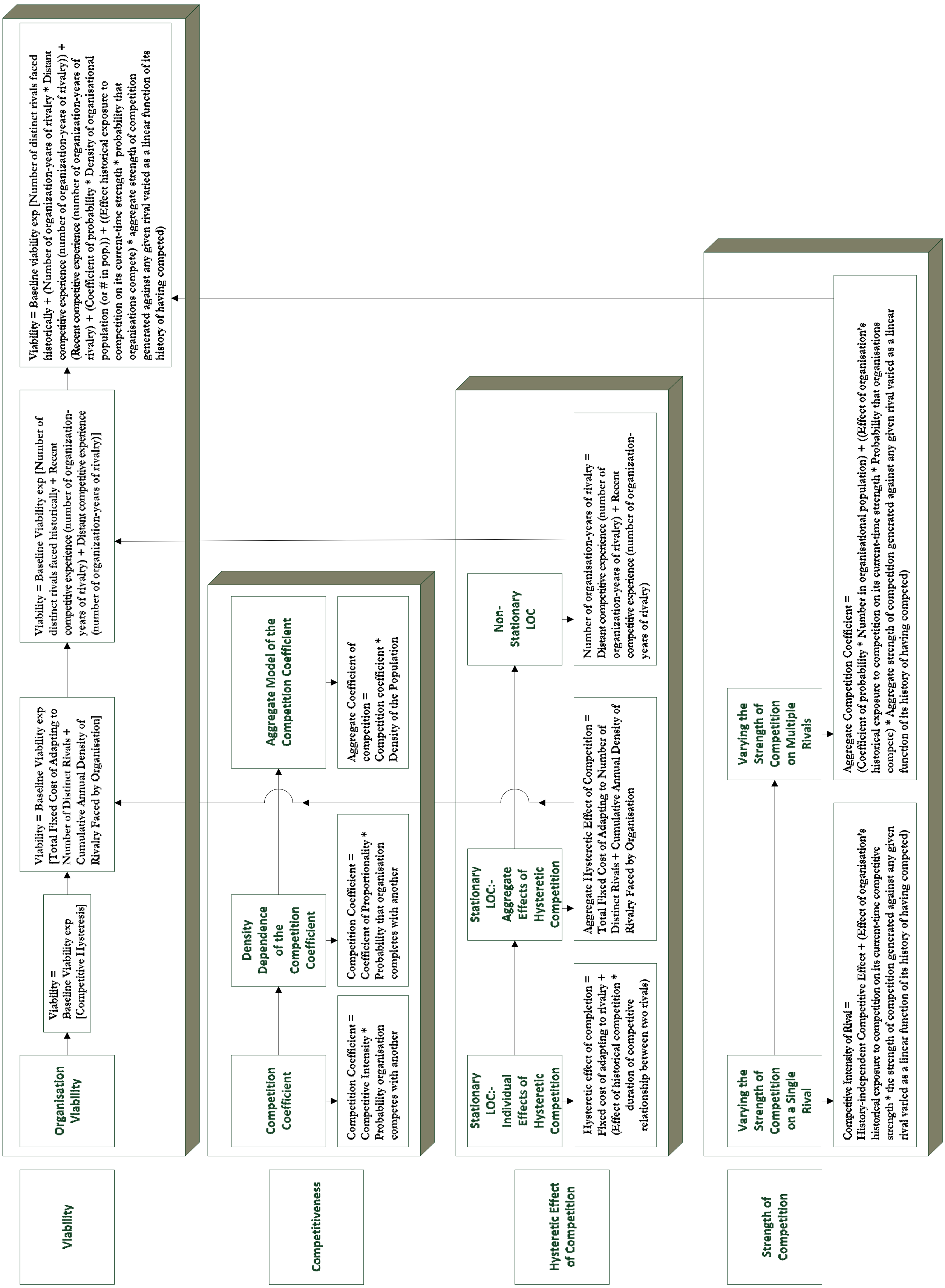

Figure 34 - The Detailed Red Queen Model

In a mathematical presentation, the detailed Red Queen model equation for organisational viability is:

$$\boldsymbol{v_j(t) = v_j(t)^{*}exp\left[aK_j + b_D T_{Dj} + b_R T_{Rj} + nN + c\sum_k T_k\right]}$$

In a narrative format this is can be expressed thus:

> **'Viability = Baseline viability exp [Number of distinct rivals faced historically + (Number of organisation-years of rivalry * Distant competitive experience (number of organisation-years of rivalry)) + (Recent competitive experience (number of organisation-years of rivalry) + (Coefficient of probability * Density of organisational population (or # in pop.)) + ((Effect historical exposure to competition on its current-time strength * probability that organisations compete) * aggregate strength of competition generated against any given rival varied as a linear function of its history of having competed)' (Barnett, 2008).**

As Red Queen theory implies, the strength of a rival's competition intensifies as it experiences historical competition, then estimates of the model will reveal that the constant C is greater than O[38].

Full details of the model are presented in 'The Red Queen among Organisations - How Competitiveness Evolves', Barnett, W. P. (2008), Princeton University Press.

10.1.4.1 RED QUEEN MODEL DATA AND VARIABLES

The models developed by Barnett have a common construction in terms of the data used. Obviously, a different set of data has been used for the electricity generator industry – for details see section 11.2 below - but the basic structure of the data will be similar, as far as this is possible:

Environmental effects of bank / generator viability - size, changes in size, and degree of urbanisation of the human population in a given locale

Broader Organisational context covers the density of – manufacturing, retail, wholesale, and farms enterprises in a bank's county, Wealth – average farm value in a bank's county and, Income – (indexed) wage per worker in a bank's county.

Banking Market Age effects – measured in years, starting with the date of founding of first bank in a given local

Ecological constructs amongst the banks covering: bank density in a given locale, population mass in local banking market (aggregate bank assets in a given locale – specified as a natural logarithm to allow for the greater effects of initial growth in the banking market. This allows for the competition to vary with

[38] Note, that under the null hypothesis, where: c = 0, competition is density dependent. In that case, competition depends only on the number of competitors N and so is homogeneous across rivals, varying only according to the probability that j encounters a given rival

the sizes of banks in a given local and Population Dynamics Theory on failure and founding rates – using the One-year lagged numbers of bank failures, foundings and acquisitions).

Founding Model Specifics: Presence of Competition indicator variable – to designate presence of competition (used for founding models to allow for difference in competition when first rival enters.

Failure Model Specifics: Legitimation Effect Theory - Presence of Organisational Monopoly – measured in terms of bank's local asset share (used or failure models to allow for organisational legitimisation by use of logarithmic nonlocal density), Density Delay Theory - density of existing banks at the time of organisation's birth, and size-dependence control – using a natural logarithm of each bank's assets in a given year. This was done using five-year panels and interpolating for the intervening years.

Piecewise Periods: Time Duration Periods - At the Organisation level - One, or Two-year for young organisations. Five-year intervals for intermediate aged organisations. Ten-year intervals for older organisations, and Calendar Periods were defined – to allow the effects of normative, legal and market changes occurring over the period of analysis i.e. the market waves such as Depression 1929-1932), Glass-Steagall (1933), End of bank regulation (1939), war (1940-1945), decade by decade effects for second half of century.

Hysteretic Effects of Recent and Past Competition – discounting the level of historical competition - using a discount factor of $1/(\surd\delta)$ where δ is the time from the present to the a given year in the past, before entering that year's rival into an organisation's competitive experience score. Distant-past rivalry is defined as the difference between total (organisation-years of) historical rivalry and recent- past-historical rivalry (The square root attenuates the speed of discounting).

The above highlights the comprehensiveness of the model, its complexity in terms of data collection and presentation. These events have parallels to the changes in policy experienced by electricity generators in the UK context over the period of the study.

10.2 MARKET COMPETITION DATA AND VARIABLES

The method adopted to test the hypotheses is to utilise the Red Queen Theory based Founding and Failure models to investigate how competitive forces have operated over the twenty-year period between 1991 and 2011 and the relevance and applicability of the Red Queen model to the EGI.

The model will utilise the dataset that has been used for the study. Specifically, the following:

The initial data collection process investigated the Power Station event history records for all the power plants operating in the UK, since the electricity industry was nationalised in 1954 to March 2011. This included ownership records, technology utilised to generate the electricity, and the fuels and locations of the stations. It collected data on: 570 Power stations (of which 134 were decommissioned before 1991), Two-hundred and fifty nine owners of one or more power stations – with 1966 vital (excluding the decommissioned plants) using 41 vital event classifications and a maximum of 33 data elements (This involved the collection and processing of circa 45,000 data elements), 87 counties across England, Northern Ireland, Scotland and Wales, which utilise: 48 fuel type permutations, 27 energy conversion technologies, and 8 primary fuel types.

The above in effect gives a life history record of the power stations that have operated in the UK since the EGI was nationalised in 1954, at the power station level. The data also records the ownership of each power station over this period. The data collection process took some six months to complete.

In addition to the data above, a series of records were also produced that showed the relationship between the commissioning operator and the subsequent ownership history. This information was collated to enable investigation of the Social Network relationships between players, which when coupled with the Power Purchase Agreements (PPA) will be utilised to investigate the impact of Structural Holes as proposed by (Burt, 1992). Given the lack of space in this thesis this analysis will be the subject matter for further research.

The Red Queen Theory required that the collected data be organised in a form of 'Owner by Year'. Whilst this is simple to write, the transformation process of reformatting and reshaping of the data took a further two months to collate and reshape. The resultant raw Generator based data produced 7,530 records with 22 data elements for the twenty-year period. This conversion process required programmatic transformation and data cleansing.

Once the data had been transformed into records that were ordered by year, owner, power station, and county these had to be reshaped into the structure required for the Red Queen model. This required the calculation of various parameters and subsets of the data to enable all of the detailed summaries and subsets of the data to be collated. This process took a further month to undertake so that the data had the correct structure and format for the model.

Additionally, because of the nature of the EGI (compared to the Banking sector) it was also necessary to utilise a different set of environment and broader contextual data.

For example, the parameters such as Population in locale / 1,000, Year change in population in local / 1,000, proportion of population urban in county, number of manufacturing establishments in county / 1,000, number of farms in county / 1,000, number of retail establishments in county / 1,000, number of wholesale establishments in county / 1,000, Indexed average value of farms in the county / 1,000 and Indexed wage per worker in county were not deemed to be relevant to the EGI study. These data elements were replaced with other macro-economic and industry relevant data.

These include data such as: Bank of England Base Rate of interest, crude oil price, domestic consumer price of electricity (pence per Kilo Watt Hour), US Dollar to Sterling exchange rate, industry commercial price of electricity (pence per KiloWatt Hour), Inflationary Deflator Index, and industry data such as: co-firing indicator, country power station is located in, county power station is located in, days of power station ownership by generator, years of power station ownership by generator, power station vital event number, fuel type used by power station, primary fuel type, renewable power station classification indicator, as set out in Table 93.

The results of the above were a set of twenty-four STATA Data sets that contained all of the required data results and interim transformations. In summary, the data contains a set of 70 variables as shown in table 41:

Type	Description	Independent Variable	Obs	Mean	Std. Dev.	Min	Max
Competitor Experience	Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)	comporgpast	7,529	111.08	152.62	0.08	775.37
	Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B)	comporgrcnt	7,529	29.48	36.63	0.02	169.20
	Subtract B from A	comporgdst	7,529	81.60	116.91	0.00	606.17
Corporate Events	Cox Cumulative Hazard of Acquisition	coxac	3,861	-0.26	0.00	-0.26	-0.26
	Cox Cumulative Hazard of Failure	coxfl	3,861	-0.31	0.00	-0.31	-0.31
	Cox Cumulative Hazard of Takeover	coxto	3,861	-0.11	0.00	-0.11	-0.11
	Number of other Generators operating at the birth of the new Generator in the county	fdothers	636	19.56	16.34	0.00	54.00
	Lagged number of acquisitions in locale	ngenaclg	854	1.36	0.95	1.00	7.00
	Lagged number of Generator Foundings in the County	ngenfdlg	375	10.26	10.83	1.00	29.00
	Lagged number of Generator Failures in the County	ngenfl	534	1.63	1.14	1.00	5.00
	Lagged number of Generator Takeovers in the County	ngentolg	147	9.32	9.66	1.00	25.00
EGI Capacity	Load Factor (Percentage of Power Station Utilisation across EGI)	lf	7,529	68.93	19.98	0.69	81.00
	Millions of Tonnes of Oil Equivalent (Energy Input used by EGI)	mtoe	7,529	81.17	4.12	73.36	87.73
	MW of Output Reported by EGI	mw	7,529	251.85	533.42	0.08	3,925.00
EGI Generation	MW Generation capacity in each county	mwcounty	7,529	499.17	879.35	0.10	7,630.00
	1 Year change in MW Generation capacity in each county	mwcounty1yr	7,529	5.54	298.66	-7,441.00	4,024.00
	Sum of MW Capacity by Generator by County	mwgen	7,529	3,903.36	5,696.93	0.10	23,716.00
	Share of MW capacity in County operated by Generator	mwpercent	7,500	0.56	6.10	0.00	262.75
	MW Produced by EGI (Total)	mwprod	7,529	59,568.31	4,177.17	51,663.00	70,192.00
	Indicator showing that No Other Generators are operating in the County - '0' is monopoly	nmloc	7,529	0.95	0.46	0.00	11.00
	Rival Generator Stations operating across all Counties (Number)	rgsoc	7,529	394.75	137.67	173.00	613.00
	Rival Generator Stations (minus stations owned by same Generator) operating in the same County	rvlstatsc	7,529	8.49	10.68	0.00	82.00
	Sum of number of Generator's Competitor org-years in each county since 31/3/1991	sumorgage	7,529	41.80	38.32	-1.00	168.00
	Cumulative sum of Generator Stations faced by incumbent Generator in each year since 31/3/1991	sumpstcomp	7,529	91.39	145.10	0.00	899.00
Generator Data	Generator Name and Number	asatnos	7,529	70.32	44.17	3.00	224.00
	Co-Firing Indicator - Power Plant Burns Biomass and Fossil Fuel	cofire	7,529	0.01	0.11	0.00	1.00
	Country Power Station is Located in	country	7,529	1.79	0.83	1.00	4.00
	County Power Station is Located in	county	7,529	43.06	22.72	1.00	88.00
	Days of Power Station Ownership by Generator	days	7,529	304.22	105.90	1.00	366.00
	Years of Power Station Ownership by Generator	duration	7,529	0.83	0.29	0.00	1.00
	Detailed Power Station Vital Event Number	evtdetnos	7,529	13.22	7.45	1.00	35.00
	Mid-Level Power Station Vital Event Number	evtgrtnos	7,529	2.46	0.88	1.00	6.00
	Summary Power Station Vital Event Number	evtsumnos	7,529	5.94	3.35	1.00	13.00
	Fuel Type and Number used by Power Station	fuelnos	7,529	31.74	14.21	1.00	48.00
	Primary Fuel Type and Number	primnos	7,529	6.03	2.24	1.00	8.00
	Renewable Power Station Classification Indicator	reind	7,529	0.71	0.45	0.00	1.00
	Sequence Number of Generator Data	seq	7,529	2.99	1.55	1.00	12.00
	Power station number	statnos	7,529	295.30	162.19	1.00	583.00
	Average Temperature in Year	technos	7,529	16.99	7.58	1.00	27.00
	Year of Generator Activity	year	7,529	2,003.13	5.95	1,991.00	2,011.00
Gini - Competitor	Gini of all Generator org-years (use comporgdst)	compgini	7,529	0.71			
Gini - Individual	Gini of Generator's competitors org-years (use indorgdst)	indgini	7,529	0.68			
Individual Generator Experience	Sum total number of the individual generator's org-years in each County since 31/3/1991 (D)	indorgpast	7,529	74.48	125.85	0.00	771.21
	Total individual generator's org-years /square root of # of years in each County counted since 31/3/1991 (E)	indorgrcnt	7,529	18.72	28.99	0.00	168.29
	Subtract E from D	indorgdst	7,529	55.76	97.13	0.00	602.92
Log-Likelihood Ratio	Log Likelihood Ratio of Failure with No Covariates	loglikefl	7,529	-29.56	-29.56	-29.56	-29.56
Log-Likelihood Ratio	Log Likelihood Ratio of Founding with No Covariates	loglikefd	7,529	-3.92	-3.92	-3.92	-3.92
Macro	Bank of England Base Rate of Interest	boe	7,529	4.96	2.90	0.50	13.88
	Crude Oil Price	cop	7,529	62.82	38.80	16.35	143.95
	Domestic Consumer Price of Electricity (Pence per Kilo Watt Hour)	dcp	7,529	9.63	2.59	6.99	13.89
	US Dollar to Sterling Exchange Rate	exch	7,529	1.79	0.18	1.50	2.11
	Industry Commercial Price of Electricity (Pence per Kilo Watt Hour)	icp	7,529	5.56	1.91	3.35	8.61
	Inflationary Deflator Index	idf	7,529	0.96	0.07	0.82	1.04
Organisation Data	Sum of number of Generator Station org-years in each county since 31/3/1991	gabc	7,529	111.08	152.62	0.08	775.37
Organisation Data	Total Generator Stations operating in the same County	gssc	7,529	14.00	15.20	1.00	83.00
Policy	Generator Acquisitions and Mergers period	acqmer	5,749	1.00	0.00	1.00	1.00
	Emission Management by Regulator period	emismgt	7,529	1.00	0.00	1.00	1.00
	Government Ownership period	govdivest	1,116	1.00	0.00	1.00	1.00

Type	Description	Independent Variable	Obs	Mean	Std. Dev.	Min	Max
	Price Control and Management period	pricemgt	3,132	1.00	0.00	1.00	1.00
	Regional Electricity Company Monopoly period	recmonop	2,144	1.00	0.00	1.00	1.00
	Technology Management by Regulator period	techmgt	6,637	1.00	0.00	1.00	1.00
Right Censor	Right Censoring Indicator	rc	7,529	0.94	0.25	0.00	1.00
Technology	Waste Power Stations were Commissioned Indicator (1 indicates being built during period)	waste	5,388	1.00	0.00	1.00	1.00
	Hydro Electric Power Stations were Commissioned Indicator (1 indicates being built during period)	water	6,948	1.00	0.00	1.00	1.00
	Offshore Wind Farms were Commissioned Indicator (1 indicates being built during period)	windoff	5,969	1.00	0.00	1.00	1.00
	Onshore Wind Farms were Commissioned Indicator (1 indicates being built during period)	windon	6,948	1.00	0.00	1.00	1.00

Table 41 - Variables Used for the Analysis

It is important to note that for the EGI dataset there were only 375 Founding events over the 20 year period (of which 307 were right censored), and 534 failure events over the 20 year period (of which 383 were right censored). The implication of this being that the 'actual' dataset that could be used had a small number of observations. This is one of the major limitations with this technique when power plants and generators make long-term commitments to the industry.

The original conception was to adopt the Red Queen model 'as is', excepting that the environmental and broader context data would be replaced with information that was more pertinent to the EGI. Following the Red Queen model processing developed by Barnett, and utilising the Piecewise Constant Exponential model. The initial idea was to be able to use covariates as a mechanism to allow modelling of the public energy policy and technological change data:

> Policy Waves – split into year based observations based on: emission management by regulator period indicator, generator acquisitions and mergers period indicator, government ownership period indicator, price control and management period indicator, regional electricity company monopoly period, and technology management by regulator period indicator.
>
> Technology Waves – also split into year based observations based on: hydroelectric power stations were commissioned indicator, offshore wind farms were commissioned indicator, onshore wind farms were commissioned indicator, and waste power stations were commissioned indicator.

However, in practice it proved impossible to use most policy and technology covariates because of the 'insufficient data' warning, or 'collinearity' being evident between the covariates, when using STATA's Stpiece command.

10.3 MARKET COMPETITION RESEARCH CONTEXT

The Research Question in the context of market competition – Does the Red Queen among Organisations apply to the EGI and if so, in what ways?

Market Competition Research Theory - the government's policy interventions have increased the level of 'market competition' being exhibited by the EGI as evidenced by analysis of the generators' viability:

The supporting sub theories being investigated are:

'Hysteretic Competition – (Current-Time Effects of Competing in the past):-

- Competitive Hysteresis Sub Theory - Recent competition makes organisations more viable and generates stronger competition
- Competency Trap Sub Theory - Distant history of competition makes organisations less viable and generates weaker competition

Spatial Constraint (Organisations forget the right lessons):-

- Costly Adaptation Sub Theory - An organisation's viability falls with the number of distinct historical rivals it has faced

Constrained Sampling: Myopic Learning in Red Queen Evolution:-

- Myopic Learning Sub Theory: The greater the dispersion of historical exposure to competition, the more viable the organisation.

Predation and the Learning Process:-

- Costly Predation Sub Theory: An organisation's viability falls with the number rivals it has acquired' Barnett (2008).

There are two sets of hypotheses relating to market competition, those relating to generator founding rates and the other relating to generator failure rates:

Hypotheses using generator-founding rates:

The Costly Predation theory is valid within the EGI, and shows that the founding rate viability of a generator decreases in relation to the number of distinct historical rivals that are faced, when controlling for the current-time position of an organisation (see founding models 1 and 2)

The Competitive Hysteresis and Competency Trap theories are valid in the EGI, and show that founding rate for generators that have a history of more recent competition are more viable and generate stronger competition when disaggregated into recent and distant-past competitive experience (see founding model 3)

The Myopic Learning theory is valid in the EGI, and shows that founding rate generators are more viable when they have a greater dispersion of historical exposure to competition, when disaggregated into the inequality of density between competitors, the size of the founding cohorts, the density of competitors & the size of rival founding cohorts, and the age of the competitor (see founding models 4 thru 7)

All founding models test the Costly Predation Theory.

Hypotheses using generator failure rates:

The Costly Adaption theory is valid within the EGI, and shows that for a given amount of historical competition an organisation's failure rate viability falls with the number of distinct rivals it has faced, when disaggregated into the past competitive experience faced by the generator, and the past competitive & number of past competitors faced by an organisation (see failure models 1 and 2)

The Competency Trap theory is valid in the EGI, and shows that generators with more exposure to competition in the distant past are less viable and generate weaker competition, when disaggregated into the generator's recent-past competitive experience, the generator's distant-past competitive experience, the generator's recent-past competitive experience & recent-past competitive experience faced by competitors, and the generator's distant-past competitive experience & recent-past competitive experience faced by competitors (see failure models 3 thru 6)

The Myopic Learning theory is valid and shows that generators with a greater dispersion of historical experience to competition have a greater viability, when viewed from the perspective of inequality of the distribution of past-rivalry faced by the generator, the inequality of the distribution of cohorts of rivals, and the rivalry faced by the generator's competitors (see failure model 7).

10.4 MARKET COMPETITION MODEL SPECIFICATION

The detailed model specifications used for the hypotheses testing are based on a series of founding and a failure rate models.

10.4.1 FOUNDING MODEL STRUCTURE

The relationship of the data to the underlying hypotheses as proposed by Barnett, but summarised by the author, is shown in table 42:

<table>
<tr><th>Model</th><th>Founding1</th><th>Founding2</th><th>Founding3</th><th>Founding4</th><th>Founding5</th><th>Founding6</th><th>Founding7</th></tr>
<tr><td>Synopsis</td><td>Baseline Model, Inc. Control and Duration effects</td><td>Sum of Org-Years of rivalry faced historically by incumbent organisations alive in a given year</td><td>To test Competitive Hysteresis Hypothesis and Competency Trap Hypothesis - disaggregate into two terms 1) for recent competitive experience and 2) for distant-past competitive experience</td><td>To test average Gini coefficients measuring the degree of inequality of the historical competition faced - past rivalry</td><td>To test average Gini coefficients measuring the degree of inequality of the historical competition faced - past rivalry cohorts</td><td>To test average Gini coefficients measuring the degree of inequality of the historical competition faced - past rivalry and past cohorts</td><td>Re-estimate of the full model (F6) to investigate the robustness of this model to a specification that includes the aggregate ages of incumbents. This specification can reveal whether competitive intensity increases with age, regardless of the organisation's competitive experience</td></tr>
<tr><td>Purpose</td><td></td><td></td><td></td><td>Measures the inequality of the density of competitors over time</td><td>Measures the inequality of the sizes of rival founding cohorts over time</td><td>Measures the inequality of the sizes of the density of competitors and the sizes of rival founding cohorts over time</td><td></td></tr>
<tr><td>Hypotheses Utilised</td><td>Baseline Model – Control and Duration effects</td><td>Org-Years of rivalry historically faced</td><td>Competitive Hysteresis and Competency Trap Sub Theories</td><td colspan="4">Myopic Learning Sub Theory</td></tr>
<tr><td colspan="8">Costly Predation Sub Theory - All models include the cumulative hazard of takeover, as of a given year in a given locale</td></tr>
</table>

Table 42 - Founding Rate Sub Model Structure

A more in-depth analysis show that for the founding model structure was:

All models - include the cumulative hazard of generator takeover (as of a given year in a given locale).

They test the Costly Predation Hypothesis:

Founding Model 1 - Baseline Model, including Control and Duration effects.

Founding Model 2- Sum of Org-Years of rivalry faced historically by incumbent generators alive in a given year.

Competitive Hysteresis and Competency Trap Sub Theory:

Founding Model 3 - Tests the Competitive Hysteresis Hypothesis and Competency Trap Hypothesis - disaggregated into two terms: for recent competitive experience, and for distant-past competitive experience.

Myopic Learning Sub Theories:

Founding Model 4 - Uses the average Gini coefficients to measure the degree of inequality of the historical competition faced - past rivalry, and measures the inequality of the density of competitors over time.

Founding Model 5 - Uses the average Gini coefficients to measure the degree of inequality of the historical competition faced - past rivalry cohorts, and measures the inequality of different sizes of rival founding cohorts over time.

Founding Model 6 - Uses the average Gini coefficients to measure the degree of inequality of the historical competition faced - past rivalry and past cohorts, and measures the inequality of the sizes of the density of competitors and the sizes of rival founding cohorts over time.

Founding Model 7 - Re-estimates of the Founding Model 6, to investigate the robustness of this model to include the aggregate ages of incumbents. This reveals whether competitive intensity increases with age, regardless of the organisation's competitive experience.

In specific terms, the founding models are differentiated as shown in table 43:

Differentiating Elements / Data / Model Number	Min	Max	Mean	Std. Dev.	Founding 1	Founding 2	Founding 3	Founding 4	Founding 5	Founding 6	Founding 7
Sum of Past org-years of rivalry faced by incumbents (A)	X	X	X	X		X					
Sum of Recent-past org-years of rivalry faced by incumbents (B)	X	X	X	X			X	X	X	X	X
Sum of Distant-past org-years of rivalry faced by incumbents (A-B)	X	X	X	X			X	X	X	X	X
Inequality of past rivalry faced by incumbents (average Gini)	X	X	X	X				X		X	X
Inequality of past rivalry cohorts faced by incumbents (average Gini)	X	X	X	X					X	X	X
Sum of ages of incumbents											X
Age of local market	X	X	X	X							X

Table 43 - Founding Model Differentiation

Note: Excludes 21 Independent Variables common to all models.

10.4.2 FAILURE MODEL STRUCTURE

The relationship of the data to the underlying hypotheses is (prepared by the author) is presented in table 44:

Model	Failure 1	Failure 2	Failure 3	Failure 4	Failure 5	Failure 6	Failure 7
Synopsis	The base model and includes the past competitive experience and the number of past competitors faced by the organisation j over its history	Excludes the past competitive experience faced by the organisation j over its history	Disaggregates competitive experience into recent-past competitive experience faced by the organisation	Disaggregates competitive experience into distant-past competitive experience faced by the organisation	Disaggregates competitive experience into past competitive experience faced by j over its history, and the recent-past competitive experience faced by j's competitors	Fail5 disaggregates competitive experience into past competitive experience faced by j over its history, and the distant-past competitive experience faced by j's competitors	Fail7 includes two measures of the dispersion of each organisation's historical competition over time. One Gini coefficient measuring the inequality of the distribution over past years of the rivalry faced by j, and the other measuring the inequality of the distribution of cohorts of rivals). It also includes the rivalry faced by j's competitors
Hypotheses Utilised	Costly Adaption Sub Theory	Costly Adaption Sub Theory	Competency Trap Sub Theory				Myopic Learning Sub Theory

Table 44 - Failure Rate Sub Model Structure

A more in-depth analysis reveals the failure model structure (prepared by the author):

All models include the cumulative hazard of generator failure to date and the generator's cumulative hazard of acquiring its rivals, to test the Costly Predation Hypothesis:

Costly Adaption Sub Theory – using the competitive experience and the rival's competitive experience:

Failure Model 1- The base model and includes the past competitive experience and the number of past competitors faced by the organisation j over its history

Failure Model 2 – as model one but it excludes the number of distinct rivals faced by the organisation over its history, in order to test the Cost Adaption Hypothesis.

Competency Trap Sub Theory – Models 3 to 6 separate the various competitive experience effects according to the level of recent of experience, allowing for tests of Competency Trap Hypothesis:

Failure Model 3 - disaggregates competitive experience into recent-past competitive experience faced by the organisation

Failure Model 4 - disaggregates competitive experience into distant-past competitive experience faced by the organisation

Failure Model 5 - disaggregates competitive experience into past competitive experience faced by j over its history, and the recent-past competitive experience faced by j's competitors

Failure Model 6 - disaggregates competitive experience into past competitive experience faced by 'j' over its history, and the distant-past competitive experience faced by j's competitors.

Myopic Learning Sub Theory:

Failure Model 7 – includes the Fail7 includes the Gini coefficients measuring the inequality of an organisation's historical exposure to competition, relevant to the Myopic Learning Sub Theory. There are two measures of the dispersion of each organisation's historical competition over time:

One Gini coefficient measuring the inequality of the distribution over past years of the rivalry faced by j, and

The other measures the inequality of the distribution of cohorts of rivals. It also includes the rivalry faced by j's competitors.

In specific terms, the Failure models are differentiated[39] shown in table 45:

Differentiating Elements / Data / Model Number	Min	Max	Mean	Std. Dev.	Failure 1	Failure 2	Failure 3	Failure 4	Failure 5	Failure 6	Failure 7
Sum of Past rivalry faced by organisation (D)	X	X	X	X	X	X			X	X	X
Sum of Recent-past rivalry faced by organisation (E)	X	X	X	X			X				
Sum of Distant-past rivalry faced by organisation (D-E)	X	X	X	X				X			
Sum of Past rivalry organisations faced by organisation	X	X	X	X	X						
Inequality of past rivalry faced by organisation (Gini)	X	X	X	X							X
Inequality of past cohorts faced by organisation (Gini)	X	X	X	X							X
Sum of Past rivalry faced by organisation's competitors (A)	X	X	X	X	X	X	X	X			X
Sum of Recent-past rivalry faced by an organisation's competitors (B)	X	X	X	X					X		
Sum of Distant-past rivalry faced by an organisation's competitors (A-B)	X	X	X	X						X	

Table 45 - Failure Model Differentiation

As can be seen from the above, the Red Queen theory requires a significant amount of data collection and preparation before the statistical analysis can be undertaken.

The technique used to process and analyse this data is the Piecewise Constant Exponential Model.

10.4.3 PIECEWISE CONSTANT EXPONENTIAL MODEL

The Piecewise model is the most simple transition rate model used by researchers, and is widely applied in many research contexts for that reason.

The model assumes that the duration variable (for example, the period of time a generator is active in the UK EGI marketplace) can be described by an exponential distribution. Recall that an exponential distribution, unlike a linear regression, is applicable when the data has right censoring problems.

[39] Excludes 22 Independent Variables common to all models

'The exponential distribution allows the following to be described for the duration variable T:

$$f(t) = \alpha \exp(-\alpha t), \qquad where\ \alpha > 0$$

$$G(t) = \exp(-\alpha t)$$

$$r(t) = \alpha$$

Assuming a given origin state, the definition for the model for a transition to a destination state $k$can de defined:

$$r(t) \equiv r_t = \exp\left(\alpha_{k_0} + A_{k_1}\alpha_{k_1} + \cdots\right) = \exp(A_k\alpha_k)$$

Where $r_k$is the time –constant transition rate to the destination state k. The exit rate, defined as the rate of leaving the origin state to any of the possible destination states is:

$$r = \sum_{k \in D} r_k$$

Where Ddenotes the set of all possible destination states.

The survivor function for the duration in the original state can be described using the exit rate:

$$G(t) = exp\left(-\int_0^t r\, d\tau\right) = \exp(-rt)$$

The exponential model assumes that the transition rate $r_k(t)$ to a destination stake $k$can vary with different permutations of covariates, where the transition rate,$r_k(t) = r_k$, is constant throughout each duration. This means that the transition rate is not time dependent throughout each duration.

In terms of the practical application, the relationship between the transition rate and the vector covariates A_k is specified as a log-linear to ensure that the estimates of the transition rate cannot become negative. The coefficients for the unknown parameters α_k the observed covariates A_k are specific for each destination state k.

The covariate parameter specification also includes a constant terms, αk_0, which can be estimated in a model without any covariates being present.

The covariates in the vector A_k are assumed to be measured at the beginning of each episode and are assumed to be time constant.

The standard survivor function with (transition rate, r = 1) shows an exponential decay curve.

In general, the density function is obtained by multiplying the survivor function by the transition rate.' (Barnett, 2008)

10.5 MARKET COMPETITION RESULTS

Despite some of the limitations above, the EGI lends itself very well to investigation because at the moment of privatisation the market had no left censoring – in effect everyone commenced as a new business entity, albeit that in effect the major players (except the Independent Power Producers) were demerged from the CEGB. However, in statistical terms there was no problem of left censoring in the data.

10.5.1.1 The Founding Rate Model Variables Utilised

The variables used are shown in table 46:

Variable / Founding Model	1	2	3	4	5	6	7
Regression Used	stpiece	stpiece	stpiece	stpiece	stpiece	stpiece	stpiece
Indicator showing that No Other Generators are operating in the County - '0' is monopoly	nmloc	nmloc	nmloc	nmloc	nmloc	nmloc	nmloc
Number of other Generators operating at the birth of the new Generator in the county	fdothers	fdothers	fdothers	fdothers	fdothers	fdothers	fdothers
Total Generator Stations operating in the same County	gssc	gssc	gssc	gssc	gssc	gssc	gssc
Lagged number of Generator Foundings in the County	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd
Lagged number of Generator Failures in the County	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl
Lagged number of Generator Takeovers in the County	ngento	ngento	ngento	ngento	ngento	ngento	ngento
Locale will be replaced by County and value will be calculated by STATA	coxac	coxac	coxac	coxac	coxac	coxac	coxac
Sum of MW Capacity by Generator by County	mwgen	mwgen	mwgen	mwgen	mwgen	mwgen	mwgen
MW Generation capacity in each county	mwcounty	mwcounty	mwcounty	mwcounty	mwcounty	mwcounty	mwcounty
1 Year change in MW Generation capacity in each county	mwcounty1yr	mwcounty1yr	mwcounty1yr	mwcounty1yr	mwcounty1yr	mwcounty1yr	mwcounty1yr
Locale will be replaced by County and value will be calculated by STATA	coxfl	coxfl	coxfl	coxfl	coxfl	coxfl	coxfl
Locale will be replaced by County and value will be calculated by STATA	coxto	coxto	coxto	coxto	coxto	coxto	coxto
Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)		comporgpast					
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B)			comporgrcnt	comporgrcnt	comporgrcnt	comporgrcnt	comporgrcnt
Subtract B from A			comporgdst	comporgdst	comporgdst	comporgdst	comporgdst
Gini of all Generator org-years (use comporgdst)				compgini		compgini	compgini
Gini of Generator's competitors org-years (use indorgdst)					indgini	indgini	indgini
Sum of number of Generator’s Competitors org-years in each county since 31/3/1991							Sumpstcomp
Sum of number of Generator Station org-years in each county since 31/3/1991							sumorgage
Generator Acquisitions and Mergers period	acqmer	acqmer	acqmer	acqmer	acqmer	acqmer	acqme
Government Ownership period	govdivest	govdivest	govdivest	govdivest	govdivest	govdivest	govdivest
Technology Management by Regulator period	techmgt	techmgt	techmgt	techmgt	techmgt	techmgt	techmgt
Emission Management by Regulator period	emismgt	emismgt	emismgt	emismgt	emismgt	emismgt	emismgt
Price Control and Management period	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt
Regional Electricity Company Monopoly period	recmonop	recmonop	recmonop	recmonop	recmonop	recmonop	recmonop
Waste Power Stations were Commissioned Indicator	waste	waste	waste	waste	waste	waste	waste
Hydro Electric Power Stations were Commissioned Indicator	water	water	water	water	water	water	water
Onshore Wind Farms were Commissioned Indicator	windon	windon	windon	windon	windon	windon	windon
Offshore Wind Farms were Commissioned Indicator	windoff	windoff	windoff	windoff	windoff	windoff	windoff
Log Likelihood ratio of no covariate model	loglikefd	loglikefd	loglikefd	loglikefd	loglikefd	loglikefd	loglikefd
Bank of England Base Rate of Interest	boe	boe	boe	boe	boe	boe	boe
Crude Oil Price	cop	cop	cop	cop	cop	cop	cop
MW Produced by EGI (Total)	mwprod	mwprod	mwprod	mwprod	mwprod	mwprod	mwprod
Millions of Tonnes of Oil Equivalent (Energy Input used by EGI)	mtoe	mtoe	mtoe	mtoe	mtoe	mtoe	mtoe
Load Factor (Percentage of Power Station Utilisation across EGI)	lf	lf	lf	lf	lf	lf	lf
US Dollar to Sterling Exchange Rate	exch	exch	exch	exch	exch	exch	exch
Average Temperature in Year	temp	temp	temp	temp	temp	temp	temp
Inflationary Deflator Index	idf	idf	idf	idf	idf	idf	idf
Industry Commercial Price of Electricity (Pence per Kilo Watt Hour)	icp	icp	icp	icp	icp	icp	icp
Domestic Consumer Price of Electricity (Pence per Kilo Watt Hour)	dcp	dcp	dcp	dcp	dcp	dcp	dcp
Stpiece rules	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)

Table 46 - Parameters Used for Founding Rate Models

10.5.1.2 The Failure Model Variables Utilised

The variables used are shown in table 47:

Variable / Failure Model	1	2	3	4	5	6	7
Regression Used	stpiece	stpiece	stpiece	stpiece	stpiece	stpiece	stpiece
Number of other Generators operating at the birth of the new Generator in the county	fdothers	fdothers	fdothers	fdothers	fdothers	fdothers	fdothers
Lagged number of Generator Foundings in the County	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd	ngenfd
Lagged number of Generator Failures in the County	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl	ngenfl
Lagged number of Generator Takeovers in the County	ngento	ngento	ngento	ngento	ngento	ngento	ngento
Rival Generator Stations operating across all Counties	rgsoc	rgsoc	rgsoc	rgsoc	rgsoc	rgsoc	rgsoc
Rival Generator Stations (minus stations owned by same Generator) operating in the same County	rvlstatsc	rvlstatsc	rvlstatsc	rvlstatsc	rvlstatsc	rvlstatsc	rvlstatsc
Share of MW capacity in County operated by Generator	mwpercent	mwpercent	mwpercent	mwpercent	mwpercent	mwpercent	mwpercent
Sum of MW Capacity by Generator by County	mwgen	mwgen	mwgen	mwgen	mwgen	mwgen	mwgen
Locale will be replaced by County and value will be calculated by STATA	coxfl	coxfl	coxfl	coxfl	coxfl	coxfl	coxfl
Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)	comporgpast	comporgpast	comporgpast	comporgpast			comporgpast
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B)					comporgrcnt		
Subtract B from A						comporgdst	
Gini of all Generator org-years (use comporgdst)							compgini
Gini of Generator's competitors org-years (use indorgdst)							indgini
Sum of number of Generator Station org-years in each county since 31/3/1991	gabc	gabc	gabc	gabc	gabc	gabc	gabc
Sum total number of the individual generator's org-years in each County since 31/3/1991 (D)	indorgpast	indorgpast			indorgpast	indorgpast	indorgpast
Total individual generator's org-years /square root of # of years in each County counted since 31/3/1991 (E)			indorgrcnt				
Subtract E from D				indorgdst			
Cumulative sum of Generator Stations faced by incumbent Generator in each year since 31/3/1991	sumpstcomp						
Generator Acquisitions and Mergers period	acqmer	acqmer	acqmer	acqmer	acqmer	acqmer	acqmer
Government Ownership period	govdivest	govdivest	govdivest	govdivest	govdivest	govdivest	govdivest
Technology Management by Regulator period	techmgt	techmgt	techmgt	techmgt	techmgt	techmgt	techmgt
Emission Management by Regulator period	emismgt	emismgt	emismgt	emismgt	emismgt	emismgt	emismgt
Price Control and Management period	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt	pricemgt
Regional Electricity Company Monopoly period	recmonop	recmonop	recmonop	recmonop	recmonop	recmonop	recmonop
Waste Power Stations were Commissioned Indicator	waste	waste	waste	waste	waste	waste	waste
Hydro Electric Power Stations were Commissioned Indicator	water	water	water	water	water	water	water
Onshore Wind Farms were Commissioned Indicator	windon	windon	windon	windon	windon	windon	windon
Offshore Wind Farms were Commissioned Indicator	windoff	windoff	windoff	windoff	windoff	windoff	windoff
Log Likelihood ratio of no covariate model	loglikefl	loglikefl	loglikefl	loglikefl	loglikefl	loglikefl	loglikefl
Bank of England Base Rate of Interest	boe	boe	boe	boe	boe	boe	boe
Crude Oil Price	cop	cop	cop	cop	cop	cop	cop
MW Produced by EGI (Total)	mwprod	mwprod	mwprod	mwprod	mwprod	mwprod	mwprod
Millions of Tonnes of Oil Equivalent (Energy Input used by EGI)	mtoe	mtoe	mtoe	mtoe	mtoe	mtoe	mtoe
Load Factor (Percentage of Power Station Utilisation across EGI)	lf	lf	lf	lf	lf	lf	lf
US Dollar to Sterling Exchange Rate	exch	exch	exch	exch	exch	exch	exch
Average Temperature in Year	temp	temp	temp	temp	temp	temp	temp
Inflationary Deflator Index	idf	idf	idf	idf	idf	idf	idf
Industry Commercial Price of Electricity (Pence per Kilo Watt Hour)	icp	icp	icp	icp	icp	icp	icp
Domestic Consumer Price of Electricity (Pence per Kilo Watt Hour)	dcp	dcp	dcp	dcp	dcp	dcp	dcp
Stpiece rules	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)	(0(30)366)

Table 47 - Parameters Used for Failure Rate Models

10.5.2 TABULAR PRESENTATION OF THE MODEL RESULTS

The Red Queen model has been applied to the EGI over the period from 1991 to 2011, and shows:

10.5.2.1 Founding Model Results

The results from the founding models are show in table 48:

Variable / Founding Model	1	2	3	4	5	6	7
tp1	-4.880*	-5.336	-7.333**	-43.72	-45.37	-49.72	-64.12*
	(2.871)	(3.378)	(3.576)	(30.04)	(30.63)	(32.35)	(37.11)
tp2	-5.172*	-5.705	-7.490**	-43.71	-45.34	-49.62	-64.05*
	(2.890)	(3.562)	(3.702)	(29.91)	(30.49)	(32.19)	(36.98)
tp3	-5.724*	-6.209*	-8.330**	-44.30	-45.93	-50.32	-64.40*
	(3.011)	(3.553)	(3.767)	(29.69)	(30.28)	(32.03)	(36.69)
tp4	-5.825**	-6.345*	-8.319**	-44.43	-46.07	-50.40	-64.70*
	(2.879)	(3.526)	(3.715)	(29.82)	(30.41)	(32.12)	(36.86)
tp5	-5.689*	-6.132*	-8.184**	-44.26	-45.89	-50.19	-64.70*
	(3.140)	(3.588)	(3.807)	(29.81)	(30.40)	(32.10)	(36.95)
tp7	-1.893	-2.343	-5.141	-42.09	-43.50	-45.90	-61.88
	(3.888)	(4.256)	(4.556)	(30.50)	(30.88)	(31.95)	(37.84)
tp8	-3.340	-3.820	-6.003	-42.18	-43.83	-48.20	-62.76*
	(3.108)	(3.631)	(3.828)	(29.89)	(30.48)	(32.21)	(37.14)
tp9	-4.270	-4.789	-6.847*	-43.07	-44.72	-49.13	-63.59*
	(3.076)	(3.691)	(3.862)	(29.92)	(30.51)	(32.27)	(37.11)
tp10	-4.028	-4.507	-6.421*	-42.47	-44.10	-48.38	-62.57*
	(3.006)	(3.538)	(3.699)	(29.77)	(30.35)	(32.04)	(36.77)
tp11	-4.010	-4.521	-6.436*	-42.86	-44.52	-48.97	-63.41*
	(3.162)	(3.741)	(3.860)	(30.07)	(30.66)	(32.45)	(37.22)
tp12	-4.518	-5.010	-6.795*	-43.16	-44.82	-49.30	-63.69*
	(3.130)	(3.680)	(3.804)	(30.03)	(30.63)	(32.42)	(37.17)
tp13	-4.252	-4.697	-6.795*	-43.14	-44.78	-49.14	-63.53*
	(2.921)	(3.402)	(3.644)	(30.03)	(30.62)	(32.34)	(37.10)
Total Generator Stations operating in the same County	0.00924	0.0329	-0.156	-0.198	-0.210	-0.294	-0.181
	(0.0217)	(0.0947)	(0.160)	(0.156)	(0.158)	(0.216)	(0.250)
Lagged number of Generator Failures in the County	-0.0166	-0.00311	0.0229	0.0348	0.0353	0.0376	0.0404
	(0.0379)	(0.0645)	(0.0652)	(0.0685)	(0.0686)	(0.0686)	(0.0713)
Sum of MW Capacity by Generator by County	1.56e-05	1.72e-05	1.96e-05	1.44e-05	1.41e-05	1.34e-05	1.35e-05
	(2.27e-05)	(2.36e-05)	(2.38e-05)	(2.40e-05)	(2.40e-05)	(2.39e-05)	(2.39e-05)
1 Year change in MW Generation capacity in each county	0.000742	0.000689	0.000348	-0.000343	-0.000187	0.00117	-0.000413
	(0.000974)	(0.000990)	(0.000983)	(0.00111)	(0.00106)	(0.00270)	(0.00324)
Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)		-0.00228					
		(0.00887)					
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B			0.202	0.157	0.166	0.252	
			(0.143)	(0.136)	(0.133)	(0.204)	
Sum of Distant-past org-years of rivalry faced by incumbents (A-B)			-0.0442	-0.0268	-0.0284	-0.0449	-0.131
			(0.0304)	(0.0323)	(0.0315)	(0.0433)	(0.312)
MW Produced by EGI (Total)	4.70e-05	5.41e-05	9.10e-05	0.000387	0.000435	0.000745	0.000613
	(5.41e-05)	(6.07e-05)	(6.44e-05)	(0.000246)	(0.000279)	(0.000631)	(0.000637)
Gini of all Generator org-years (use comporgdst)				31.68		-254.0	24.88
				(26.33)		(462.3)	(557.6)
Gini of Generator's competitors org-years (use indorgdst)					32.03	281.3	20.93
					(25.97)	(454.4)	(538.2)
Sum of number of Generator's Competitor org-years in each county since 31/3/1991							-0.0178
							(0.0211)
Sum of number of Generator Station org-years in each county since 31/3/1991							0.117
							(0.256)
Model Parameters and Output Summary							
Observations	50	50	50	50	50	50	50
Subjects	26	26	26	26	26	26	26
Failures	50	50	50	50	50	50	50
Time at risk	433	433	433	433	433	433	433
Log likelihood	115.94307	115.95283	116.69577	117.0321	117.16261	117.66729	117.91341
Chi2	198.46	198.40	198.81	198.05	198.17	198.84	198.38
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Note: tp=30 months, tp6 dropped due to collinearity and mwcounty also dropped.

Table 48 - Founding Model Results[40]

[40] Note: the 'tp' variables represent the control variables.

10.5.2.2 Failure Model Results

Variable / Failure Model	1	2	3	4	5	6	7
tp1	-9.555	-9.641	-7.408	-10.50	-10.72	-10.72	99.86
	(15.48)	(15.40)	(15.29)	(15.47)	(15.73)	(15.73)	(195.9)
tp2	-9.676	-9.765	-7.507	-10.62	-10.84	-10.84	99.92
	(15.61)	(15.51)	(15.40)	(15.59)	(15.84)	(15.84)	(195.9)
tp3	-9.939	-10.02	-7.797	-10.88	-11.10	-11.10	99.67
	(15.60)	(15.52)	(15.41)	(15.60)	(15.84)	(15.84)	(196.0)
tp4	-10.05	-10.13	-7.917	-10.98	-11.19	-11.19	99.67
	(15.65)	(15.56)	(15.45)	(15.64)	(15.88)	(15.88)	(196.0)
tp5	-7.474	-7.561	-5.356	-8.416	-8.634	-8.634	102.2
	(15.71)	(15.62)	(15.51)	(15.69)	(15.94)	(15.94)	(196.0)
tp6	-9.906	-9.995	-7.819	-10.84	-11.05	-11.05	99.64
	(15.38)	(15.29)	(15.19)	(15.37)	(15.61)	(15.61)	(196.0)
tp7	-7.560	-7.645	-5.407	-8.509	-8.727	-8.727	102.0
	(15.44)	(15.36)	(15.25)	(15.43)	(15.69)	(15.69)	(196.0)
tp8	-7.176	-7.264	-5.076	-8.095	-8.307	-8.307	102.5
	(15.64)	(15.55)	(15.44)	(15.63)	(15.86)	(15.86)	(196.0)
tp9	-8.205	-8.291	-6.061	-9.148	-9.365	-9.365	101.4
	(15.63)	(15.54)	(15.43)	(15.62)	(15.86)	(15.86)	(195.7)
tp10	-8.626	-8.715	-6.486	-9.566	-9.780	-9.780	101.0
	(15.59)	(15.50)	(15.39)	(15.58)	(15.82)	(15.82)	(196.0)
tp11	-8.552	-8.640	-6.369	-9.502	-9.716	-9.716	101.1
	(15.60)	(15.51)	(15.39)	(15.59)	(15.83)	(15.83)	(196.0)
tp12	-8.319	-8.407	-6.232	-9.240	-9.452	-9.452	101.1
	(15.48)	(15.39)	(15.28)	(15.46)	(15.70)	(15.70)	(195.8)
tp13	-8.022	-8.109	-5.790	-8.967	-9.177	-9.177	101.6
	(15.54)	(15.45)	(15.33)	(15.53)	(15.78)	(15.78)	(196.0)
Lagged number of Generator Failures in the County	0.0807	0.0797	0.110	0.0893	0.0958	0.0958	0.0478
	(0.170)	(0.169)	(0.174)	(0.164)	(0.175)	(0.175)	(0.173)
Rival Generator Stations operating across all Counties	0.00252	0.00264	-0.00107	0.00396	0.00421	0.00421	-0.0683
	(0.0171)	(0.0170)	(0.0167)	(0.0171)	(0.0176)	(0.0176)	(0.0708)
Rival Generator Stations (minus stations owned by same Generator) operating in the same County	0.0349	0.0367	0.0339	0.0331	0.0317	0.0317	-0.0379
	(0.0580)	(0.0467)	(0.0486)	(0.0460)	(0.0491)	(0.0491)	(0.0819)
Share of MW capacity in County operated by Generator	-0.0788	-0.0794	-0.0808	-0.0752	-0.0743	-0.0743	-0.0469
	(0.389)	(0.388)	(0.387)	(0.388)	(0.388)	(0.388)	(0.392)
Sum of MW Capacity by Generator by County	2.41e-05	2.41e-05	2.72e-05	2.43e-05	2.44e-05	2.44e-05	2.86e-05
	(2.42e-05)	(2.42e-05)	(2.43e-05)	(2.41e-05)	(2.42e-05)	(2.42e-05)	(2.52e-05)
Sum of number of Generator Station org-years in each county since 31/3/1991 (A)	0.00580	0.00591	0.00142	0.00629	0.00275	0.0163	0.00252
	(0.00706)	(0.00677)	(0.00624)	(0.00666)	(0.0113)	(0.0306)	(0.00787)
Total individual generator's org-years /square root of # of years in each County counted since 31/3/1991 (B)			-0.0151				
			(0.0262)				
Sum of distant-past rivalry faced by organisation's competitors (A-B)						-0.0136	
						(0.0388)	
Gini of all Generator org-years (use comporgdst)							-1,833
							(2,168)
Gini of Generator's competitors org-years (use indorgdst)							1,844
							(2,403)
Sum total number of the individual generator's org-years in each County since 31/3/1991 (D)	-0.0100	-0.00838			-0.00817	-0.00817	-0.00452
	(0.0317)	(0.00663)			(0.00665)	(0.00665)	(0.00762)
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (E)					0.0136		
					(0.0388)		
Sum of distant-past rivalry faced by organisation (D-E)				-0.0112			
				(0.00830)			
Cumulative sum of Generator Stations faced by incumbent Generator in each year since 31/3/1991	0.00168						
	(0.0314)						
Bank of England Base Rate of Interest	-0.308	-0.310	-0.299	-0.309	-0.310	-0.310	-0.239
	(0.237)	(0.232)	(0.231)	(0.232)	(0.232)	(0.232)	(1.609)
Crude Oil Price	-0.00470	-0.00483	0.00309	-0.00758	-0.00805	-0.00805	0.0664
	(0.0407)	(0.0406)	(0.0402)	(0.0409)	(0.0417)	(0.0417)	(0.0697)
MW Produced by EGI (Total)	-0.000110	-0.000113	-5.79e-05	-0.000130	-0.000133	-0.000133	0.00205
	(0.000308)	(0.000304)	(0.000300)	(0.000306)	(0.000310)	(0.000310)	(0.00202)
Millions of Tonnes of Oil Equivalent (Energy Input used by EGI)	0.0966	0.0976	0.0779	0.104	0.105	0.105	-0.304
	(0.143)	(0.142)	(0.141)	(0.143)	(0.144)	(0.144)	(0.512)
Load Factor (Percentage of Power Station Utilisation across EGI)	0.0797	0.0815	0.0417	0.0948	0.0978	0.0978	-1.293
	(0.239)	(0.237)	(0.234)	(0.238)	(0.242)	(0.242)	(1.164)
	Model Parameters and Output Summary						
Observations	130	130	130	130	130	130	130
Subjects	32	32	32	32	32	32	32
Failures	130	130	130	130	130	130	130
Time at risk	1425	1425	1425	1425	1425	1425	1425
Log likelihood	261.82633	261.8249	261.3086	261.92727	261.88498	261.88498	261.55263
Chi2	616.00	616.99	615.34	616.17	616.13	616.13	614.86
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Note tp=30 months.

Table 49 - Failure Model Results[41]

[41] Note: the 'tp' variables represent the control variables.

10.6 MARKET COMPETITION DISCUSSION

As can be seen from the above, on such a small set of observations (and more specifically giving rise to a small set of subject events) there is not much that can be done to address this, especially when one considers that the industry ‘life’ is short at twenty years.

10.6.1 FOUNDING RATE MODELS

There are seven founding rate models, each one builds incrementally into a full implementation of the Red Queen theory.

The first observation relating to the founding models is that none of the variables are statistical significant at either the 99%, 95% or 90% level. In part, this is related to the small number of observations (50 observations) and consequently wth the exception of Models 1 and 2 there are too many variables. I.e. with 50 observations, only seven variables should be used.

However, given that this is a replication study the results will be interpreted as if the model were valid. The detailed analysis of the models shows that for new founding generators (when using the mean level of impact), shown table 50:

Description / Mean Impact	Variable	1	2	3	4	5	6	7
Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)	comporgpast		-0.25					
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B)	comporgrcnt			5.95	4.63	4.89	7.43	0.00
Sum of distant-past rivalry faced by organisation’s competitors (A-B)	comporgdst			-3.61	-2.19	-2.32	-3.66	-10.69
Gini of all Generator org-years (use comporgdst)	compgini				22.49		-180.34	17.66
Gini of Generator's competitors org-years (use indorgdst)	indgini					21.78	191.28	14.23
Sum of number of Generator's Competitor org-years in each county since 31/3/1991	sumpastcomp							Omit
Sum of number of Generator's Station org-years in each county since 31/3/1991	sumorgage							-0.74
Generic Parameters								
MW Produced by EGI (Total)	mwprod	2.80	3.22	5.42	23.05	25.91	44.38	36.52
Total Generator Stations operating in the same county	gssc	0.13	0.46	-2.18	-2.77	-2.94	-4.12	-2.53
Lagged number of Generator Foundings in the County	ngenfdlg	-6.23	-1.17	8.59	13.05	13.24	14.10	15.15
Sum of MW Capacity by Generator by County	mwgen	0.06	0.07	0.08	0.06	0.06	0.05	0.05
1 Year change in MW Generation capacity in each county	mwcounty1yr	Omit	Omit	Omit	Omit	Omit	Omit	Omit
Sum of number of Generator Station org-years in each county since 31/3/1991	gabc							13.00
Regression Results								
Observations		50	50	50	50	50	50	50
Subjects		26	26	26	26	26	26	26
Failures		50	50	50	50	50	50	50
Time at risk		433	433	433	433	433	433	433

Description / Mean Impact	Variable	1	2	3	4	5	6	7
Log likelihood		115.94307	115.95283	116.69577	117.0321	117.16261	117.66729	117.91341
Chi2		198.46	198.40	198.81	198.05	198.17	198.84	198.38
Prob > chi2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
INDUSTRY COMPETITIVE VIABILITY								
Summary of Mean Impact		**-3.23**	**2.33**	**14.25**	**58.32**	**60.62**	**69.13**	**82.64**

Table 50 - Aggregate Magnitude Impact of Red Queen Foundings

Interpreting these results indicates a number of interesting factors:

Model 1 the baseline model uses control effects and covariates including the number of generator stations operating in each county, the lagged number of new generator foundings, the current and 1-year past level of MW output in the county and the total output of all generators operating in the UK. This shows that the base level of competition (measured by competitive rivalry) was -3.23.

Model 2 – includes a term to assess to what extent organisational history (measured in organisational years) of rivalry for incumbent generators affects a new generator's prospects. This shows that the competitive rivalry (for competitors) was 2.33. This suggests that the level of competition for competitors was (2.33-3.23 = -0.9). This therefore shows that the level of competitive rivalry was slightly less for the competitors than for incumbent generators.

Model 3 – develops the model to include terms for recent competitive experience and distant past experience (comporggdst and comporgrcnt). Inclusion of these parameters suggests that competitive experience actually enhances the founding rate for new generators. This highlights that the level of distant past competitive rivalry was (14.25 – 3.23 = 11) and shows that the distant past competitive rivalry was higher. I.e. distant past competition was more pronounced.

Model 4 – builds upon model 3, by including a Gini term that determines the impact of the concentration of generator competition. The results show that level of organisational history faced by generators in the industry was (58.32 – 11 [M3] = 47.32). This suggests that competitive rivalry was higher because it was concentrated amongst fewer generators.

Model 5 – develops model 4 to include terms to allow for a Gini concentration term reflecting competition from the same generator. The results show that the level of competitive rivalry was (60.32 – 11 [M3] = 49.32). This illustrates that the level of competitive rivalry faced by other generators was slightly higher than that faced by individual generators.

Model 6 – includes all of the terms used of Model 3 thru model 5. This is used to shows how organisational experience (org-years and concentration of org-years) affect the competitive rivalry of the industry. The results show that when both factors are taken into account the level of competitive rivalry is (69.13 – 3.23 = 65.9). This indicates that competitive rivalry is significantly more intense when org-years of one's own concentration is taken into account.

Model 7 – is the full Red Queen model that includes a term to cover the impact of the aggregate age of the market (sumorgage) and the individual generator age within the county, as a refinement on Model 6. This shows that the level of competitive rivalry is (82.64 – 3.23 = 79.41). Therefore indicating that the level of competitive rivalry in the generation sector is significantly greater that was the case in the past.

Overall, the results suggest that the level of competitive rivalry is higher. This is made up from a small contribution from distant-past experience competitive concentration, a large amount from competitive concentration and a small contribution from an individual generator's own experience.

Obviously, these results suffer from a lack of statistical significance, but indicate an interesting series of findings. They also show that the level of competition faced by new generators in the industry is significantly higher than was the case in the past.

10.6.2 FAILURE RATE MODELS

The failure rate models are also suffer from the same statistical limitations (too few observations and too many variables within the model as a result of a short organisational history) as the founding models, with the results being shown in table 51:

Description / Mean Impact	Variable	1	2	3	4	5	6	7
Sum of number of Generator Station org-years in each county since 31/3/1991 (A)	comporgpast	Omit	Omit	Omit	Omit			Omit
Sum total competitor generator org-years Discounted (B)	comporgrcnt					0.40		
Subtract B from A	comporgdst						-1.11	0.00
Gini of Generator's competitors org-years (use indorgdst)	indgini							1253.92
Gini of all Generator org-years (use comporgdst)	compgini							-1301.43
Sum total number of the individual generator's org-years (D)	indorgpast	-0.74	-0.62			-0.61	-0.61	-0.34
Total individual generator's org-years /square root of # of years in each County counted since 31/3/1991 (E)	indorgrcnt			-0.28				
Subtract E from D	indorgdst				-0.62			
Cumulative sum of Generator Stations faced by incumbent Generator	sumpstcomp	0.15						
Generic Parameters								
Lagged number of Generator Foundings in the County	ngenfl	30.26	29.89	41.25	33.49	35.93	35.93	17.93
Rival Generator Stations operating across all Counties	rgsoc	0.99	1.04	-0.42	1.56	1.66	1.66	-26.96
Rival Generator Stations	rvlstatsc	0.30	0.31	0.29	0.28	0.27	0.27	-0.32
Share of MW capacity in County operated by Generator	mwpercent	-0.04	-0.04	-0.05	-0.04	-0.04	-0.04	-0.03
Sum of MW Capacity by Generator by County	mwgen	0.09	0.09	0.11	0.09	0.10	0.10	0.11
Sum of number of Generator Station org-years in each county since 31/3/1991	gabc	0.64	0.66	0.16	0.70	0.31	1.81	0.28
Bank of England Base Rate of Interest	boe	-1.53	-1.54	-1.48	-1.53	-1.54	-1.54	-1.19
Crude Oil Price	cop	-0.30	-0.30	0.19	-0.48	-0.51	-0.51	4.17
MW Produced by EGI (Total)	mwprod	-0.46	-0.47	-0.24	-0.54	-0.56	-0.56	8.56
Millions of Tonnes of Oil Equivalent (Energy Input used by EGI)	mtoe	7.84	7.92	6.32	8.44	8.52	8.52	-24.68
Load Factor (Percentage of Power Station Utilisation across EGI)	lf	5.49	5.62	2.87	6.53	6.74	6.74	-89.13
Regression Results								
Observations		130	130	130	130	130	130	130
Subjects		32	32	32	32	32	32	32
Failures		130	130	130	130	130	130	130
Time at risk		1425	1425	1425	1425	1425	1425	1425
Log likelihood		261.82633	261.8249	261.3086	261.92727	261.88498	261.88498	261.55263
Chi2		616.00	616.99	615.34	616.17	616.13	616.13	614.86
Prob > chi2		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
INDUSTRY COMPETITIVE VIABILITY								
Summary of Mean Impact		**42.71**	**42.55**	**48.72**	**47.88**	**50.67**	**50.67**	**-159.09**

Table 51 - Aggregate Magnitude Impact of Red Queen Failures

Model 1 - the baseline model uses control effects and covariates including the past generator org-years of experience, the summation of each individual generator's org-years of experience and the cumulative density of power plants faced by the individual generator companies. This shows that the base level of competition (measured by rivalry) was 42.71 for generator failures.

Model 2 – removes the density of power plants to show if there is any effect from density of production facilities (as opposed to org-years of experience). This shows that the net mean level of competition for competitors was (42.71 – 42.55 = 0.16), and shows that the level competitive rivalry was very slightly less for the competitors than incumbent generators. This indicates that a very small part of the competitive rivalry could be attributed to the number of power plants, but mostly it was due to the competitive experience of generators.

Model 3 – develops the model to analyse the effect of distant past org-years to explore whether or not the competitive rivalry was due to distant past experience. That the level of distant past competitive rivalry was (42.71 – 48.72 = -6.01) and shows that the distant past experience does give rise to a slightly lower level of competitive rivalry as suggested by Barnett.

Model 4 – builds upon model 3, by including a Gini term that determines the impact of recent and distant past org-years of generator competition. The results show that level of organisational rivalry faced by generators in the industry was (47.88 – 42.71) = 5.17). This suggests that competitive rivalry was slightly higher in the recent past.

Model 5 – develops a model to reflect the competition from both the current competition and individual generator. The results show that the level of competitive rivalry was (42.71 – 50.67 = -7.96). This illustrates that the level of current-time competitive rivalry faced by all failing generators was slightly lower than with the base case.

Model 6 – develops a model that looks at the effect of distant past competition of all generators versus the individual's competiveness in terms of current-time org-years. The results shows that taken into account the level of competitive rivalry is (42.71 – 50.67 = -7.96). This indicates that historical and current-time competitive rivalry is less intense and is no higher historically than the case in the recent time for failing generators.

Model 7 – is the full Red Queen model that includes competitive concentration of org-years of generator experience and the individual generator's own org-years. This shows that the level of competitive rivalry was (42.71 - 159.09 = -116.38). Therefore indicating that the level of competitive rivalry in the generation sector is significantly reduced for those generators exiting the market.

Overall, this shows that the level of competitive rivalry for failing generators was slightly higher for newer generators and for those with distant-past experience. It was slightly higher for those with recent and current time experience, although when both factors were taken jointly into the level of competition. Finally, the effect of all parameters in the model was that the generation market was significantly less than the base case. This is because the level of a lower Gini concentration of the all generator org-years i.e. the concentration org-years of experience for failing generators is reducing and the number of years of generator experience is reducing. Clearly, this shows reduced tenure in the industry than was the base case.

Obviously, these results suffer from a lack of statistical significance, but indicate an interesting series of findings. They also show that the level of competition faced by new generators in the industry is significantly higher than was the case in the past.

In concluding the discussion on the failure rate models it can be also seen that the Red Queen theory and the practice within the EGI is broadly confirmed, and despite the small sample size, and the difficulties of being able to include the public policy and technology change information, the model has shown itself to be remarkably robust. In making this assessment, one must once again be mindful of the fact that the number of founding occurring within the EGI over the period (1991-2011) was a limitation and although the coefficients were all valid at a 99% confidence level, the standard error terms were not significant at the 90% confidence level. This suggests that from a statistical validation perspective the results are unfortunately not conclusive, and therefore must be questioned even though the model has been observed to work.

10.7 MARKET COMPETITION SUMMARY

The chapter has presented the results from the analysis of market competition by consideration of relevant research literature, data and variables, research context, model specification, results and discussion.

The theories proposed were that the government's policy interventions have increased the level of 'market competition' being exhibited by the EGI. The sub theories being assessed are:

- The Competitive Hysteresis sub theory: organisations with more exposure to a recent history of competition are more viable and generate stronger competition
- Competency Trap sub theory: organisations with more exposure to competition in the distant past are less viable and generate weaker competition
- Costly Adaptation sub theory: for a given amount of historical competition, an organisation's viability falls with the number of distinct historical rivals it has faced
- Myopic Learning sub theory: the greater the dispersion of historical exposure to competition, the more viable the organisation
- Costly Predation sub theory: an organisation's viability falls with the number of rivals it has acquired.

As can be seen from the results above, the results broadly confirm that the competitive viability can be measured using Barnett's model and they suggest that each sub theory refines and develops the parametric framework to demonstrate a higher level of competitiveness.

The exception to this, in the context of the EGI relates, to the failing model. The results from the failing model showed that concentration factors, predominantly those relating to the 'all competitor Gini' indicate a lower level of competitiveness i.e. from the viewpoint of exiting companies. This suggests that the market has become more concentrated and less competitive overall. In Carroll's formulation this suggests that resource partitioning is operating or is about to do so.

The results from this analysis are also very heartening and show that Barnett's model can provide relevance and application even when the control variables are significantly different to those proposed in the original model.

11. MARKET CONCENTRATION IN THE EGI

11 MARKET CONCENTRATION

This chapter presents the market concentration analysis under the headings of market competition relevant research, resource partitioning in the EGI sector, market concentration data and variables, market concentration research context, market concentration model specification, market concentration results, market concentration discussion and market concentration summary.

The chapter represents the fourth and final research component and was designed to assess whether the choice of a generalist or a specialist strategy affects the life prospects (in terms of organisational survivability) of generators. More specifically, the key is to assess how the generators have responded to environmental changes related to energy policy and technology change over the period of the study. This will inform how the level of market concentration has changed and is an important component of the overall study. It complements the groups of theories and hypotheses previously discussed by understanding how energy policy may have changed the market structure operating within the EGI industry.

11.1 MARKET CONCENTRATION RELEVANT RESEARCH

The review of literature relating to organisational dynamic analysis outlines how the use of the resource partitioning theory fragment (Carroll, 1985a) could be adopted to understand market concentration in the EGI.

Before it is possible to develop the framework for the EGI it is necessary to consider how an extension to the niche width model to account for resource partitioning might be applicable to the EGI. The objective is to understand how partitioning impacts upon EGI companies. The resource-partitioning model developed by Carroll is premised upon two scenarios: concentrated and non-concentrated markets as illustrated by the figure 35 below (Carroll, 1985a).

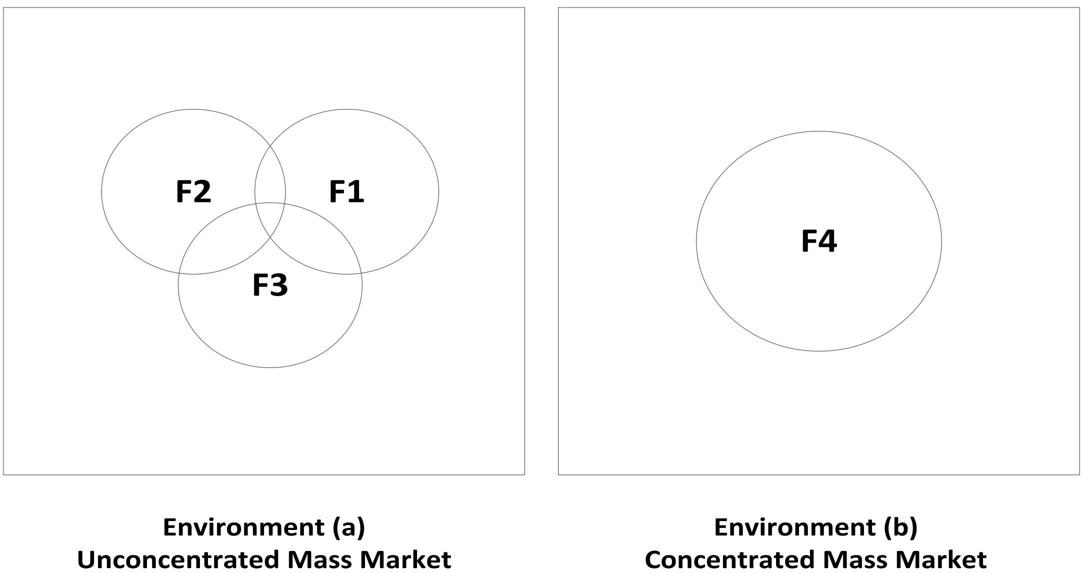

Figure 35 - Model of Ecological Resource Partitioning

> 'The diagram above illustrates two environments (A & B). The squares that bound each environment reflect the total resources (resource space) available to the organisations that exist in the environment. In the case of environment A, there are three different organisations (F1, F2, and F3), where the circles identify the resources used by the three organisations. The overlapped areas represent the areas wherein the organisations compete for the environment's resource pool. Environment B reflects a different situation in which the organisation F4 is the only organisation present, and which therefore has no competition for environmental resources. In both cases, it is assumed that the organisations are generalist organisations, as opposed to specialist producers.
>
> In environment B, the organisation assumes the position at the market centre and is able to grow to a size that is larger than would be the case in a competitive environment (environment A). Further, organisation F4 has been able to grow to a larger size (represented by the area of the resource space that it occupies), than is the case in a competitive market. However, the total area (resources) consumed by F1, F2 and F3 is larger than the resources consumed by F4.
>
> The model above also makes the assumption that the resource pool is homogeneous, which is clearly not the case in practice, and also suggests that economies of scale and economies of scope will enable organisations to grow to consume all available resources without constraint, which again in practice by virtue of consumer preferences and choice cannot be the case.
>
> The dominance of generalist organisations achieves equilibrium as long as the competitive processes are driven by the economies of scale. The dynamics of competition prior to the equilibrium state give rise to important insights into the organisational behaviour concerning the interplay between generalists and specialists.' Carroll, 1985a)

The resource-partitioning theorem proposes that the scale of resources used will be predicated upon consumer choice. Looking at how producers make their organisational choices brings the concept of what denominates a market. Carroll (1985) suggests that the common denominators are language and identity. If there is a common language and a common identity this would imply that generalism would prevail, and if not then specialism would arise.

The use of specialism would ensure that organisations were able to exploit their language and identity differences such that they could move to other parts of the resource space, and avoid the impact of the competition between them and other organisations. I.e. they would specialise so that they reduced the competition on shared and common resources.

Carroll's research identifies that not all markets are partitioned, and that for them to be so requires a number of theoretical conditions to be met. These are that organisations are not fully pliable because they cannot change their business strategies instantaneously or regularly, the strategy chosen by the organisation constrains the options and activities that are open to the organisation in future, the market contains finite resources that can be used, economies of scale exist in the activities that are undertaken by the organisation, that no real price competition occurs between the firms, the consumers in the market are homogeneous and that the exchange boundaries of the market are the basis for choosing the unit of analysis. The key limitation on the ability of existing generalists to become specialists is their organisational inertia. Therefore, the key factors underpinning market development are language, identity and inertia.

Carroll further proposes that the impact of resource partitioning is that markets in equilibrium appear as though the generalists and specialist organisations operate in entirely different resource spaces. Differentiation is a consequence of prior competition over the same resources (this can also be seen in less concentrated markets where generalist organisations make direct appeals to specialist organisations). The consequence of this is that by the time competition reaches equilibrium the generalist and specialists have achieved a symbiotic relationship, in as much as initially they relied upon the same resources but at equilibrium they rely on different resources because of the existence of resource-partitioning. This means that while previously the fates of the generalists and specialist organisations were inversely related to one-another, they are now directly related to each other.

In summary, the resource-partitioning model predicts that increased competition enhances the life chances of specialist producers or service providers. This implies that a decline in the density of generalists does not represent a decline in the total number of organisations operating in the market, instead the overall outcome depends on the size of the increases in the population of specialist organisations.

11.1.1 RESOURCE PARTITIONING THEORY

Having outlined the background to resource partitioning it is necessary to understand its development and operation in detail as a prerequisite to the evaluation of how market participants in the EGI have responded to the policy initiatives of various governments. This theory exposition will consider two theories, resource partitioning lifecycle, and resource partitioning in practice.

The heart of this debate is Sutton's (1991) observation that 'Many technological, political, cultural and class-based theories have been offered to explain concentration in markets, but most cannot explain the emergence of small specialist organisations in certain highly concentrated industries like airlines, banking, film production and the utilities'. Indeed, most deny the possibility of such developments (Boone et al., 2002b).

11.1.1.1 The Two Theories

There are two key theories pertaining to how market players operate in a resource space. The first is the concept of Niche Width that seeks to address the ideas about how generalist and specialist producers act in a market. This is attributed to Hannan and Freeman's 1977 paper entitled 'The Population Ecology of Organisations' (Hannan and Freeman, 1977). It posits that 'The principle of isomorphism implies that social organisations in equilibrium will exhibit structural features that are specialized to salient features of the resource environment.' The concept of 'niche' was initially borrowed from biologists and the early work by sociologists such as Whittaker and Levin (1976), who define a Fundamental Niche as the permutations of resource levels at which a population can survive and reproduce itself. Hannan and Freeman refine this concept to describe a Realised Niche of a population, which is defined as that area in constraint space (the space whose dimensions are levels of resources, etc.) in which the population outcompetes all other local populations. The difference between the Fundamental niche (theoretical space that populations can occupy) and the Realised niche (the actual space that is occupied by a population) is therefore crucially significant. The use of the term niche implies the concept of organisational fitness and the range of positions that are spanned by the organisation (Hannan and Freeman, 1977) as shown in figure 36:

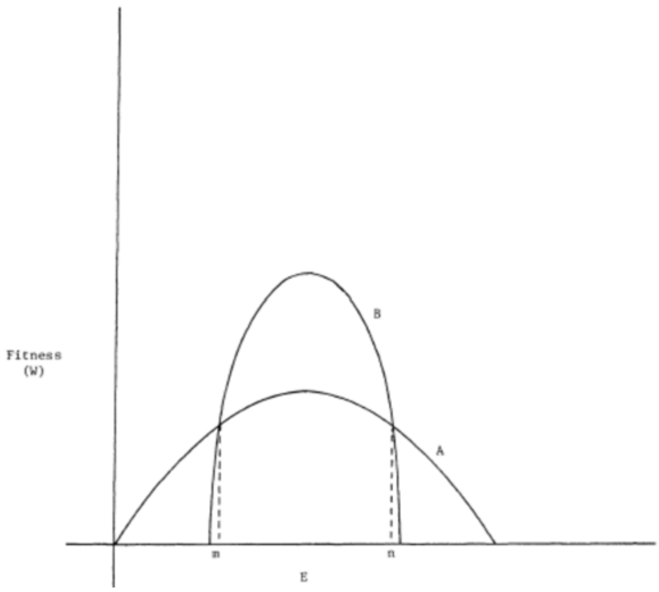

Figure 36 - Fitness Function (Niches) for Generalists and Specialists

The diagram above shows that organisation A is a generalist that operates using a wide range of environmental resources (E), whereas organisation B operates as a specialist that has a higher degree of fitness (W) but utilises a narrow range of the environmental resources. 'In essence, the distinction between specialism and generalism refers to whether a population of organisations flourishes because it maximizes its exploitation of the environment and accepts the risk of having that environment change or because it accepts a lower level of exploitation in return for greater security. Whether or not the equilibrium distribution of organizational forms is dominated by the specialist depends on the shape of the fitness sets and on properties of the environment' (Hannan and Freeman, 1977 p.20).

The concepts behind resource partitioning proposed by Carroll (1985) use insights about the economics of scale to make different predictions about niche width based upon the two trends of 'variety proliferation' (Jovanovic, 2001) and the three stage industry lifecycle of discovery, mass entry, and shakeout (Gort and Klepper, 1982). The theory of Resource Partitioning therefore explains how variety proliferation and the industry lifecycle can occur simultaneously within the same industry i.e. The Resource Partitioning theory 'views the two trends as fundamentally interrelated; it predicts that under certain conditions the resource space becomes partitioned into generalist and specialist segments' (Carroll, 1985a). This suggests that resource partitioning in a market is characterised by two components: the first is that generalists compete for the parts of the resource space that are occupied by the greatest number of consumers, as opposed to the specialists who occupy areas of the resource space that are narrow and have fewer consumers, and the second is the impact of concentration by generalists on the life chances of the specialist organisations (Boone et al., 2002b).

The theory of resource partitioning states that 'in markets with strong scale advantage, large organisations aim to maximise the demand for products and services by targeting the areas of the market with the greatest number of consumer resources. Given a particular distribution of resources in the market, such targeting leads generalists to produce products that are designed to appeal to many types of consumers' (Boone et al., 2002b p.2). Further, 'resource partitioning explains how in heavily concentrated populations specialist organisations arise and proliferate. It is argued that that the higher the homogeneity and concentration of relevant environmental resources, the higher the concentration of large generalist organisations competing on the basis of scale' (Boone et al., 2002b p.2).

11.1.2 RESOURCE PARTITIONING LIFECYLE

The resource-partitioning lifecycle has been developed by the author using Boone et al. (2002) as shown in figure 37:

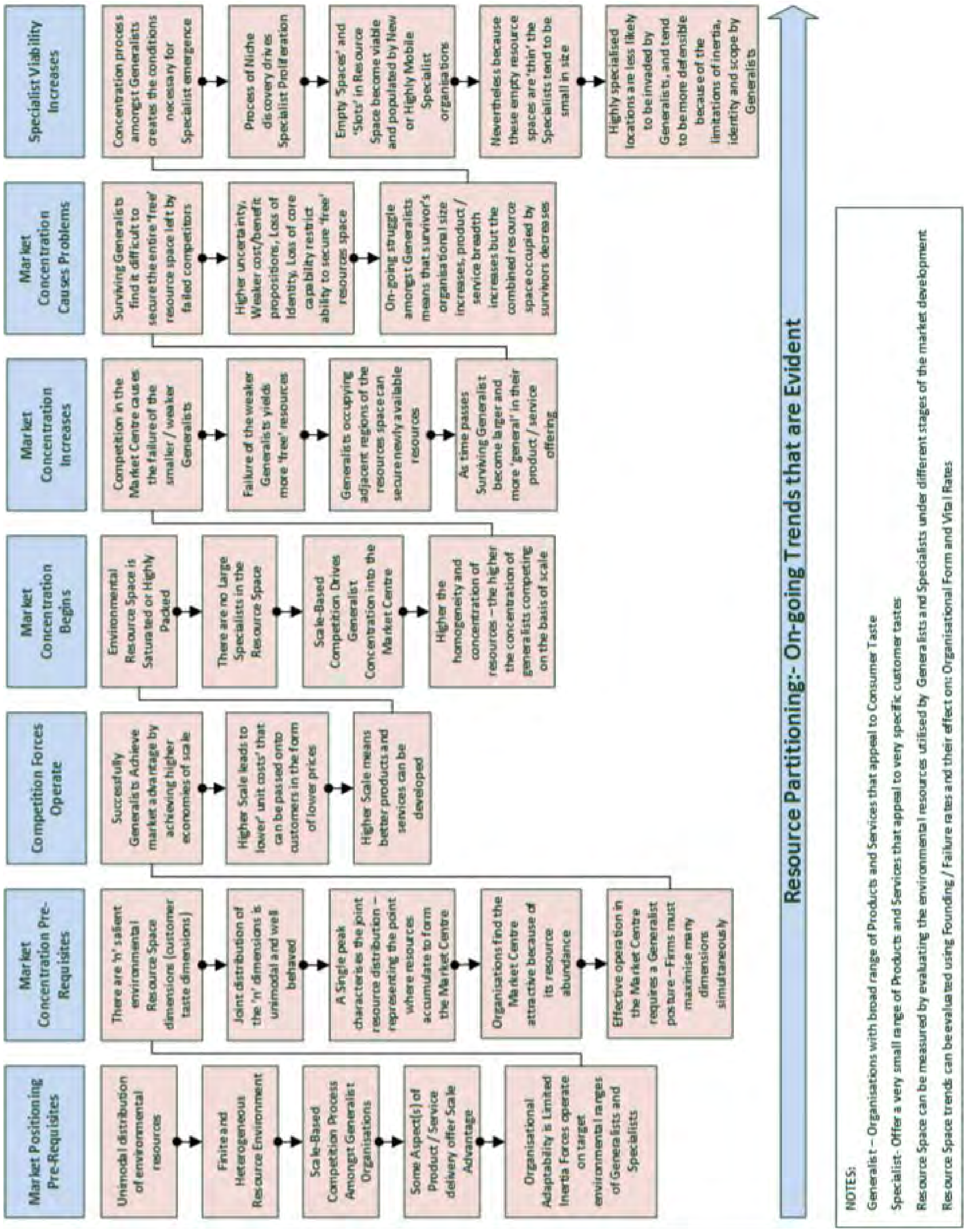

Figure 37 - Resource Partitioning Lifecycle

11.1.3 RESOURCE PARTITIONING IN PRACTICE

The theory synopsis presented above now needs to be translated into a practical realisation in order to understand what resource-partitioning means to the EGI. The literature search in this regard identifies two research papers that embrace the dynamic perspectives of organisational ecology using spatial and inter-temporal niche width theory and the industrial organisations' sunk cost theory, with a static organisational perspective from Michael Porter's generic strategies framework using the static equilibrium perspective (Witteloostuijn and Boone, 2006)

The practical realisation of resource partitioning will be discussed by consideration of: economy-based approach, market strategy, market structure, product focus, and resource space profile.

In the economy-based approach, Witteloostuijn and Boone posit that that there are three different permutations of economy. The first is when scale-based economic factors dominate as exhibited by industries where there are high fixed setup costs, low advertising rates, and research & development intensity as per Carroll's 1985 resource partitioning theory. The second is when scope-based economic factors dominate where there are relatively low fixed setup costs, relatively high advertising rates, and / or research & development intensity as per the Suttonian theory. The third is the combination of scale and scope-based economic factors both existing in organisational populations (Witteloostuijn and Boone, 2006). The relationship between these is shown in table 52:

Economy Type	Market Participant Role	Causal Factor	Result
Scale-based Economies dominate	Concentration amongst generalists	Enhances	Performance of specialists who adopt a differentiation strategy
	Large-scale single-product generalists (with broad positions near the resource peak) with a low-cost strategy, and specialists (narrowly focused positions in the market periphery) with a differentiation strategy	Experience	Better performance than specialists whose niches and strategy overlap with generalist organisations
Scope-based Economies dominate	Concentration amongst generalists	Enhances	Performance of specialists with a low-cost strategy
	Large-scale multi-product generalists with a differentiation strategy, and specialists with a low-cost strategy	Experience	Better performance than specialist whose niches and strategy overlap with generalist organisations
Scale and Scope-based economies dominate	Concentration amongst generalists	Enhances	Concentration among generalists enhances the performance of both specialists with a low-cost strategy and those with a differentiation strategy
	Large scale multi-product generalists with a differentiation strategy, and specialists with a low-cost or differentiation strategy	Experience	Better performance than specialists whose niches and strategy overlap with generalist organisations

Table 52 - Economy and Strategy Contrasts

Applying the above to the EGI, one it would be expect to find that scale economies dominate because of the very high upfront capital cost of electricity generation equipment, installation, set-up, planning and licensing. This is the case for both the traditional and renewables generators, who have major capital outlays to receive a figure of between £50-£100 per MWhour of output (DECC, 2010) over a period of 25-40 years of plant life. To retain greater flexibility it is probably wise to assume that generators might be able to adopt scale & scope economies.

The second is the market strategy / competitive approach, wherein Witteloostuijn and Boone extend Porter's work to highlight the relationship between the economy, organisational strategy and product range. This approach reconciles the use of a specialist or generalist strategy into Porter's two generic industry-wide strategies of differentiation and overall low cost leadership, and extends it to consider the product position adopted by specialist or generalist producers as shown in table 53[42]:

ECONOMY	STRATEGY		PRODUCTS	
	Low-Cost	Differentiation	Single	Multiple
Scale	Generalist	Specialist	Generalist	Specialist
Scope	Specialist	Generalist	Specialist	Generalist
Scale and Scope	Specialists	Generalist and Specialist	Specialist	Generalist / Specialist

Table 53 - Economy and Strategy Contrast Summary

Applying Witteloostuijn and Boone's theory to the EGI, it can be seen that the product adopted is electricity, albeit that 'green electricity' is available but at a low level of penetration, circa 1%. However, electricity generation also has a 'time of availability element' to its supply[43] and is therefore multi-product. This suggests that whether or not a scale, scope or scale & scope generator approach is utilised, generators can adopt either a single or multiple product outputs.

However, using knowledge of the economic approach, i.e. generators have high fixed setup costs, this must also imply that all generators are either scale-based single product low-cost generalists or multiple product-differentiated specialists. Alternatively, if they can use both scale & scope economies, they may act as single or multiple product specialists or multiple product generalists or specialists.

The third approach outlined by Witteloostuijn and Boone was to define market structure by means of the degree of market concentration and product density using economic theory as shown in table 54:

MARKET CONCENTRATION	PRODUCT DENSITY	
	High	Low
High	Dual Market Structure (Fringed Oligopoly)	Concentrated Market Structure (Pure Oligopoly)
Low	Fragmented Market Structure (Perfect Competition)	Uniform Market Structure (Monopolistic Competition)

Table 54 - Market Structure Classification

In this model, the dual market structure with a fringed oligopoly arises when there is a 'market centre with large dominant generalist firms that tolerate small-firm specialists at the market fringes', the concentrated market with a pure oligopoly arises as an oligopoly 'in which a limited number of firms strategically compete at the attention of the industry's demand side'. A fragmented market structure gives rise to perfect competition when 'many small firms are subject to auction-like processes that determine equilibrium

[42] See Competitive Strategy – Techniques for Analysing Industries and Competitors, Michael E. Porter, Free Press, 1980, p.30

[43] Electricity generation is classified as Peak Load that is met by combustion turbines, Intermediate Load typically met with CCGT plants, and Base Load that is met by coal fired and nuclear power plants.

quantities and prices at the market level'. A uniform market structure gives rise to monopolistic competition when 'a countable number of non-dominant firms differentiate their products in industries with quality and / or taste sensitive clients' (Witteloostuijn and Boone, 2006).

In terms of the EGI, which exhibits high levels of market concentration by the 'Big 6'[44], the above discussion and approaches one and two, suggests that a fringed oligopoly exists. This arises because there are large dominant single product low-cost generalists using multiple generation fuels, technologies and generating plants in multiple locations i.e. using scale economies, and also single product low-cost specialists who operate at the market fringe. This would tend to imply that the market structure is a dual-market fringed oligopoly in practice.

The fourth approach proposed by Boone and Witteloostuijn defines an organisation's product focus according to the operating niche and the product range as shown in table 55:

Niche Width	PRODUCT FOCUS	
	Single	Multiple
Narrow	Single Product (Specialist)	Multi-Product (Specialist)
Broad	Single Product (Generalist)	Multi-Product (Generalist)

Table 55 - Product Focus Classification

Given what we have identified above, we can see that the broad niche players will operate as generalists and the narrow niche players will operate as specialists.

The last of Boone and Witteloostuijn's approaches relates the resource space utilised by the organisation to the resource distribution and the presence of a market centre as shown in table 56.

RESOURCE DISTRIBUTION	MARKET CENTRE	
	Present	Not Present
Distributive Homogeneous	Not Applicable	No Market Centre and Scale Economies operating (Condensed Resource Space)
Distributive Heterogeneous	Market Centre and Scale or Scope Economies operating, or Market Centre & Periphery and Scope Economies operating (Tailed Resource Space)	No Market Centre and Scope Economies operating (Rectangular Resource Space)

Table 56 - Resource Space Profile

44 The Big Six supply electricity to 90% of domestic consumers, source Information in this table taken from UK Power "UK Power". 2012-05-17. Retrieved 2012-05-17.

Diagrammatically this is shown in figure 38:

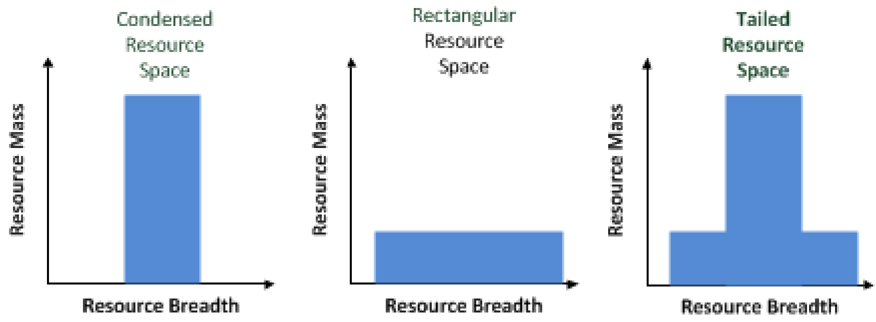

Figure 38 - Diagrammatic Representation of Resource Space Profile

The deductions from Boone and Witteloostuijn's first three approaches imply that the resource distribution is heterogeneous with two different uses of the resource distribution being evident. The first are the low-cost generalists, i.e. The Big 6, who are exploiting scale economies at the market centre. The second are low-cost specialists operating at the periphery, using scope economies.

11.1.4 APPLICATION TO THE ELECTRICITY GENERATORS

The theory and techniques discussion from above can now be used to categorise the EGI market to illustrate how the electricity generation market can be classified and structured as shown in table 57:

Economy Type	Market Participant Role			
Scale-based Economies dominate	Concentration amongst generalists			
	Large-scale single-product generalists with a low-cost strategy			
Scope-based Economies dominate	Concentration amongst generalists			
	Large-scale multi-product generalists with a differentiation strategy, and Specialists with a low-cost strategy			
Scale and Scope-based economies dominate	Concentration amongst generalists			
	Large scale multi-product generalists with a differentiation strategy			
	Specialists with a low-cost or differentiation strategy			
ECONOMY	STRATEGY		PRODUCTS	
	Low-Cost	Differentiation	Single	Multiple
Scale	Generalist	Specialist	Generalist	Specialist
Scope	Specialist	Generalist	Specialist	Generalist
Scale and Scope	Specialists	Generalist and Specialist	Specialist	Generalist
MARKET CONCENTRATION	PRODUCT DENSITY			
	High		Low	
High	Dual Market Structure (Fringed Oligopoly)		Concentrated Market Structure (Pure Oligopoly)	
Low	Fragmented Market Structure (Perfect Competition)		Uniform Market Structure (Monopolistic Competition)	
Niche Width	PRODUCT FOCUS			
	Single		Multiple	
Narrow	Single Product (Specialist)		Multi-Product (Specialist)	
Broad	Single Product (Generalist)		Multi-Product (Generalist)	
RESOURCE DISTRIBUTION	MARKET CENTRE			
	Present		Not Present	
Distributive Homogeneous	Not Applicable		No Market Centre and Scale Economies operating (Condensed Resource Space)	
Distributive Heterogeneous	Market Centre and Scale or Scope Economies operating (Tailed Resource Space)		No Market Centre and Scope Economies operating (Rectangular Resource Space)	

Table 57 - Resource Partitioning Appraisal of the EGI

The appraisal above and particularly those sections highlighted in yellow tint, show that both scale and scale & scope economies are operating in the EGI market. It also shows that low-cost and differentiated business strategies are operating with specialists and generalists using both single and multiple product offerings. The market concentration could be operating as a Fringed Oligopoly. The resource distribution could be expected to be heterogeneous with a market centre and a Tailed Resource Space.

11.2 RESOURCE PARTITIONING IN THE EGI SECTOR

In the case of the EGI, the main determinants on the generator's use of resources are the production techniques used (since they will give rise to competition in terms of energy inputs) and the scale of operation (the MW capacity of the power stations. These will both give rise to output based competition i.e. there is only so much electricity that the UK marketplace will be able to use. This implies that the two main underlying considerations for generators are availability and pricing of fuel inputs, and the availability and pricing of electricity outputs.

The UK electricity 'product' has a number of unique characteristics that imply that there is a common identity and language (a prerequisite of the resource-partitioning model) used. Firstly, electricity is a 'product' that cannot be easily stored (albeit that pumped hydro storage and chemical batteries etc. can be used for specialist applications) – it must be used as soon as it is generated or it is lost. Secondly, electricity is a homogeneous 'product' at present. It is difficult (but not impossible) to buy differentiated offerings. The differentiation can occur with the generator, but given that the transmission and distribution networks are common, the real differentiation takes place at the electricity supplier entity. For example, if the consumer wishes to purchase 'Green' electricity from a renewable source this requires a relationship between generator and supplier. This relationship can be achieved by means of vertical integration (generators and supplier companies in the same business entity) or bi-lateral relationships between generator and supplier. Both of which can occur, but the level of demand in the UK for green electricity is currently relatively low[45]. Lastly, the BETTA system, the marketplace used to determine purchase prices of electricity between the electricity Generator and Supplier companies. The market differentiates directly between the fuels and generation technology used by means of the generation price. Indirectly the market also differentiates by virtue of the renewables obligation, government subsidies, demand profile (base, intermediate or peak merit or), intermittency of renewables generation and resultant generation prices.

[45] The Green Electricity Code of Practice, identified that 'green electricity schemes by domestic consumers; the market share is still below 1% of residential sales' BOARDMAN, B., JARDINE, C. N. & LIPP, J. 2006. Green Electricity Code of Practice A Scoping Study.

Electricity has a common language and identity in ecological terms. In this situation, Carroll (1985) argued that there are four mechanisms used by organisations:

> **Generalist Strategy with a Single-Product** – a producer makes only one product that is designed to appeal to all consumers. The research includes generators that adopt a traditional generation fossil fuel based technology that utilises multiple fuels types that are only fossil fuel i.e. coal, gas or oil
>
> **Generalist Strategy with Multiple Appeal Single-Product** – a producer makes a single product but it is designed to appeal to multiple diverse segments of the audience. The main problem with this strategy is that it can be difficult for organisations to maintain competencies that appeal to all segments concurrently. The research has categorised generators that use multiple fuel types that include both fossil and renewable fuels
>
> **Generalist Strategy with Multiple Products from Different Subsidiaries** – the producer makes multiple products that appeal to different segments of audience, using a holding company approach and a uni-product strategy from each sub entity. The difficulty is similar to the approach above, but the adoption of a peripheral mimicry required by the environment and the decentralisation can offset some of the difficulties. The study includes generators that use multiple fuel types, e.g. fossil and renewable and adopt a holding company form
>
> **Specialist Strategy** – This is designed to appeal to only one segment of the audience. The study has defined specialists as those generators that adopt a single fuel sub-type for all their generation assets.

These four also fit with the classification-based approach used above.

The application of the above to the EGI hinges obviously on the definition of 'product'. In the UK, there has been very limited uptake of green-electricity and therefore in the UK, unlike Germany for example, there is only one electricity product. This means that the purist view of the definition of product would not distinguish between any of the generators. However, generators clearly follow different strategies, in terms of the type of fuel and organisational form they have adopted. Consequently, generators can be classified as either generalists or specialists on this basis.

The choice of which mechanism is adopted by a generator company will depend upon many factors, but as outlined above the heterogeneity of the market place is one of the main determinants. With these factors in mind, one might expect that most organisations would adopt a specialist approach, but when generalists attempt to adopt this stance they lose their economies of scale and typically lose out to those generators that devote their resources to a single segment or product.

It could therefore be anticipated that in a generalist market, as shown in Environment b, there is a greater resource space outside of the organisation, F4, than the resource space remaining from environment A. Therefore, one would expect that in a concentrated market more specialist organisations would be found.

Carroll's work with newspapers suggests that this situation does exist in practice and that when it does the life chances of generalists and specialists (measured through their rate of death) will be lower in a partitioned market than in an un-partitioned concentrated market.

Carroll uses the level of concentration of the market to investigate his predictions.

11.3 MARKET CONCENTRATION DATA AND VARIABLES

The key data used in market concentration research is related to the fuel types used, the organisational form of the generator[46], the MW outputs of the generation plants, and the number of generation plants. The data used in summarised below.

The detailed breakdown of the power plants by fuel is shown in table 58:

Fuel Type	Primary Fuel	Number of Power Stations
Renewable	Biomass	11
	Nuclear	19
	Waste	1
	Water	97
	Wind	312
	Renewable Total	**440**
Fossil Fuel	Coal	55
	Gas	62
	Oil	26
	Fossil Fuel Total	**143**
Grand Total		**588**

Table 58 - Fuel Usage by Power Station

The fuel technology by power station is shown in table 59:

Technology Type	Number of Power Stations
AGR	7
CCGT	38
CCGT / CHP	16
CCGT / Embed. Gen.	5
CHP	8
Coal CF, PF	1
Coal CG	1
Coal PF	31
Coal TG	1
Conventional Steam	24
Diesel	1
Embedded Generation	3
Hydro	93
Island Generation	6
Magnox	11
OCGT	20
Offshore	20
Onshore	292
Pumped	4
PWR	1
Grand Total	**583**

Table 59 - Fuel Technology by Power Station

46 Specialist or generalist (single product, multi-product, or multi-product in a holding company organisational form.

The organisational form adopted by the generator has been classified following the framework proposed by Carroll (1985) to make the distinction based on the fuel type / count they have adopted for their power stations is shown in table 60:

Organisation Form Type Number	Classification	Rules for Allocation	Number of Generators Classified	MW Outputs of Power Plants
1	Specialist strategy	The generator makes use of only one fuel type i.e. Biomass, Coal, Gas, Nuclear, Oil, Waste, Water, or Wind	185	46,178
2	Generalist strategy with a single-product	Multiple fuel types that are only fossil fuel in nature (i.e. Coal, Gas and / or Oil)	9	12,874
3	Generalist strategy with multiple appeal single-product	Multiple fuel types that include both fossil and renewable fuels	17	27,036
4	Generalist strategy with multiple products from different subsidiaries	Multiple fuels being adopted and company adopts a Holding Company organisational form. Typically using the fossil fuels in the original company and renewables in the form of subsidiaries and / or Joint Ventures with other companies	7	10,224
Totals			**218**	**96,136**

Table 60 - Classification of Generators Operating 1990 – 2011

The data pertaining to the organisational form adopted by generators reveals is shown in table 61:

Year	Generators	Specialists	Generalist - Uni-Product	Generalist Multi Product	Generalist Holding Co.
1989	21	17	2	2	0
1990	26	21	1	4	0
1991	35	30	1	4	0
1992	43	39	0	4	0
1993	44	39	0	4	1
1994	47	42	0	4	1
1995	50	43	0	6	1
1996	57	50	0	6	1
1997	60	54	0	5	1
1998	70	63	0	6	1
1999	73	65	0	7	1
2000	82	73	1	7	1
2001	85	74	1	8	2
2002	86	74	1	9	2
2003	86	75	1	9	1
2004	98	85	3	9	1
2005	102	87	4	10	1
2006	112	96	4	9	3
2007	121	102	5	10	4
2008	130	106	6	13	5
2009	141	116	6	13	6
2010	148	123	7	13	5
2011	148	123	7	13	5

Table 61 - Breakdown of Generalists and Specialists over Period 1989 – 2011

Looking at the Generator count in 1989 (just ahead of privatisation), and that in 2011, one can see some interesting statistics. In 1989, there were twenty-one generators; by 2011, this number had increased to one hundred and forty eight.

In 1989, there were seventeen generalist generators [of which two were generalist (Uni-Product generators), two were generalist (Multi-Product) generators and there were no Generalist (Holding Companies], by 2011 this number had increased to one hundred and twenty three specialist generators, seven generalist (Uni-Product generators), thirteen generalist (Multi-Product) generators and five generalist (Holding Company) generators.

The breakdown of the number across the twenty-year period highlights that there have been changes in the market structure of the generator mix (i.e. because the organisational form classification is based on fuel type used), and that there may be some form of resource-partitioning occurring over the period.

Looking at the percentage breakdown between the different organisational form types by year shows the following data is shown in table 62:

Year	% Specialists	% Generalist - Uni Product	% Generalist Multi Product	% Generalist Holding Co
1989	81.0%	9.5%	9.5%	0.0%
1990	80.8%	3.8%	15.4%	0.0%
1991	85.7%	2.9%	11.4%	0.0%
1992	90.7%	0.0%	9.3%	0.0%
1993	88.6%	0.0%	9.1%	2.3%
1994	89.4%	0.0%	8.5%	2.1%
1995	86.0%	0.0%	12.0%	2.0%
1996	87.7%	0.0%	10.5%	1.8%
1997	90.0%	0.0%	8.3%	1.7%
1998	90.0%	0.0%	8.6%	1.4%
1999	89.0%	0.0%	9.6%	1.4%
2000	89.0%	1.2%	8.5%	1.2%
2001	87.1%	1.2%	9.4%	2.4%
2002	86.0%	1.2%	10.5%	2.3%
2003	87.2%	1.2%	10.5%	1.2%
2004	86.7%	3.1%	9.2%	1.0%
2005	85.3%	3.9%	9.8%	1.0%
2006	85.7%	3.6%	8.0%	2.7%
2007	84.3%	4.1%	8.3%	3.3%
2008	81.5%	4.6%	10.0%	3.8%
2009	82.3%	4.3%	9.2%	4.3%
2010	83.1%	4.7%	8.8%	3.4%
2011	83.1%	4.7%	8.8%	3.4%

Table 62 - Generator Counts by Organisational Form

This highlights that the market structure has remained reasonably stable in terms of its organisational form between specialists and generalists, albeit that there have been changes in the structure adopted by generalists. This suggests that some form of market restructuring and change was evident. The data also shows that since privatisation the EGI market has exhibited resource partitioning when assessed by the organisational form adopted by generators i.e. generalists have modified their structures.

Using Gini-based concentration measures of MW output of the power plants and the numbers, reveals the following, with regard to the market concentration data, when viewed from the perspective of the organisational form adopted by the generator in table 63:

Generator Classification	Variable	Obs	Mean	Std. Dev.	Min	Max
Calendar Period of Analysis	Year	1965	1993	21	1901	2035
Specialist Strategy	ginimw 1	1436	.712	.166	0	.831
	ginistat 1	1436	.373	.085	0	.5
Generalist Strategy with a Single-Product	ginimw 2	1436	.398	.306	0	.801
	ginistat 2	1436	.174	.141	0	.619
Generalist Strategy with Multiple Appeal Single-Product	ginimw 3	699	.287	.265	0	.7
	ginistat 3	1419	.427	.158	0	.607
Generalist Strategy with Multiple Products from Different Subsidiaries	ginimw 4	1419	.614	.196	0	.859
	ginistat 4	850	.034	.055	0	.147
Total MW Capacity of the Generators	totcapmw	1436	79,153	5,692	67,499	88,937

Table 63 – Gini Concentration of the MW Output and Generator Density by Organisational Form

11.4 MARKET CONCENTRATION RESEARCH CONTEXT

The EGI lends itself very well to investigation because at privatisation, the market was very concentrated, with National Power and PowerGen having the vast majority of the generation capacity outside[47] of the nuclear stations and the Independent Power Producers. Over time due to regulatory pressures, the market was progressively liberalised and fragmented. This should give a range of data that will enable a review of the role of specialist and generalist providers in the EGI.

The Market Concentration research questions:

> **Can the effect of resource partitioning be observed in the liberalised EGI marketplace?**
>
> **Has Government energy policy been positive for the EGI stability when controlling for market concentration changes?**

Market Concentration Research Theories:

> **Resource partitioning in the EGI industry has followed Boone and Witteloostuijn's (2006) theory, such that the government's energy policy interventions have operated positively when measured by the impact of the MCM, PC, PTE, SOS and SROEG) policies when controlling for market concentration**.

[47] 'National Power was assigned 46% of all generation capacity in England and Wales, while PowerGen received around 28% (both privatised on March 1991). Almost 17% consisted of nuclear power (transferred to Nuclear Electric, remaining public until 1996), just 1% was generation by independent producers (IP), and the remainder consisted of other sources, including imports from France and Scotland GORINI DE OLIVEIRA, R. & TOLMASQUIM, M. T. 2004. Regulatory performance analysis case study: Britain's electricity industry. *Energy Policy,* 32**,** 1261-1276.

The Research Hypotheses:

> **The UK electricity generation market favours those who adopt a generalist form of organisation with either a single or a multi-product fuel sourcing strategy**
>
> **The government's energy policies (MCM, PPC, PTE, SOS and SROEG) have been positive for the stability of the generation industry when controlling for the effects of power output, industry age and niche width.**

These hypotheses attempt to model the data using survival regression techniques to understand how market concentration is related to power plant ownership.

11.5 MARKET CONCENTRATION MODEL SPECIFICATION

The model specification utilised can be broken down into two sub sections. The first uses Gini coefficients, based on a generator's MW outputs and the number of power stations they owned, to analyse the relationships between different generator types i.e. generalist or specialist to obtain a market concentration assessment. The second model uses survival regression techniques to derive models showing how market concentration influences the length of time that generators retain their power plant holdings, to obtain the market concentration modelling analysis.

The initial intention was to use Dobrev et al.'s (2002) framework as the starting point for modelling market concentration. The idea was to build a model that had a similar structure to that adopted for the Dobrev's analysis of US Automobile manufacturers. The data was collected and the model structure replicated, but once the regression analysis was performed, it was found that there was insufficient data to provide any outputs[48].

Therefore, an alternative approach had to be developed by the author. The concept was to utilise the underlying theme of this research to focus on understanding how energy policy influences market concentration in the EGI. The policy model framework was that based on the principles adopted for the earlier generator and power plant duration testing chapter. The key principle was to understand how market concentration parameters influence the ownership durations of power plant ownership in terms of founding and failure duration of tenure analysis.

The market concentration modelling approach was further developed to allow modelling of two different techniques. The first was regression of the organisational form adopted by generators to power plant founding and failure ownership durations. The second was the development of a model to analyse the relationship between market concentration parameters and the energy policy implemented by successive governments.

[48] The data had the following profile: generator company based founding – 46 failures, generator company based failures – 120 failures, power station based founding – 375 failures, power station based failures – 76 failures, and power plant growth rate changes – 146 failures.

The first approach utilised the four organisational form definitions outlined above[49] and calculated their Gini coefficients for each year of the study. This information was then regressed to the generator power plant ownership durations to enable an assessment of the relationship between generator organisational form and ownership duration to be made.

The second approach required three stages. Firstly, the power plant data was transformed into the variable structure proposed by Dobrev (2002). This required the calculation of eighteen parameters[50], plus some control data variables. Secondly, each independent variable parameter was tested for statistical significance using a bivariate Cox regression against both generator power plant founding and failure ownership durations (this resulted in nine founding and fifteen failure variables remaining). Thirdly, the remaining independent variables were combined with the significant energy policy variables, from the earlier energy policy testing work, to develop six models that regressed the government's five broad energy policy objectives[51], to generator power plant founding and failure ownership durations using the Cox semi parametric regression technique.

[49] Specialist, Generalist Strategy with a Single-Product, Generalist Strategy with Multiple Appeal Single-Product, and Generalist Strategy with Multiple Products from Different Subsidiaries

[50] Max mw output of the generator, Min mw output of the generator, MW mid-point, Niche-width MW range, Niche-width MW mid, EGI Industry age, EGI industry age squared, C4 generator MW output, C4 mid MW output, Distance above Market Centre (MW) for each generator, Distance Below Market Centre (MW), C4 ratio of each generator's output, Density of generators squared, Density of generators squared / 1000, Total MW output of EGI, De novo, and De alio generator counts by year over the period 1990 – 2011.

[51] Maintaining Competitive Markets (MCM), Protecting Consumers (PC), Protecting the Environment (PTE), Security of the Energy Supply (SOS), and Sustainable Rate of Economic Growth (SROEG).

11.6 MARKET CONCENTRATION RESULTS

The results are presented for both of the hypotheses tested.

11.6.1 ORGANISATIONAL FORM BASED MARKET CONCENTRATION ASSESSMENT

The hypothesis to be tested is:

> **Generator market operating strategy and power plant ownership tenure are correlated to one another such that ownership duration is directly influenced resource partitioning approach chosen by a generator in the EGI over the period 1999-2010.**

The graphical presentation of the Gini data for specialist and generalist producers is shown in figure 39:

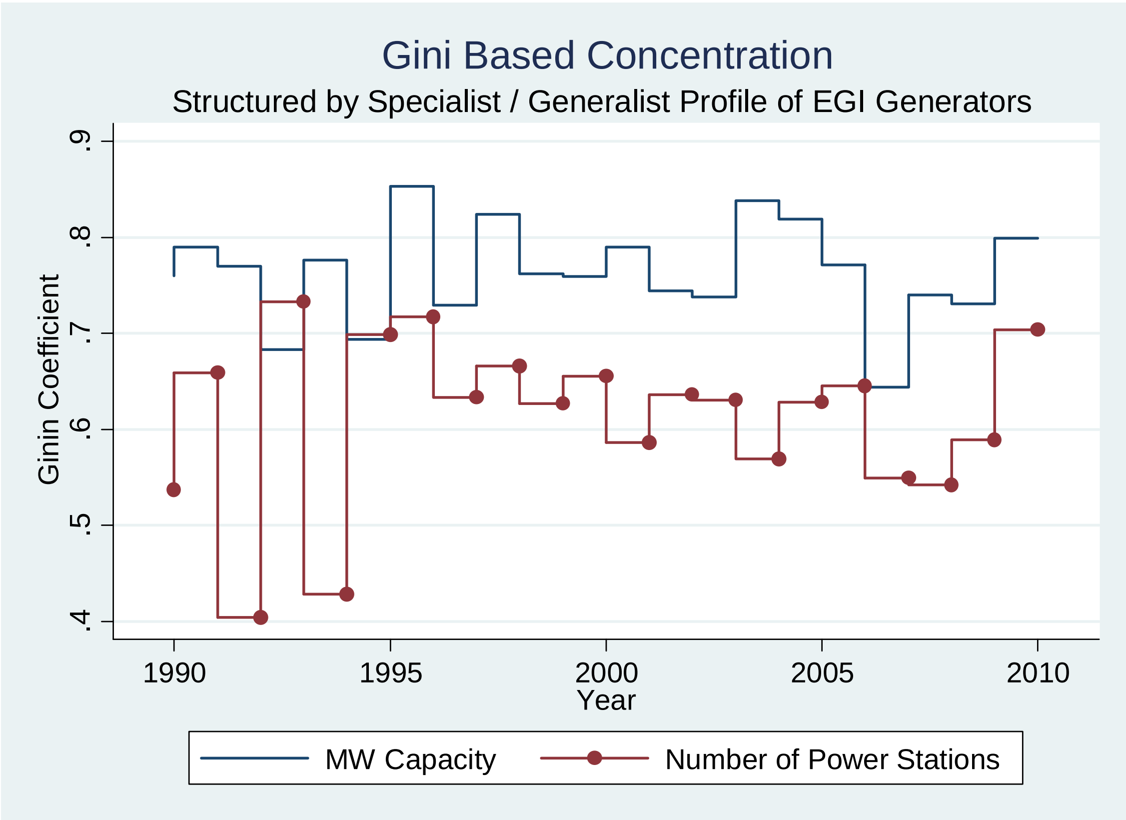

Figure 39- The Gini Across all Specialists and Generalists

This shows that the level of market concentration has varied since 1991. However, despite the various policy prescriptions, invoked by successive governments, the level of MW-based market concentration is the same as where the industry started after privatisation. The results from the cox regression of duration between failure-based vital event and the concentration of the MW output by generator type are shown in table 64:

Power Plant MW Output Model	Variable	1	2	3	4
Specialist Strategy	gini1mw	-0.176 (0.236)			
Generalist Strategy with a Single-Product	gini2mw		-0.757*** (0.125)		
Generalist Strategy with Multiple Appeal Single-Product	gini3mw			1.188*** (0.225)	
Generalist Strategy with Multiple Products from Different Subsidiaries	gini4mw				-0.844*** (0.186)
Density	Observations	936	936	465	465

Table 64 – Analysis of MW Output Concentration and Generator Classification

Table 64 shows that in terms of tenure in the industry, when viewed from the density of power plant capacity (product), all forms of generator form except the 'generalist strategy with multiple appeal single-product' have shorter period of tenure between failure events i.e. they are more volatile when mw output concentration is analysed.

The results from the cox regression of duration between failure-based vital event and the concentration of the density of generator type are shown in table 65:

Power Plant Density Model		1	2	3	4
Specialist Strategy	ginis1tat	-1.791*** (0.407)			
Generalist Strategy with a Single-Product	gini2stat		-0.413 (0.277)		
Generalist Strategy with Multiple Appeal Single-Product	gini3stat			0.116 (0.258)	
Generalist Strategy with Multiple Products from Different Subsidiaries	gini4stat				5.944*** (0.996)
Density	Observations	936	936	930	565

Table 65 - Analysis of Power Plant Density Concentration and Generator Classification

Table 72 highlights that when viewed from the density-based concentration of power plants the above shows that a 'generalist strategy with multiple appeal single-product' or a 'generalist strategy with multiple products from different subsidiaries' form of organisational structure (organisation) have a longer duration of tenure, with the latter showing a significantly longer mean tenure period.

If we use the resource-partitioning appraisal presented in table 63, we can see that the most effective strategy for generators is presented in table 66:

Economy Type	Market Participant Role			
Scale-based Economies dominate	Concentration amongst generalists			
	Large-scale single-product generalists with a low-cost strategy			
Scope-based Economies dominate	Concentration amongst generalists			
	Large-scale multi-product generalists with a differentiation strategy, and Specialists with a low-cost strategy			
Scale and Scope-based economies dominate	Concentration amongst generalists			
	Large scale multi-product generalists with a differentiation strategy			
	Specialists with a low-cost or differentiation strategy			
ECONOMY	STRATEGY		PRODUCTS	
	Low-Cost	Differentiation	Single	Multiple
Scale	Generalist	Specialist	Generalist	Specialist
Scope	Specialist	Generalist	Specialist	Generalist
Scale and Scope	Specialists	Generalist and Specialist	Specialist	Generalist
MARKET CONCENTRATION	PRODUCT DENSITY			
	High		Low	
High	Dual Market Structure (Fringed Oligopoly)		Concentrated Market Structure (Pure Oligopoly)	
Low	Fragmented Market Structure (Perfect Competition)		Uniform Market Structure (Monopolistic Competition)	
Niche Width	PRODUCT FOCUS			
	Single		Multiple	
Narrow	Single Product (Specialist)		Multi-Product (Specialist)	
Broad	Single Product (Generalist)		Multi-Product (Generalist)	
RESOURCE DISTRIBUTION	MARKET CENTRE			
	Present		Not Present	
Distributive Homogeneous	Not Applicable		No Market Centre and Scale Economies operating (Condensed Resource Space)	
Distributive Heterogeneous	Market Centre and Scale or Scope Economies operating (Tailed Resource Space)		No Market Centre and Scope Economies operating (Rectangular Resource Space)	

Table 66 - Resource Partitioning Findings in the EGI

If we consider the above, further we can posit that the EGI economy type and economy favours generalists, who operate in a dual market fringed oligopoly structure using a generalist-based broad single and multi-product (fuel) niche width, and a resource distribution of tailed resource space. The results of the above show that the resource-partitioning hypothesis is confirmed and that generator market in the UK favours those who adopt a generalist form of organisation using either a single or multi-product fuel sourcing strategy.

11.6.2 REGRESSION ON MARKET CONCENTRATION FOUNDING DATA

As stated above, the initial proposal for this chapter was to be able to replicate the model used by Dobrev et al. (2002). The alternative mechanism was to merge the power plant data with the energy policy data variables found to be statistically significant along with the concentration data variables that were prepared for the Dobrev approach. The model produced was regressed with the dependent variables used in the energy policy-testing chapter, i.e. the generator founding rate vital event durations. The variables used are shown in table 67:

Policy	Class	Description	Variable Name	Obs	Mean	Std. Dev.	Min	Max
MCM	GIS	Equity - Equity Investment	giseqinv	2282	1.5657	1.1265	0	3
		Subsidy - Subsidy	gissub	2282	1.7638	0.4248	1	2
		Taxation - Tax Incentive	gistaxoff	2282	2.4277	1.613	0	4
	PI - Class	Regulatory - Policy Count by Cumulative Policy Years of Experience	pcrg	1118	8.602	5.195	3	21
		Regulatory - Policy Count by Policy Years of Experience	pcrgyr	1118	101.7317	86.7602	12	231
		Regulatory - Policy Count by Year Policy Announced	pcrgyrcum	1118	71.22	36.3137	21	116
	PI - Nature	Regulatory - Policy Count by Year	pnrg	963	7.352	8.1968	1	27
	Regulatory	Ownership - Ownership Total	rwowntotp	2759	1.1243	0.8383	0	3
		Technology - Technology Total	rwtechtot	2759	1.8246	0.3804	1	2
PC	PI - Class	Political - Policy Count by Year	pnpo	1118	5.6673	3.6959	2	11
		Political - Policy Count by Year Policy Announced	pcpoyrcum	1118	54.2934	31.0985	13	95
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	methanech4	2739	59.4691	18.7161	41.3	97.4
		Millions of Tonnes of CO2 Equivalent	mtco2e	2739	663.6787	52.6579	572.5	773.3
		Net CO2 emissions (emissions minus removals)	netco2emis~n	2739	543.4127	29.5456	477.8	597.5
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	nitrousox~2o	2739	45.6967	10.3044	35.1	68
		Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	perfluoroc~c	2739	0.3961	0.3104	0.1	1.4
		Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	sulphurhex~6	2739	1.0753	0.2979	0.7	1.8
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	pcctyrcum	1118	27.6056	18.1616	5	49
		Carbon Tax - Policy Count by Policy Years of Experience	pcctyr	1118	18.1172	20.5622	1	65
		Energy Efficiency - Policy Count by Cumulative Policy Years of Experience	pcee	1118	3.9249	4.369	1	16
		Energy Efficiency - Policy Count by Policy Years of Experience	pceeyrcum	1118	37.7898	21.4677	16	67
		Energy Efficiency - Policy Count by Year Policy Announced	pceeyr	1118	31.3828	39.863	1	128
		Transport - Policy Count by Cumulative Policy Years of Experience	pctr	648	5.7145	1.2801	4	7
		Transport - Policy Count by Policy Years of Experience	pctryrcum	1118	30.1422	20.4974	7	56
		Transport - Policy Count by Year Policy Announced	pctryr	648	61.8148	33.6554	16	105
	PI - Nature	Environmental - Policy Count by Year	pnev	1118	8.7415	5.1155	2	17
	Regulatory	Environmental - Environmental Total	rwentotp	2759	3.8927	0.3095	3	4
SOS	GIS	Grant - Implementation Grant	gisrg	2282	4.9693	4.9964	0	14
		Grant - Research Grant	gisgrnttot	2282	15.5342	12.6772	0	38
SOS	PI - Class	Technologies - Policy Count by Cumulative Policy Years of Experience	pcte	1118	8.0984	6.5525	2	25
		Technologies - Policy Count by Policy Years of Experience	pcteyr	1118	124.9633	127.6597	6	425
		Technologies - Policy Count by Year Policy Announced	pcteyrcum	1118	70.966	30.9359	25	108
		Technology - Policy Count by Year	pnte	1118	6.5304	4.9184	1	16
SROEG	PI - Nature	Economic - Policy Count by Year	pnec	1118	7.3927	4.8945	2	19
Concentration	Niche Width	Distance Above Market Centre	damc	2737	- 8933.705	4067.423	- 18651.45	-410
		Distance Below Market Centre	dbmc	2737	8686.217	4055.975	410	18650.95
		Generator Number	opernos	2737	13.1831	23.2387	1	110
		Industry Age of all Generators	indage	2737	13.1158	6.0066	1	21
		Industry Age of all Generators - Squared	indagesq	2737	208.0906	142.4049	1	441
		Maximum MW output of each Generator	maxmw	2737	620.3729	971.6479	0.08	3925
		Mid MW output of each Generator	mwmid	2737	339.1521	546.5728	0.075	3705
		Mid of Niche Width MW	nichmid	2737	253.743	475.1862	0.075	1962.25
		Minimum MW output of each Generator	minmw	2737	125.3964	368.4201	0.08	3705
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	nwmwrange	2737	507.0913	950.5824	0.15	3924.5
		Number of Years Generator has been Producing Electricity	genyears	2737	7.0387	4.9603	1	21
		Ratio of Generator's Output to Top Four Generator's Output MW	c4ratio	2737	0.5018	0.1095	0.391182	0.7551677
		Sum of Generator's MW Output	summw	2737	2500.778	5058.341	0.08	23716
		Top Four Generator MW Total Output	c4totmw	2737	45944.58	8335.444	36516.2	64382.82
		Top Four Mid MW Output	c4midmw	2737	9272.857	4121.146	4115	18651.95
		Total MW Output of all Generators	totmwout	2737	92390.36	7923.265	76463.92	111108.8
		Years in the Industry of each Generator	yrsinind	2737	13.4582	5.5995	1	21

Table 67 - Data Used for Energy Policy Market Concentration Regression[52]

[52] Note: the independent variables are those termed MCM, PC, PTE, SOS and SROEG, the reminder are the control variables.

The 99%, 95% and 09% significant variable results from the market concentration bivariate analysis (with ownership duration as the dependent variable) are shown in table 68:

Policy	Class	Description	coef	se	pval	N	Mean	ci low	ci high
MCM	GIS	Subsidy - Subsidy	0.175*	-0.102	0.086	2,282	1.7638	-0.0248	0.376
	Regulatory	Ownership - Ownership Total	0.118***	-0.0426	0.0058	2,759	1.1243	0.034	0.201
	Regulatory	Technology - Technology Total	0.329***	-0.0968	0.000676	2,759	1.8246	0.139	0.519
PC	PI - Class	Political - Policy Count by Year Policy Announced	-0.00360*	-0.00203	0.0758	1,118	54.2934	-0.00757	0.000374
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	0.196**	-0.0962	0.0421	2,739	0.3961	0.007	0.384
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	-0.00673*	-0.00347	0.0529	1,118	27.6056	-0.0135	8.31E-05
	PI - Class	Energy Efficiency - Policy Count by Policy Years of Experience	-0.00612**	-0.00309	0.0475	1,118	37.7898	-0.0122	-6.69E-05
	PI - Class	Transport - Policy Count by Policy Years of Experience	-0.00550*	-0.00313	0.0784	1,118	30.1422	-0.0116	0.000626
SOS	PI - Class	Technologies - Policy Count by Year Policy Announced	-0.00358*	-0.00196	0.0681	1,118	70.966	-0.00743	0.000266
Concentration	Niche Width	Generator Number	0.00444***	-0.00106	2.90E-05	2,737	13.1831	0.00236	0.00653
		Maximum MW output of each Generator	0.000147***	-3.17E-05	3.56E-06	2,737	620.3729	8.48E-05	0.000209
		Mid MW output of each Generator	0.000248***	-6.04E-05	4.03E-05	2,737	339.1521	0.00013	0.000366
		Mid of Niche Width MW	0.000266***	-6.38E-05	3.07E-05	2,737	253.743	0.000141	0.000391
		Minimum MW output of each Generator	0.000240**	-0.000115	0.0368	2,737	125.3964	1.47E-05	0.000464
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	0.000133***	-3.19E-05	3.08E-05	2,737	507.0913	7.05E-05	0.000196
		Sum of Generator's MW Output	2.50e-05***	-5.55E-06	6.55E-06	2,737	2500.778	1.42E-05	3.59E-05
		Top Four Generator MW Total Output	7.73e-06*	-4.05E-06	0.056	2,737	45944.58	-1.99E-07	1.57E-05

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 68 – Bi-Variate Founding Analysis of Market Concentration Data[53]

The multi-variate Cox regression using the most significant variable is shown in table 69:

No. of subjects	384
Number of obs	548
No. of failures	325
Time at risk	1192.569473 (Days)
LR chi2(13)	34.85
Log likelihood	-1619.208
Prob > chi2	0.0015
Incidence rate	0.1569306

The multivariate founding regression for these variables is shown in table 69:

Policy	Class	Description	coef	se	pval	N	ci low	ci high
MCM	GIS	Subsidy - Subsidy	0.3677184	0.2044754	1.8	0.072	-0.033046	0.7684827
	Regulatory	Ownership - Ownership Total	0.3146896	1.501995	-0.21	0.834	-3.258546	2.629167
		Technology - Technology Total						
PC	PI - Class	Political - Policy Count by Year Policy Announced	0.0150844	0.0199439	0.76	0.449	-0.024005	0.0541737
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	4.777212	3.820033	1.25	0.211	-2.709915	12.26434
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	-0.0162788	0.0825438	-0.2	0.844	-0.1780618	0.1455041
		Energy Efficiency - Policy Count by Policy Years of Experience	-0.0127189	0.0775519	-0.16	0.87	-0.1647178	0.13928
Concentration	Niche Width	Generator Number	0.0139002	0.0050578	2.75	0.006	0.003987	0.0238134
		Maximum MW output of each Generator	0.0014981	0.0010918	1.37	0.17	-0.0006417	0.003638
		Mid MW output of each Generator	-0.0013112	0.0007105	-1.85	0.065	-0.0027037	0.0000814
		Mid of Niche Width MW	0.4273998	0.3963745	1.08	0.281	-0.3494799	1.20428
		Minimum MW output of each Generator	-0.0000494	0.0011057	-0.04	0.964	-0.0022166	0.0021178
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	-0.2142614	0.1979889	-1.08	0.279	-0.6023125	0.1737896
		Sum of Generator's MW Output	-0.0000273	0.0000252	-1.09	0.277	-0.0000766	0.000022
		Years in the Industry of each Generator	-0.0439726	0.0152928	-2.88	0.004	-0.0739458	-0.0139993

Table 69 – Multivariate Founding Analysis of Market Concentration Data

[53] Note: the independent variables are those termed MCM, PC and PTE, the reminder are the control variables.

The mean magnitude of the factors is shown in table 70:

Policy	Class	Description	coef	se	Magnitude	Sub Group Magnitude	Group Magnitude
MCM	GIS	Subsidy - Subsidy	0.3677	0.2045	0.6486	0.6486	
	Regulatory	Ownership - Ownership Total	0.3147	1.5020	0.3538	0.3538	1.0024
PC	PI - Class	Political - Policy Count by Year Policy Announced	0.0151	0.0199	0.8190	0.8190	0.8190
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	4.7772	3.8200	1.8923	1.8923	
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	-0.0163	0.0825	-0.4494		
		Energy Efficiency - Policy Count by Policy Years of Experience	-0.0127	0.0776	-0.4806	-0.9300	0.9622
Concentration	Niche Width	Generator Number	0.0139	0.0051	0.1832	0.1832	
		Maximum MW output of each Generator	0.0015	0.0011	0.9294	0.9294	
		Mid MW output of each Generator	-0.0013	0.0007	-0.4447	-0.4447	
		Mid of Niche Width MW	0.4274	0.3964	108.4497	108.4497	
		Minimum MW output of each Generator	0.0000	0.0011	-0.0062	-0.0062	
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	-0.2143	0.1980	-108.6501	-108.6501	
		Sum of Generator's MW Output	0.0000	0.0000	-0.0683	-0.0683	
		Years in the Industry of each Generator	-0.0440	0.0153	-0.5918	-0.5918	-0.1987

Table 70 – Mean Impact of Founding Market Concentration Data[54]

[54] Note: the independent variables are those termed MCM, PC and PTE, the reminder are the control variables.

11.6.3 REGRESSION ON MARKET CONCENTRATION DURATION DATA

The 99%, 95% and 09% significant variable results from the market concentration bivariate analysis (with ownership duration as the dependent variable) are shown in table 71:

Policy	Class	Description	coef	se	pval	N	ci low	ci high
MCM	GIS	Equity - Equity Investment	-0.192*	-0.11	0.0812	2,282	-0.407	0.0238
		Subsidy - Subsidy	-0.351*	-0.185	0.0586	2,282	-0.714	0.0128
	PI - Class	Regulatory - Policy Count by Cumulative Policy Years of Experience	0.0671***	-0.0198	0.000715	1,118	0.0282	0.106
		Regulatory - Policy Count by Policy Years of Experience	0.00459***	-0.00156	0.00323	1,118	0.00154	0.00765
		Regulatory - Policy Count by Year Policy Announced	-0.00921*	-0.00518	0.0756	1,118	-0.0194	0.000947
	PI - Nature	Regulatory - Policy Count by Year	0.0410***	-0.013	0.00161	963	0.0155	0.0665
PC	PI - Class	Political - Policy Count by Year	0.138***	-0.044	0.00177	1,118	0.0513	0.224
		Political - Policy Count by Year Policy Announced	-0.0133**	-0.00671	0.0482	1,118	-0.0264	-0.000102
PTE	Emissions	Millions of Tonnes of CO2 Equivalent	-0.00410**	-0.00205	0.0456	2,739	-0.00812	-8.09E-05
		Net CO2 emissions (emissions minus removals)	-0.00785*	-0.00407	0.0536	2,739	-0.0158	0.000121
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	-0.0162*	-0.00897	0.0704	2,739	-0.0338	0.00135
		Sulphur hexafluoride (SF6), Millions of Tonnes of CO2 Equivalent	0.694**	-0.316	0.0281	2,739	0.0747	1.313
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	-0.0225*	-0.0119	0.0574	1,118	-0.0458	0.000707
		Energy Efficiency - Policy Count by Cumulative Policy Years of Experience	0.0718***	-0.0198	0.000298	1,118	0.0329	0.111
		Energy Efficiency - Policy Count by Year Policy Announced	0.00802***	-0.00235	0.000661	1,118	0.0034	0.0126
		Transport - Policy Count by Cumulative Policy Years of Experience	0.242*	-0.131	0.0645	648	-0.0145	0.498
SOS	PI - Class	Technologies - Policy Count by Cumulative Policy Years of Experience	0.0436***	-0.0156	0.00527	1,118	0.013	0.0743
		Technologies - Policy Count by Policy Years of Experience	0.00177**	-0.00085	0.0376	1,118	0.000101	0.00343
		Technologies - Policy Count by Year Policy Announced	-0.0155**	-0.00604	0.0101	1,118	-0.0274	-0.0037
SROEG	PI - Nature	Economic - Policy Count by Year	0.0701***	-0.0196	0.000362	1,118	0.0316	0.109
Concentration	Niche Width	Distance Above Market Centre	6.32e-05***	-1.97E-05	0.00135	2,737	2.45E-05	0.000102
		Distance Below Market Centre	-7.13e-05***	-1.98E-05	0.000319	2,737	-0.00011	-3.25E-05
		Maximum MW output of each Generator	0.000188***	-5.86E-05	0.00136	2,737	7.28E-05	0.000303
		Mid MW output of each Generator	0.000322***	-0.00011	0.00329	2,737	0.000107	0.000537
		Mid of Niche Width MW	0.000295***	-0.000112	0.00829	2,737	7.59E-05	0.000513
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	0.000147***	-5.58E-05	0.00828	2,737	3.80E-05	0.000257
		Number of Years Generator has been Producing Electricity	0.0801***	-0.0171	2.97E-06	2,737	0.0465	0.114
		Ratio of Generator's Output to Top Four Generator's Output MW	-2.431***	-0.749	0.00118	2,737	-3.9	-0.962
		Sum of Generator's MW Output	1.71e-05*	-9.27E-06	0.065	2,737	-1.07E-06	3.53E-05
		Top Four Generator MW Total Output	-2.05e-05**	-9.32E-06	0.0278	2,737	-3.88E-05	-2.23E-06
		Top Four Mid MW Output	-5.21e-05***	-1.93E-05	0.00677	2,737	-8.99E-05	-1.44E-05
		Total MW Output of all Generators	3.30e-05***	-9.92E-06	0.000893	2,737	1.35E-05	5.24E-05

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 71 – Bi-Variate Failure Analysis of Market Concentration Data[55]

[55] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

The multi-variate Cox regression using the most significant variable is shown in table 69:

No. of subjects	384
Number of obs	162
No. of failures	46
Time at risk	171.3812457 (Days)
LR chi2(13)	20.70
Log likelihood	-157.45807
Prob > chi2	0.0233
Incidence rate	0.1685596

The multivariate regression of the statistically significant variables is shown in table 72 (note a large number of variables were omitted due to collinearity):

Policy	Class	Description	coef	se	pval	N	ci low	ci high
MCM	GIS	Subsidy - Subsidy	0.3677184	0.2044754	1.8	0.072	-0.033046	0.7684827
	Regulatory	Ownership - Ownership Total	0.3146896	1.501995	-0.21	0.834	-3.258546	2.629167
		Technology - Technology Total						
PC	PI - Class	Political - Policy Count by Year Policy Announced	0.0150844	0.0199439	0.76	0.449	-0.024005	0.0541737
PTE	Emissions	Perfluorocarbons (PFC), Millions of Tonnes of CO2 Equivalent	4.777212	3.820033	1.25	0.211	-2.709915	12.26434
	PI - Class	Carbon Tax - Policy Count by Cumulative Policy Years of Experience	-0.0162788	0.0825438	-0.2	0.844	-0.1780618	0.1455041
		Energy Efficiency - Policy Count by Policy Years of Experience	-0.0127189	0.0775519	-0.16	0.87	-0.1647178	0.13928
Concentration	Niche Width	Generator Number	0.0139002	0.0050578	2.75	0.006	0.003987	0.0238134
		Maximum MW output of each Generator	0.0014981	0.0010918	1.37	0.17	-0.0006417	0.003638
		Mid MW output of each Generator	-0.0013112	0.0007105	-1.85	0.065	-0.0027037	0.0000814
		Mid of Niche Width MW	0.4273998	0.3963745	1.08	0.281	-0.3494799	1.20428
		Minimum MW output of each Generator	-0.0000494	0.0011057	-0.04	0.964	-0.0022166	0.0021178
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	-0.2142614	0.1979889	-1.08	0.279	-0.6023125	0.1737896
		Sum of Generator's MW Output	-0.0000273	0.0000252	-1.09	0.277	-0.0000766	0.000022
		Years in the Industry of each Generator	-0.0439726	0.0152928	-2.88	0.004	-0.0739458	-0.0139993

Table 72 – Multivariate Duration-based Analysis of Market Concentration Data[56]

The mean magnitude of the factors is shown in table 73:

Policy	Class	Description	coef	se	Magnitude	Sub Group Magnitude	Group Magnitude
MCM	GIS	Equity - Equity Investment	2.29	1.52	3.59		
		Subsidy - Subsidy	7.92	4.06	13.97	17.55	
	PI - Class	Regulatory - Policy Count by Policy Years of Experience	0.11	0.05	10.93	10.93	28,48
Concentration	Niche Width	Distance Above Market Centre	0.00	0.00	-2.05		
		Distance Below Market Centre	0.00	0.00	31.65		
		Maximum MW output of each Generator	0.00	0.00	3.16		
		Mid of Niche Width MW	0.74	1.59	250.60		
		Niche Width of Generator (MW) i.e. Maxmw-Minmw	- 0.37	0.79	-187.42		
		Number of Years Generator has been Producing Electricity	0.09	0.05	0.60		
		Sum of Generator's MW Output	0.00	0.00	0.43	96.97	96.97

Table 73 – Mean Impact of Duration-based Market Concentration Data[57]

[56] Note: the independent variables are those termed MCM, PC and PTE, the reminder are the control variables.
[57] Note: the independent variables are those termed MCM, the reminder are the control variables.

11.7 MARKET CONCENTRATION DISCUSSION

The results show a number of interesting things. Firstly, looking at the Witteloostuijn and Boone's categorisation we can see that the market has significant concentration amongst generalists who adopt either scale or scale & scope economies with single or multiple products, whilst the specialists focus on low cost or differentiation strategies with single products. The resource space implications highlight that a tailed resource space is operating (fringed oligopoly). I.e. suggesting the relevant requirements for resource partitioning.

Secondly, the categorisation is supported by the regression of the four types of generalist and specialist generator organisations. Looking at the generator power plant MW outputs, the statistically significant results, in terms of tenure in the EGI market, for generators highlighted a number of interesting findings. Firstly, those who adopted a generalist strategy with a single-product (-0.757) or a generalist strategy with multiple products from different subsidiaries (-0.844) had a lower tenure in the industry. Whilst those who adopted a generalist strategy with multiple appeal single product (+1.88) had a longer tenure in the industry. This implies that in terms of MW output generalists who has a multiple appeal single product will survive longest. The second assessment looked at the concentration of generators from the viewpoint of their organisational density (count). This showed that for the statistically significant organisational forms the level of market concentration was reduced over the period 1991-2011. In detail, the concentration levels showed that generalist strategy with multiple products from different subsidiaries (+5.944) had a longer tenure and specialist strategy (-1.791) had a reduce tenure. In summary, the following can be observed:

Power Plant Assessment of Generators / Industry Tenure (Significant Results)	MW Outputs	Power Plant Density
Specialist Strategy		Reduced
Generalist Strategy with a Single-Product	Reduced	
Generalist Strategy with Multiple Appeal Single-Product	Increased	
Generalist Strategy with Multiple Products from Different Subsidiaries	Reduced	Increased

Table 74 - Summary of Generalist / Specialist Organisation Type Tenure

Table 74 shows that specialists had a reduced tenure in the industry and generalists had an increased tenure when viewed from the power plant tenure (by generator company) perspective. Further, it can be seen that despite successive Governments' interventions the level of concentration in terms of output capacity ownership is almost exactly at the same position, as was the case at privatisation. This is what Carroll proposed, when he stated that after resource partitioning the number of competitors would remain at roughly the same level.

Lastly, the Dobrev's measure regressions highlight the policy underpinning that has influenced the market concentration. They show that MCM policies were positive for generator tenure (28.42), relating to three policies (equity investments, 3.59. subsidies, 13.97, and regulatory policy count years, 10.93) in terms of tenure. However, the market concentration factors were much more significant in term of their mean impact (+96.97). Looking in detail at the key factors highlights that the position of a generator with regard to its

Distance Below Market Centre (31.65), Mid-Point of its Niche Width (250.60) increased its duration (lifespan), and the Niche Width of the generator reduced the tenure (-187.42). This implies that to remain in the industry means that your MW output capacity should be lower than those at the market centre, have a high Midpoint in terms of niche width MW output and that they should have a small niche width. In a practical sense this suggests that you should operate below the market centre, but with a high mid-point in terms of niche MW output and have a small niche width overall. This could imply that if you were a specialist generator of a reasonable output capacity operating similar sized plants you could look forward to a longer life tenure. Observing the market one can see that the new specialists prefer to operate CCGTs and Renewables plants with high MW outputs i.e. new wind turbine technology.

11.8 MARKET CONCENTRATION SUMMARY

This chapter presented the market concentration analysis by means of a discussion covering relevant research, resource partitioning, data and variables, research context, model specification, market concentration results and discussion.

At the outset of this chapter, two research questions were posed and despite the early difficulties in not being able to utilise Dobrev's full model, the development of three alternative bespoke approaches (categorisation, Gini analysis, generalist / specialist regression and Dobrev equivalent regression) to understand the impact of government energy policy in the EGI.

The above showed that a 'tailed' resource space is operating and that the level of market concentration in terms of MW output has remained reasonable constant over the period of the study, specialists have shorter tenure than generalists do, MCM policies (equity investments, subsidies, and regulatory burden in terms of policy years) influence the resource space. However, a major consideration in terms of tenure is to operate below the market centre (in MW terms), with a high niche MW mid-point and a small niche-width span.

In essence, all of the above suggest that the conditions are correct for resource partitioning to operate. Therefore, confirming Carroll's theory that in a concentrated market polarisation occurs and a symbiotic relationship emerge between the generalist and specialist producers as the theory predicted. This might suggest that generators have over time sought to achieve a level of market concentration that they find profitable and acceptable whatever the government policy prescriptions attempt to do to change this.

12. SUMMARY OF RESEARCH OUTPUTS

12 SUMMARY OF RESEARCH OUTPUTS

The purpose of this chapter is to summarise the research outputs for the reader. The chapter is structure under the following headings research overview, generator and power plant founding and failure rates, generator and power plant duration of tenure, founding & failure and tenure summary, market competitiveness (viability) of generators, market concentration in generation and research summary discussion and research summary. This relates to the structure of each of the four research assessments made in the course of the research.

12.1 RESEARCH OVERVIEW

The research has focused upon evaluating the actions and impact of successive governments' use of energy policy instruments and objectives. The research findings have revealed a number of very insightful revelations and these indicate that the research outputs have provided valid information for both Governmental policy makers and corporate strategy planners in the electricity utilities

The research adopted four discrete research approaches. Firstly, the using the founding & failure rates of generators & their power plants. Secondly, generator and power plant ownership durations. Thirdly, the competitive viability of generators, and lastly the level of concentration exhibited by generators in terms of their output capacity, density and the overall impact of the energy policy instruments and objectives upon the level of industry concentration using niche width analysis. All of these factors have been assessed by means of a population-based study in the EGI between 1991-2011. These are illustrated in figure 40:

Figure 40 - Summary of Research Methods

The theoretical base for the research can be categorised using Tsang and Kwan's (1999) theory development approach, shown in table 75 (the yellow shading illustrates the theory types used):

Data Used	Theory	Same Analysis Measures	Different Analysis Measures
Same Data Set	Existing	Checking Analysis (CA): of the prior theory using the same measures and the same data / population	Re-Analysis (RA): of the prior theory using different measures with the same data / population
Same Population	Existing	Exact Replication (ER): of prior theory using the same measures, but with different data set drawn from the same population	Conceptual Extension (CE): or prior theory using different measures, and a data set drawn from the same population
Different Population	Existing	Empirical Generalisation (EG): of prior theory using the same measures, with a different data set, and different population	Generalisation and Extension (GE): of prior theory using different measures, with a different data set, and a different population
Same or Different Population	New	Theoretical Generalisation (TG): new theory using the similar measures, with a different data set, and the same or different population	Theoretical Development (TD): new theory using different measures, with a different data set, and the same or a different population

Table 75 - Tsang and Kwan's Theory Develop Approach (extended by Author)

The theoretical literature underpinning the research draws from a number of key insights. The first is Hawley's (1968) statement that the 'Diversity of forms is isomorphic to environmental variation', which Burns & Stalker (1961) and Stinchcombe (1965) extended to recognise that 'Organisation structures contain a large inertial component' that prevent rapid change and adaptation in response to changes in environmental conditions. The work by Blau & Scott (1962) suggested that an organisational ecology perspective has some differences to the ecological world because 'Unlike biological organisations, individual and organisation populations can expand almost without limit'.

Attempting to understand how organisations might thrive or decline in environments Hannan and Freeman (1972) suggested that organisational 'Fitness is the probability that a given form exists in a certain environment'. This was placed in to an empirical setting by Levins (1962, 1968) and Hutchinson (1957) who suggested that fitness could be understood by the 'Theory of Niche Width suggests that a niche is a combination of resource levels that allow populations to survive and reproduce themselves'. In this situation, Hannan and Freeman stated that 'Niche theory operates unless the duration of environmental states is short-lived, in which case resource partitioning may arise'.

Placing this into the energy policy setting, to assess how policy instruments and policy objectives relate to environmental conditions Dobbin and Dowd (1997) remarked that 'Policy creates competition in the first place by establishing the legal framework, monetary system and rules of exchange'. However, this statement was at variance with the OE founding father's views in as much as that Dobbin and Dowd identified that Hannan and Freeman (1995) were wrong. They stated that 'Regulatory directives in any population do pre-emptively affect population evolution before selectional and adaptational forces operate'.

Looking at how they evaluate the impact of energy policy suggests that an evaluation of competitive viability might be insightful using Barnett's (2008) observation that 'Competitiveness is not a property of markets, but varies from organisation to organisation'. Having considered competitiveness it is also important to evaluate how market concentration might be impacted by energy policy. This highlighted Witteloostuijin & Boone's

(2005) amalgamation of organisational ecology and industry organisation to conduct analysis of the EGI market and further recognised that Dobrev et al.'s (2002) research findings that 'Almost all important variations in market concentration can be attributed to crowding and concentration'

Drawing upon the above framework, the findings from these four approaches are summarised under the respective headings.

12.2 GENERATOR AND POWER PLANT FOUNDING AND FAILURE RATES

The founding and failure rate analysis utilised three sub types of analysis to evaluate how government energy policy had affected the founding and failure rates of generators and the electricity generation plants they owned. Given the paucity of empirical policy evaluation research in the literature, the author developed each research method[58]. The results of the policy analysis show that:

Generator Foundings - from of pool of 83 policy instruments evaluated, there are only seven policy instruments significant to generator foundings. These relate to MCM (price regulations, +0.02 mean magnitude of impact), PC (power plant planning permissioning, -0.10), PTE (Total UK economy methane emissions, +20.24. Obligations on electricity generators, +1.67. Obligations on electricity suppliers, -6.90), SOS (regulatory controls on technology implementation). The most significant in terms of impact are levels of UK methane output (which positively increased foundings), followed by controls on technology (which negatively reduce foundings). The combined magnitude of policy impact on generator foundings is +16.14 i.e. it encourages generator foundings.

Generator Failures – Three PTE policy instruments have bearing on generator failures (market exits). Whilst higher methane levels in UK encourage generator foundings, they have eight times the effect on delaying generator exits from the market, -173.15. The second policy variable related to UK Nitrous Oxide emissions, which had a 25% stronger mean impact than methane levels, +192.15. The last policy instrument was obligations on electricity generators that have +23.35 mean impact. The magnitude of policy impact on generator failures was +42.35 i.e. it encouraged generator failings. This suggests that the net effect on generators of energy policy had been slightly negative and has increased the number of failings overall in policy terms. If one looked at the full founding model, it can be seen that impact of all factors was +14.34, whilst the mean impact of all factors on failures was -164,621.75. This suggests that the impact of all policies and other variables on generator foundings are much reduced when all the other factors (predominantly capital costs of new plant are taken into account). Suggesting that the economics of new build are such that generators would prefer to remain with existing plant than undertake new builds, unless the new builds adopt Hydro, IGCC, MSW, Nuclear or Solar technologies. This is a very significant finding because it implies that all things being equal generators prefer to extend the life of existing plant rather than build new power stations. Alternatively, it could be interpreted, as suggesting that once in the industry a generator prefers to remain in

[58] Note: the figures in brackets are the mean effect i.e. the relevant coefficient multiplied by the mean value of the variable.

the market than to exit, this is confirmed by looking at the net position between founding counts and failure counts over the period of the study.

Power Plant Foundings – the policy variables remaining in the plant-founding model are MCM (equity investment schemes, -11.34. Tax incentives, +19.67) which shows that the net MCM impact on powers plants was +8.32. The PC (Obligations relating to planning permissioning, -11.04) meaning that these reduce power plant foundings. The PTE obligations (On Electricity generators, -6.18. On Energy suppliers, +1.23. Electricity users, +11.46) gave rise to a net mean impact of +6.51, suggesting that PTE policies encouraged power plant builds. In terms of the other independent variables, these did not appear in the final regression model for power plant foundings. This implied that policy was more significant on power plant foundings than on generator foundings and failures. Further, it should be noted that it was impossible to compute the power plant failures regression due to a small number of vital events in the dataset.

These above figures make sense when one looks at the industry backdrop and observes that the generator numbers have been increasing slowly, whilst the number of power plants has increased significantly.

Lastly, the detailed analysis at the policy instrument level also showed that Dobbin and Dowd's (1997) work in terms of impact Anti-Trust and Pro-Cartel policies was replicated in this part of the research, as shown in table 76:

Impact Factor / Policy Framework	Anti-Trust Policies	Pro-Cartel Policies
Founding Rate	Reduced	Increased
Failure Rate	Increase	Decreased
Market Competition	Increased	Decreased
Market Concentration	Increased	Decreased

Table 76 – Dobbin and Dowd's Findings

12.3 GENERATOR AND POWER PLANT DURATION OF TENURE

The duration of tenure analysis was undertaken for both generator and power plant tenure. Once again, because of a limited number of uncensored vital events the generator tenure could be performed but the power plant regression could not be computed.

The generator tenure showed that four of the policy objectives were present in the final model. These showed that MCM regulator pricing controls had a mean impact of +27.75, implying that MCM policies encourage generators to remain in the industry. PC planning permissioning had a mean impact of -14.01, implying that PC planning policies reduced ownership periods. PTE (UK methane emissions, -259.38. UK Carbon dioxide emissions, +80.06. UK Nitrous oxide emissions, -102.67. Net carbon dioxide equivalent emissions, -102.67. Obligations on electricity generators, +4.34) gave rise to a net impact of +531.53, suggesting that emissions and obligations on generators significantly increased industry tenure (just as Dobbin and Dowd suggested). SOS based research grants had a +91.98 mean impact, once again following Dobbin and Dowd.

The combined net effect of these is that generator tenure was +637.25, which correlated with the founding and failure analysis in as much as generators wish to remain in the industry.

12.4 FOUNDING, FAILURE AND TENURE SUMMARY

The first two research techniques highlight that generator foundings were slightly positively increased by government energy policy (and especially power plant formations), generator failures were very strongly reduced and generator duration of tenure in the industry showed an increase in the length of ownership. Therefore, overall it could be argued that the EGI marketplace was more stable.

The net mean results comparatively for the foundings, failures and durations are shown in table 77:

Policy	Class	Variable Description	Gen-Found	Gen-Fail	PP - Found	Gen-Tenure
MCM	GIS	Equity - Equity Investment			-11.34	
	GIS	Taxation - Tax Incentive			19.67	
	Regulatory	Pricing - Pricing Total	0.02			27.75
PC	Obligations	Planning and Development Total	-0.10		-11.04	-14.01
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	20.24	-173.15		-259.38
		Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent		192.15		-102.67
		Millions of Tonnes of CO2 Equivalent				80.06
		Net CO2 emissions (emissions minus removals)	0	1	551.28	809.18
	Obligations	Electricity Generators Total	1.67	23.35	-6.18	4.34
		Electricity Users Total			11.46	
		Energy Supplier Total	1.20		1.23	
SOS	GIS	Grant - Research Grant	0.01	0.996	10.79	91.98
	Regulatory	Technology - Technology Total	-6.90			
TECH	Tech. Cap.	Maximum Output (MW s.o)	-16.75			
		Other Renewables Capacity (MW)	3.27			
		Total Installed Capacity (MW)	-7.44			
CAPITAL	Plant Cost	CCGT Cost (USDmill/kwh)		-18671.01		
		Coal Cost (USDmill/kwh)		-6563.76		
		Conventional Thermal Cost (USDmill/kwh)		-1462.18		
		Fuel Cell Cost (USDmill/kwh)		-96561.95		
		Geothermal Cost (USDmill/kwh)		-203429.68		
		Hydro Cost (USDmill/kwh)		12165.57		
		IGCC Cost (USDmill/kwh)		1531.66		
		MSW Landfill Cost (USDmill/kwh)		70812.30		
		Nuclear Cost (USDmill/kwh)		63367.98		
		Solar PV Cost (USDmill/kwh)		14146.97		
FUEL	Fuel Usage	Nuclear Used MTOE	6.94			
MACRO	Core	GDP Billions (£)	7.93			
		Implied Investment Deflator	5.93			
UTILISATION	Plant Usage	Hydro Pumped Load Factor	-1.68			
TOTALS			**14.34**	**-164619.76**	**565.86**	**637.25**

Table 77 - Summary of Mean Impact Arising From Policy Vital Event Models[59]

[59] Note: the independent variables are those termed MCM, PC, PTE and SOS, the reminder are the control variables.

12.5 MARKET COMPETITIVENESS (VIABILITY) OF GENERATORS

The competitive viability of the generators was assessed using Barnett's Red Queen model[60], albeit recognising that significant adjustments had to be made to enable the EGI data to be modelled to the original framework.

The summary of the results from the market competition analysis are shown in table 78:

Foundings	Fd 1	Fd 2	Fd 3	Fd 4	Fd 5	Fd 6	Fd 7	Fl 1	Fl 2	Fl 3	Fl 4	Fl 5	Fl 6	Fl 7
Sum total number of competitor generator org-years (less own years) since 31/3/1991 and deducting the organisation-years relating to the current generator (A)		-0.3												
Sum total competitor generator org-years (less own years) /square root of # of years counted since 31/3/1991 (B)			6.0	4.6	4.9	7.4	0.0					0.4		
Sum of distant-past rivalry faced by organisation's competitors (A-B)			-3.6	-2.2	-2.3	-3.7	-10.7						-1.1	0.0
Gini of all Generator org-years (use comporgdst)				22.5		-180.3	17.7							-1301.4
Sum of number of Generator's Station org-years in each county since 31/3/1991							-0.7							
Gini of Generator's competitors org-years (use indorgdst)					21.8	191.3	14.2							1253.9
Sum total number of the individual generator's org-years (D)								-0.7	-0.6			-0.6	-0.6	-0.3
Total individual generator's org-years /square root of # of years in each County counted since 31/3/1991 (E)										-0.3				
Sum of distant-past rivalry faced by organisation's competitors (E-D)											-0.6			
Sum of number of Generator's Competitor org-years in each county since 31/3/1991								0.2						
Summary of Mean Impact	**-3.2**	**2.3**	**14.3**	**58.3**	**60.6**	**69.1**	**82.6**	**42.7**	**42.6**	**48.7**	**47.9**	**50.7**	**50.7**	**-159.1**

Table 78 - Summary of Market Competition Model Mean Impacts[61]

The use of generator organisation-year tenure based data and regressions showed that market competition viability was applicable to the EGI. Further, the seven models also showed that generator founding viability had a positive mean magnitude (showing a figure of +82.64 for the complete founding model). This indicated that competitive viability for new generators had been enhanced by government energy policy.

The use of generator failures events showed that the Red Queen failure event model theory was relevant and indicated that the Costly Adaptation and Competency Trap sub theories were confirmed by the positive value of competitive viability for failure models 1 thru 6. However, the last failure (model 7) showed a large negative impact on competitive viability (159.09). Looking at the model 7 result more closely showed that a the main difference is a greater dispersion of historical experience to competition did not increase viability (for failure rates) and in fact actually reduced the viability of generators in the EGI as a result of increased market concentration. This result is at variance with Barnett's research in the banking and disk drive

[60]The Costly Adaption theory states that for a given amount of historical competition an organisation's failure rate viability falls with the number of distinct rivals it has faced, when disaggregated into the past competitive experience faced by the generator, and the past competitive & number of past competitors faced by an organisation (see RQ models 1 & 2).
The Competency Trap theory states that generators with more exposure to competition in the distant past are less viable and generate weaker competition, when disaggregated into the generator's recent-past competitive experience, the generator's distant-past competitive experience, the generator's recent-past competitive experience & recent-past competitive experience faced by competitors, and the generator's distant-past competitive experience & recent-past competitive experience faced by competitors (see RQ models 3 thru 6).
The Myopic Learning theory - states that generators with a greater dispersion of historical experience to competition have a greater viability, when viewed from the perspective of inequality of the distribution of past-rivalry faced by the generator, the inequality of the distribution of cohorts of rivals, and the rivalry faced by the generator's competitors (see RQ model 7).
[61] Note: all variables were utilised as independent regression variables.

marketplace, wherein he found a positive story throughout. However, given that generator failures have increased, more generators have been formed and significantly more power plants have been established . This means that historical competition does not benefit failing generator viability in highly concentrated markets i.e. markets that are more concentrated and are resource partitioned. This reduction in failure viability for concentrated markets suggests that the competition in the industry has increased both in terms of founding and failing rates. However, just as Carroll proposed, the completive viability story holds unless markets become more concentrated, in which case because resource partitioning starts to operate this means a shakeout of generalist producers, resulting in more competition for failing generators as shown in founding model 7.

This highlights that Barnett's research is broadly applicable to the EGI, except for the situation wherein resource partitioning is operating. This is a hugely important discovery because it suggests that in such markets competitive viability is reduced once resource partitioning has occurred. In making this statement how can we be sure that partitioning had occurred? This will be evident from the market concentration discussion below.

This correlates with the EGI situation in which competition, in terms of more generator companies and more power plants suggests increased competition. Further, it is recognised that with increasing usage of Power Plant Agreements (PPAs) the true level of independent generators and power plants is much reduced. This suggests that in this industry resource partitioning might have occurred by a 'hidden' mechanism that is not immediately obvious to the industry regulators and outsiders.

12.6 MARKET CONCENTRATION IN GENERATION

Market concentration levels exhibited by the generators were evaluated using three techniques. The first technique used Witteloostuijn and Boone's (2006) market categorisation to determine which OE and Industrial Organisation framework was operating in the EGI. The second used Gini coefficient regression of the four types of generalist and specialist generator types as proposed by Carroll (1985). The third used Dobrev et al.'s (2002) formulation to analyse how market concentration was impacted by energy policy, by means of policy objectives and policy instrument based independent variables (as used in the earlier part of the research).

The first technique illustrated that the market could broadly be broken into Generalists who adopt either scale or scale & scope economies with single & multiple products, and Specialists who focus on low-cost or differentiation strategies in a 'tailed resource' space. This suggested that because the market was a tailed space resource partitioning might be possible.

The second technique considered the generator's power plant MW outputs and the density of power plant for generators (counts). The analytical technique followed Carroll's (1985) formulation to categorise them by their organisational form and product range[62].

Looking at the generator power plant MW outputs, the statistically significant results, in terms of tenure in the EGI market, for generators highlighted for selected organisational forms the level of market concentration was reduced over the period 1991-2011. In detail, the concentration levels showed that generalist strategy with multiple products from different subsidiaries (+5.944) had a longer tenure and specialist strategy (-1.791) had a reduced tenure, as presented in table 79.

Power Plant Assessment of Generators / Industry Tenure (Significant Results)	MW Outputs	Power Plant Density
Specialist Strategy		Reduced
Generalist Strategy with a Single-Product	Reduced	
Generalist Strategy with Multiple Appeal Single-Product	Increased	
Generalist Strategy with Multiple Products from Different Subsidiaries	Reduced	Increased

Table 79 - Summary of Generalist / Specialist Organisation Type Tenure

Table 76 shows that specialists had a reduced tenure in the industry and generalists had an increased tenure when viewed from the power plant tenure (by generator company) perspective. This could be explained by understanding that many firms in recent years had built renewable plants (predominantly wind farms) and once they started operating the generalists purchased them. This suggests generalists do not like risk and do not like innovation. Perhaps this suggests that the specialists have differentiated themselves in the environment (resource space) by designing and building renewables plants and leaving the operations of these to generalists. This would make sense because under the Renewable Obligation the Big Six energy suppliers have been obliged to source an increasing proportion of their electricity from renewables generation facilities.

The third technique assessed how government energy policy objectives had affected the founding and failure rates of generators in the EGI from a market concentration perspective. This analysis showed that a 'tailed' resource space was operating and that the level of market concentration in terms of MW output had

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[62] Generalist Strategy with a Single-Product – a producer makes only one product that is designed to appeal to all consumers. The research includes generators that adopt a traditional generation fossil fuel based technology that utilises multiple fuels types that are only fossil fuel i.e. coal, gas or oil
Generalist Strategy with Multiple Appeal Single-Product – a producer makes a single product but it is designed to appeal to multiple diverse segments of the audience. The main problem with this strategy is that it can be difficult for organisations to maintain competencies that appeal to all segments concurrently. The research has categorised generators that use multiple fuel types that include both fossil and renewable fuels
Generalist Strategy with Multiple Products from Different Subsidiaries – the producer makes multiple products that appeal to different segments of audience, using a holding company approach and a Uni-product strategy from each sub entity. The difficulty is similar to the approach above, but the adoption of a peripheral mimicry required by the environment and the decentralisation can offset some of the difficulties. The study includes generators that use multiple fuel types, e.g. fossil and renewable and also adopt a holding company form
Specialist Strategy – This is designed to appeal to only one segment of the audience. The study has defined specialists as those generators that adopt a single fuel sub-type for all their generation assets

remained reasonably constant over the period of the study, specialists have shorter tenure than generalists do, MCM policies (Equity investments, Subsidies, and Regulatory burden in terms of policy years) influence the resource space. However, a major consideration in terms of tenure is to be able to operate below the market centre (in MW terms), with a high niche MW mid-point and a small niche-width span.

In essence, all of the above suggests that the conditions have been correct for resource partitioning to operate. Therefore, confirming Carroll's theory that in a concentrated market polarisation occurs and a symbiotic relationship can emerge between the generalist and specialist producers as the theory predicted. This might suggest that generators have over time sought to achieve a level of market concentration that they find profitable and acceptable whatever the government policy prescriptions attempt to change this.

12.7 RESEARCH SUMMARY DISCUSSION

In developing the research summary arising from the research identifies a number of important observations. The first is that of the five policy objectives (MCM, PC, PTE, SOS, and SROEG) only four had bearing on foundings and failures of generators and power plants and the generators' tenure in the industry i.e. SROEG did not appear in the models.

Secondly, if we look at the policy objectives, instruments and other significant variables showing influence from the 83 tested are presented in table 80:

Policy	Class	Variable Description	
MCM	GIS	Equity - Equity Investment	Slightly negative for power plant foundings
MCM	GIS	Taxation - Tax Incentive	Slightly positive for power plant foundings
MCM	Regulatory	Pricing - Pricing Total	Slightly positive for generator foundings and tenure
PC	Obligations	Planning and Development Total	Slightly negative for generator and power plant foundings, and generator tenure
PTE	Emissions	Methane (CH4), Millions of Tonnes of CO2 Equivalent	Slightly positive for generator foundings and very negative for generator failures and generator tenure
PTE	Emissions	Millions of Tonnes of CO2 Equivalent	Very positive for tenure
PTE	Emissions	Net CO2 emissions (emissions minus removals)	Extremely positive for power plant foundings and generator tenure
PTE	Emissions	Nitrous Oxide (N2O), Millions of Tonnes of CO2 Equivalent	Very positive for failures and very negative for generator tenure
PTE	Obligations	Electricity Generators Total	Slightly positive for generator and power plant foundings, and generator tenure and slightly negative for power plant foundings
PTE	Obligations	Electricity Users Total	Slightly positive for power plant foundings
PTE	Obligations	Energy Supplier Total	Slightly positive for generator foundings
SOS	GIS	Grant - Research Grant	Slightly positive for generator foundings
SOS	Regulatory	Technology - Technology Total	Slightly negative for generator foundings
CAPITAL	Plant Cost	CCGT Cost (USDmill/kwh)	Massively negative for generator failures
CAPITAL	Plant Cost	Coal and Conventional Thermal Cost (USDmill/kwh)	Very positive for generator failures
CAPITAL	Plant Cost	Fuel Cell Cost (USDmill/kwh)	Majorly negative for generator failures
CAPITAL	Plant Cost	CCGT, Geothermal Cost (USDmill/kwh)	Massively negative for generator failures
CAPITAL	Plant Cost	Hydro and Solar Cost (USDmill/kwh)	Massively positive for generator failures
CAPITAL	Plant Cost	IGCC Cost (USDmill/kwh)	Very positive for generator failures
CAPITAL	Plant Cost	MSW, Nuclear Cost (USDmill/kwh)	Majorly positive for generator failures
FUEL	Fuel Usage	Nuclear Used MTOE	Slightly positive for generator foundings
MACRO	Core	GDP Billions (£)	Slightly positive for generator foundings
MACRO	Core	Implied Investment Deflator	Slightly positive for generator foundings
TECH	Tech. Cap.	Maximum Output (MW s.o)	Slightly negative for generator foundings
TECH	Tech. Cap.	Other Renewables Capacity (MW)	Slightly positive for generator foundings
TECH	Tech. Cap.	Total Installed Capacity (MW)	Slightly negative for generator foundings
UTIL.	Plant Usage	Hydro Pumped Load Factor	Slightly negative for generator foundings

Table 80 - Summary of Policy Objectives, Instruments and other significant variables showing influence

This summary shows the impact of successive governments' energy policies on the generators, their power plants and generator tenure in the industry. As can be seen the most significant influence on generator foundings and failures has been related to capital costs. In effect showing that energy policy interventions have a very limited influence on generator decision making in the context of other environmental factors.

Having said that, in terms of policy the key policy instruments are outlined in table 81 (nos of policies):

Measure	Policy Objectives Analysis	Duration Analysis	Market Competition (Generator Viability)	Market Concentration
Generator Founding Rates	MCM (1), PC (1), PTE (3), SOS (1)			
Generator Failure Rates	PTE (3), SOS (1)			
Generator Duration in EGI	PC (1), PTE (5), SOS (1)	MCM (1), PC (1), PTE (5), SOS (1)		MCM (2)
Power Plant Founding Rates	MCM (2), PC (1), PTE (1), SOS (1)			

Table 81 - Overall Policy Analysis Summary

Looking at the above, and reading the results from the research outlined above, it can be seen that the broad policy objective formulation was unrealistic. The use of the MCM, PC, PTE, SOS and SROEG was valid, but to expect that all instruments would operate in the same manner for each measure was too detailed and unrealistic. Specifically, the results have shown that not all instruments are significant in the final analysis and further that at the instrument level some act positively and some act negatively. Therefore, whilst the idea was valid on reflection and the benefit of hindsight this could never have been possible.

Notwithstanding this, the research has identified the key policy instruments (as well as the policy objectives) and has identified the magnitude and effect that arises from their use in four different frameworks. This is highly informative and has moved the techniques for empirical policy evaluation onward.

The third observation relates to the use of the Red Queen theory to test market competition using viability has shown that Barnett's model can be made to operate in a different country and with significantly different control variables. It also has shown that viability has increased in-line with the sub theories he proposed in that all cases, except for failure viability, the models takes account of industry concentration i.e. in concentrated markets, the industry's organisational experience can yield increased tenure. This will require further analysis to determine the exact nature of the finding.

The fourth observation concerns the three market concentration analysis measures showed that Witteloostuijn and Boone's (2006), Carroll's (1985) and Dobrev et al.'s (2002) theories have been indicative at analysing and proving the occurrence of resource partitioning in the generator marketplace.

Standing back from this, and utilising my knowledge of the industry, the author believes that the analytical results obtained can also be validated from the understanding of the industry dynamics observed during the research of the industry.

At this stage, it could be stated that in summary the research has proved very informative from the perspective of the detailed outputs, and as importantly in terms of being able to confirm the research theories, answer the research questions and hypotheses. It has also been pleasing to make use of Barnett's, Dobbin and Dowd's, Dobrev et al.'s and the organisational ecology theory base in a very practical and relevant manner.

12.8 RESEARCH SUMMARY

The purpose of this penultimate chapter was to summarise the research outputs for the reader. This chapter was structured under the headings of research overview, founding and failure rates, duration of tenure, founding & failure and tenure summary, market competitiveness (viability), market concentration and research summary discussion. The above has provided a synopsis of the key research findings and outcomes from the detailed work.

13. CONCLUSION

13 CONCLUSION

This concluding chapter has been structured under the headings of; contribution to theory, contribution to academic practice, contribution to business practice, contribution to my work, further research, reflective thoughts and final thoughts.

13.1 CONTRIBUTION TO THEORY

The energy policy evaluation is encapsulated by the energy policy research question that posited how public energy policy affects generator ownership durations in the electricity sector. The energy policy research theory that was developed highlights that UK energy policy targets five broad policy groups (maintaining competitive markets, protecting the consumer, protecting the environment, security of energy supply and sustainable rate of economic growth) which are related by policy class, policy nature, macro-economic factors, electricity prices, targeted grants, and government funding stimuli when enacted in a market environment and measured by the power plant failure and founding rates, and the ownership durations of generator companies. The result of the research has shown that it is possible to use OE research methods and techniques to understand how generators respond to energy policy objectives and instruments. This statement is based upon the results shown in chapters 8 through 11.

This research work is particularly valuable, because it has identified techniques to evaluate policy and has identified the policies that are most definitive in terms of inducing changes in generator behaviour. The most important contribution of this research work is that it has identified a new set of techniques to evaluate public policy. The analysis was undertaken from both a founding and failure density, and a duration of tenure analysis. This approach has not been observed from other literature within either the organisational ecology or social science fields.

Once the energy policy instrument and policy objective factors had been understood, attention was turned towards evaluating what impact that both energy policy objectives (i.e. collections of policy instruments) on the electricity marketplace. This considered the impact on the level of competition and the level of market concentration. Interesting. It was found that both had increased, albeit with some caveats that will be outlined below.

The contribution that this work makes to academic theory can be summarised thus:

- Organisational ecology is able to provide an invaluable set of tools for social scientists. The theory, techniques and methods are of very significant benefit when conducting population studies and are most relevant when evaluating adaptational and selectional analyses (Barnett and Pontikes, 2005)
- Although many organisational ecologies do not subscribe to the use of 'Duration' analysis (although the technique is widely used in epidemiological fields), the application of the technique in this research has worked reasonably. This provides a further dimension of analysis that complements an organisational ecologist's traditional armoury of founding, failure and growth rates. The results supporting this statement can be found in chapter 9
- In-line with Dobbin and Dowd's (1997) statement than public policy is a more significant environmental factor that the adaptational and selectional forces. This position is at variance with the views held by Hannan and Carroll (1995) as cited by Dobbin and Dowd i.e. that public policy is of little importance. This statement is posited in recognition that the generator and power plant founding, failure and tenure regressions have a predominance of policy variables compared to the control variables as presented in the section entitled '7.3 data and variables'
- Following Burns & Stalker (1961), Stinchcombe (1965) 'Organisational structures contain a large inertial component'. The key contribution is that despite very significant changes in policy over the twenty-years of the study energy policy interventions have had relatively little impact on the basic structure of the EGI when viewed from the a Gini coefficient perspective on output capacity amongst generators as shown in figure 39. This also confirms Burns and Stinchcomb's observations about organisational inertia
- It is important to recognise that the base of organisational ecology theories that underlie this research do not exist in isolation - they overlap and it is important to try and synthesize them. This remark arises from the fact that the Red Queen failing model 7 appears to be at variance with Barnett's findings, although all other models confirm his findings[63] and this highlights that there may be some other factors at play that will need to be the subject of further research
- Lastly, and most importantly, the research has demonstrated a wide-ranging application of academic theory as defined by Tsang and Kwan's (1999) framework. Arguably, the use of founding, failure and duration based techniques to evaluate policy objectives and policy instruments is the work's most important contribution.

[63] Albeit that if one has to overlook the lack of statistical significance with the results, that in a large part must be attributed to the very limited observations in the tested models, given that with the earlier models did show statistical significance.

13.2 CONTRIBUTION TO ACADEMIC PRACTICE

A tabular presentation of the contribution to academic practice of both the author and wider community is indicated by the five targets that were set for the research, as shown in table 82:

Research Target	Description
New Organisational Dynamic Knowledge	Studying the impact of renewables specific energy policy on a population of organisations that has been under the same form of ownership, i.e. privately owned, will yield new EGI organisational knowledge
New Technical Impact Knowledge	EGI players have been required to implement new technology that has a negative price/performance curve (i.e. Renewables are more expensive than the generation technologies based on fossil fuels). The study will yield new knowledge about the impact of forcing technology with a negative cost curve upon an industry
New Electricity Policy Knowledge	Previous studies by Russo, Sine, and Sine & Brandon were in the US setting and considered ownership of generators under both public and private ownership. This study will provide insight into how policy instruments influence the EGI and will also provide new knowledge
New Geographic Knowledge	in a European context in the EGI – most organisational ecology studies have focused on the US, and those that have not (and in this domain) are at least ten years old
A Multi-Method based Study	Unlike most research studies, this research is conceptually and methodologically multi-dimensional. The research is underpinned by the development and use of multiple theories, empirical techniques, and research methods that utilise data drawn from 2,000 power plant vital events and 8,000 organisational vital events over the period 1991-2011.

Table 82 - Research Target Achievement

In further detail, the research has contributed to academic practice in a variety of ways. The first is the development and application of new energy policy modelling techniques. This work has developed a set of techniques that assist in the study of public policy instruments, energy policy instruments, corporate demography, and key data relating to electricity generation (i.e. electricity prices, GHG emissions, government grants incentives and funding schemes, macroeconomic data, power plant activity, power plant capacity, power plant capital costs, power plant fuel usage, power plant levelised costs, power plant load factors, and power plant ownership). These techniques clearly have some potential in terms of their application to other industries and policy areas – they are not unique to the EGI. The key relevance is to long-range population based studies where industry-wide data sets are available. This claim is based upon the fact that the research has collected a very wide set of dependent, independent and control variables and has been able to build valid models as set out in chapters 8 and 9.

The research has been wide-ranging both in terms of its context, including public policy, competition and regulation, energy policy, climate change, environmentalism, electricity generation and renewables and in its methodology encompassing organisational ecology, corporate demography, event history analysis and survival statistics. The thesis has integrated energy policy and its impact in the face of renewables technology, in terms of the organisational form of new players, understanding how technology innovation is applied to end-users of technology and the electricity generators' responses to new technology and its impact on market competition and market concentration.

The thesis concludes that UK government energy policy has overlooked the fact that most of the large electricity generation assets were a legacy of the former CEGB and the electricity industry was effectively using assets that were financially 'written off'. The focus on CCGT plants and taxpayer subsidised renewables is another factor that has been overlooked by energy policy, as evidenced by the recent difficulty in getting generators to commit to new nuclear. The last consideration that has been absent from recent government energy policy is the fact that regulators have moved from their earlier position of attempting to control prices and encourage competition into a new framework in which they dictate the technology that generators must use to produce electricity. This is a very interesting and very worrying development. Specifically, the concern is that the government has moved from owning the electricity industry into a position in which it has no direct risk, no capital invested and yet is able to dictate what type of fuel and generation plants generators can use.

In conceptual terms, the contribution to academic practice highlights that:

- The key issue with energy policy is that it in analytical terms it cannot be distilled down to five key policies (MCM, PC, PTE, SOS and SROEG) in a uniform manner. The study has shown that each of the underlying instruments can act in different ways. This means that policy must be viewed in a portfolio context such that the underlying instruments will act in a positive and negative sense to give rise to a policy objective amalgam. Whilst it may be better to utilise a larger number of discrete instruments one must be careful to recognise the statistical rules between the number of observations and number of variables
- Recognising the above it is also important to observe that, despite very dramatic changes in energy policy over the period of the study, in the end it is plant economic factors relating to capital cost that have had a much greater mean impact in the founding model than any of the policy variables
- This study has highlighted that typically commercial entities will always be a jump ahead of policymakers in terms of maximising their profit and well-being. This study has observed that although generator companies have complied with the policy initiatives, they have also increased prices to 'factor in' the additional costs and also have increased the extent of hidden collusion by utilising Power Purchase Agreements between themselves
- Lastly, the research has focused on the electricity generation industry, a sector that has been woefully under-researched since the industry's privatisation in 1991. As stated above, there is very limited literature dedicated to whole economy empirically-based policy instrument evaluation

In recognising the conceptual contributions to academic practice, it is also important to note the limitations and constraints that have been apparent from conducting the study. This first is the high upfront investment in the data collection that longitudinal studies require before any outputs are obtained. Secondly, studies of this nature rely on extensive analysis and coding of policy documents. Finally one may find that after all of the time and effort has been expended the number of valid observations is few and there is no more data to be collected and at that point one has to reduce one's expectations in term of what is possible.

In a very pragmatic sense, the following comments may be of some value for those who follow this research approach in future:

- Researchers should ensure that their supervisor has a strong interest in the topic before embarking their research in a new industry, with new theory and new methods to minimise the effort required to undertake a population based study
- Researchers should ideally seek funding because this helps to ensure greater alignment with the University 'REF' measures in terms of the topic of the research. Such an adherence will also help to ensure a more timely completion to the research because with research grant funding there is a fixed end-date i.e. the funding runs out
- Researchers should undertake a full course in structured methods that are related to their chosen field before embarking on their research to ensure that they are fully prepared before attempting to conduct their analysis
- Replication studies should be adopted with care because in population-based study it is much harder to fully replicate the research method in different industries and environmental contexts
- In conducting organisational ecology based studies researchers should seek a timeline in excess of 40 years to ensure that sufficient uncensored vital events could be utilised. This should have a minimum of 150 uncensored events
- Lastly, researchers should be very parsimonious and selective in terms of the number of variables and factors they collect and adopt. They should also carefully filter and use those that have bivariate significance at the 99% and 95% statistically significant levels.

13.3 CONTRIBUTION TO BUSINESS PRACTICE

The two main groups that could potentially benefit from the work undertaken in this research are the policymakers (Department of Energy staffs) and the strategic planners employed by the generator companies. The key insights from the research:

- The energy policy backdrop in the UK continues to be almost exclusively baselined on the recommendations arising from the Royal Commission on Environment Pollution Report (2000). Space prevents a full presentation of this reconciliation, but the working papers provide support of this finding
- The techniques and measures adopted in this research provide an important framework and approach that can be used to support strategic analysis. I.e. enabling generator owners to recognise the relative importance and magnitude of the policy and control variables on founding an d failure rates of new competitors and their likely tenure in the industry
- Assessed from market concentration and policy instrument regression it can be seen that energy policy does not make much difference in practice if generators can 'work around' the policymakers intentions i.e. by loading the increased obligations and demands onto the consumer
- Despite many interventions by policymakers, energy utilities have become very adept and finding alterative measures to overcome the policy interventions, these include electricity price rises and 'hidden' collusion using Power Plant Agreements. The latter being a requirement stipulated by banks to enable renewables generators to obtain capital investment financing
- At the conclusion of the study, one wonders if the EGI to-date has relied on old thermal plants that were acquired at privatisation (i.e. sunk costs to new build dilemma), CCGT and subsidy based renewables. With

the onset of the LCPD, it will be very interesting to see whether the generators are prepared to make significant new power plant investments at the same time as government promises of renewables subsidies are being cut and the political opposition party. I.e. Labour party have stated that any future Labour government would mandate a two-year electricity price freeze and undertake a competition inquiry. Specifically, when you have given major price uncertainty, in effect price controls, it will be very curious to see what happens next. One could speculate that at this moment energy policy might have effect that is rather more dramatic.

In terms of the specifics of the energy policy instruments and objectives associated with generator or power plant foundings, failure and duration) , the following are the key instruments:

- Maintaining Competitive Markets (MCM) – policies relating to government equity investments, tax policy and regulatory price controls
- Protecting Consumers (PC) - policies relating to planning permission and building control
- Protecting The Environment (PTE) - policies relating toCH4, CO_2 and N_20 emissions and regulatory obligations on electricity supply chain (gen, suppliers and users)
- Security of Supply (SOS) – policies relating to research grants and regulatory controls on technology.

The variables that related fuel usage, power plant capital costs, technology capacity, utilisation and economy level measures:

- Increases in the fuel equivalents usage by Nuclear facilities increases generator founding rates
- Higher Plant costs for:
    - CCGT, geothermal, and fuel cells reduce the generator failure rates
    - Hydro-electric, IGCC, and solar, increase generator failure rates
- Technology capacity in terms of
    - Max MW output, Total installed capacity are both negative for generator founding rates
    - Renewables MW output is positive for generator founding rates
- Increased pumped storage utilisation is negative for generator founding rates
- Increases in GDP and Implied Investment deflator numbers increase generator-founding rates.

In essence, it is anticipated that energy policymakers and strategic planners, within the electricity generation companies, will find the research of interest as they seek to gain a greater understanding of the policy environment, the significance of technology change and the industry response to policy and technology change. This research will allow them to gain a greater understanding of how they and their competitors should respond to policy, regulatory and competitive forces.

13.4 CONTRIBUTION TO MY OWN WORK

As an engineer by background, and a management consultant by occupation for the last thirty years, and more recently a university lecturer, there are a number of areas in which the doctoral research has provided benefit and insight to me.

Undertaking a doctoral research programme at the same time as being a lecturer has given me a much greater insight into my professional practice as an educator. It has raised my understanding and awareness of the teaching and learning process by being a student and a lecturer concurrently.

I have learnt how to postulate research questions, develop theory, develop testable hypotheses and develop testing methods and techniques that can use secondary data to derive insight and observation.

I have learnt how to perform corporate demography, record vital events, and use survival analysis techniques to derive understanding from direct and indirect data.

I have understood the business, technology and operating environment of the electricity utility business over a longitudinal study.

Lastly, I have gained a much better understanding of the how policy and regulation is formed, developed and implemented in modern societies.

13.5 LIMITATIONS TO THE RESEARCH

As with all novel research it is important to provide the 'health warning' with respect to the findings and results arising from this research. The first comment is that the study is at variance with many of the studies that provide the foundation to the organisational ecology field in as much as the study is only twenty years, whereas many span 1oo years or more. This proved to be an unexpected limitation in terms of the number of valid observations over the twenty-year span of the study.

Secondly, it should be noted that the market competition research method did not show any statistically significant variables from the regressions. Therefore although information has been derived this carries some risk of misinterpretation.

Thirdly, the study has not been able to research the linkage between the market competition and market concentration factors within the available time.

Lastly, the technical events related to power plant or technology upgrades were not utilised in this study, although they were collected. I.e. this study has focused on corporate demography and has not researched the changes to power plants whilst under the same ownership.

Despite the comments above, it should also be noted that all of the available data from the EGI over the period since privatisation have been collected i.e. there are no generators or power plants omitted[64].

[64] I.e. all power plants with greater than 250,000 Watts of output capacity were recorded.

13.6 FURTHER RESEARCH

The study has been ambitiously broad in terms of its consideration of politics, regulation, environmentalism and technology. It is therefore not surprising that the data collection and analysis has produced many more work threads than could possibly be utilised in a core thesis of 100,000 words. Indeed, the earlier data volume contained 500,000 words and throughout the course of the research phase, some 1 million words were produced.

Areas that warrant detailed consideration in terms of future research include:

1. There were two types of vital event collected; the first was related to the business events i.e. power plant acquisition, divestment etc. Moreover, the second related to technical events such as upgrades, fitting of emission control technology etc. The current research has only utilised the former vital event type. Analysis and use of generator technical investment behaviour against the government's energy policy would be a very interesting line of research and would not require any further data collection
2. The vital events analysis used elapsed durations of ownership between the individual corporate demographic events. A further analysis that used the growth rates of change would also be an interesting line of research
3. The current work has focused on historical analysis, but the survival analysis techniques may also be used for predictive forecasting
4. The policy analysis has been conducted at the level of the government's broad energy policy framework, and did not specifically attempt to look at the impact of each policy instrument per se. A more detailed study could focus on the individual instrument behaviour in a finer level of detail
5. Organisational ecology makes extensive use of the concepts of variation, selection, retention and struggle, as well as adaptational and selectional forces. These concepts could be researched further in the context of the electricity generation industry
6. Although time did not permit detailed investigation, Power Plant Agreements (PPAs) might represent a form of hidden collusion between generators, albeit that it is the banks that have mandated this arrangement. Use of Structural Hole theory (Burt, 1980, Burt, 1992, Burt, 1997) and Social Network Analysis would be very informative if the data could be obtained
7. The current research has used the organisational form, resource partitioning, core OE theory fragments along with extensions proposed by the Red Queen (Barnett 2008), policy and competition (Dobbin and Dowd, 1997) and Witteloostuijn and Boone (2006). Integration of these theory fragments and theory fragment extensions would be potentially a very worthwhile contribution to practice
8. Further integration of organisational ecology and industrial organisation as initiated by Witteloostuijn and Boone (2006) might also be informative to widening the theory base and techniques
9. New researchers entering the field of organisational ecology find the field very difficult and confusing to understand and embrace. There is a pressing need for teaching and learning aids to reduce the steepness of the learning curve for new entrants
10. One of the most difficult areas in the research was trying to understand the research and statistical methods that organisational ecologists use in their work. For new researchers there is a significant need for a research methods handbook to be published so that this information can be shared
11. A further area of research would be to understand whether the insights from this study of generators apply to the transmission, distribution and supply segments of the electricity industry and to other utilities such as airports, gas, railways and water.

These activities would provide a very informative and illuminating route map for further academic and applied research.

13.7 REFLECTIVE THOUGHTS

The first aspect is to 'look-back', and reflect, upon the journey and the route used for the preparation of this thesis. The route I selected for my study was to follow a DBA programme. At the inception of my studies, I thought this would allow me to transition into the 'academic way', and ensure that I was fully prepared for the research phase.

On reflection, I think that the DBA approach was actually the incorrect approach for me. Sadly, although the taught phase consisted of six modules (Introduction to academia, marketing, organisational ecology theory, organisational theory application, research methods, and relevance & rigour), and the preparation of a detailed research proposal (transfer document) it did not fully prepare me for what would come during the research phase. For example, it did not cover public policy, energy policy, environmental policy, climate change, EGI industry setting, traditional & renewables electricity generation technology, survival statistics, nor did it cover theory development. Further, the level of supervision provided on the DBA programme is significantly lower than that of the PhD programme, the inevitable consequence of this was that I had to do a great deal more myself. Although this in the end turned out to be positive, in as much as I had to discover things for myself, I recognise that this was not the most efficient way to learn from both a time and a fee cost perspective.

Therefore, in many ways the taught phase of the DBA was somewhat irrelevant to the research phase that was to follow. If I were commencing doctoral studies, again I would opt for a PhD and would not waste my time and funds on an expensive route to obtain a doctorate, especially given that I have been advised that thesis I have prepared is actually more akin to a PhD than a DBA in any event.

Despite this, the research phase of my work has entailed significant personal development, research and study to teach myself and undertake the following – of which I was entirely ignorant before commencing the doctoral programme:

1. Competition policy and regulatory policy theory including market and public policy failures
2. Public policy (formulation, implementation and management) , policy instruments and UK energy policy between 1900-2011
3. Environmental policy Climate change including the Club of Rome, Brundtland Commission, Kyoto Protocol, Royal Commission on Environmental Pollution, and Mandatory & voluntary emissions trading registries and systems
4. Organisational Theory and in particular the following theory fragments organisational form, technological innovation, niche width, 'Red Queen' theory, and resource partitioning. These theory fragments have been synthesized and extended to enable a practical realisation of the socio-cognitive concepts
5. Organisational dynamic methods including event series & history analysis, vital events (founding, growth and failure events)

6. Survival statistics and the use of the STATA software with emphasis on non-parametric, semi-parametric and parametric analysis techniques
7. Theory Development focuses on classification, categorisation, theoretical building blocks (concepts, constructs, and variables), theoretical components (propositions and hypotheses)
8. Data collection, cleansing, transformation and storage methods for both twenty years of power plant & generator company dependent variables, independent variables and control variables).

Looking at the eight phases of work above, one could be forgiven for thinking that there was a highly structured and well-designed project plan used to structure and effect the learning and thesis development. This must however be placed into the context of 'Scientific method' and 'Actual Method' as presented in figure 41:

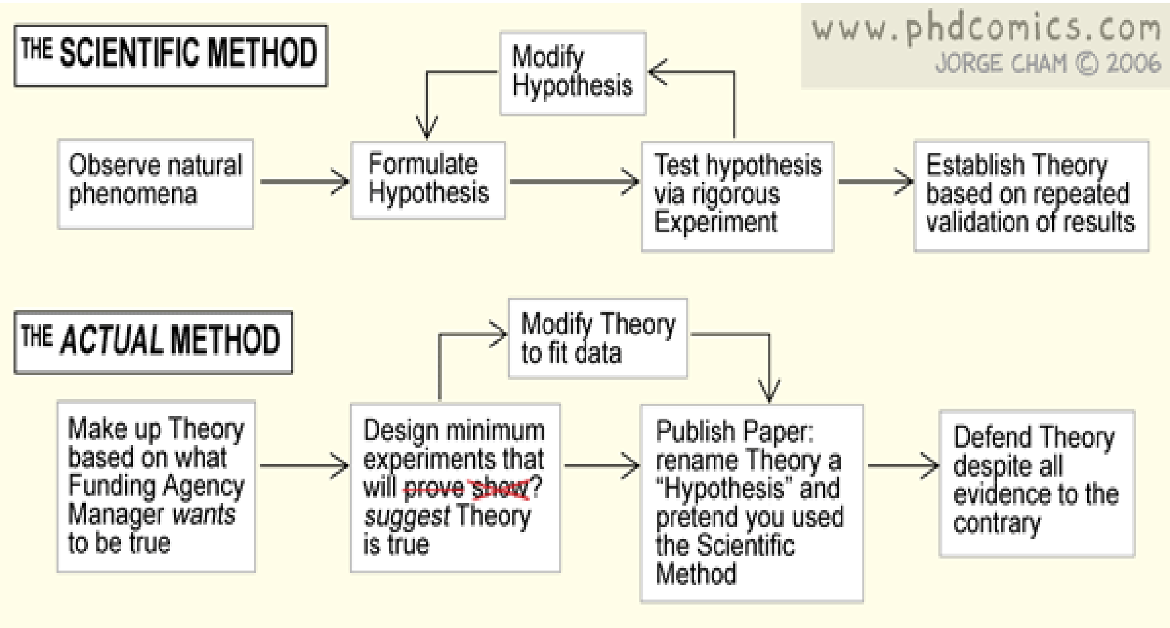

Figure 41 - The Scientific Research Method versus the Actual Method

Despite my engineering background and training, I must confess that I am appalled and embarrassed to admit to the fact that my research adopted the 'actual' method. Thus, the highlighted structured and logical nine-phased approach was predominantly run in multiple parallel iterations and regressions. Whether or not a higher level of doctoral supervision might have avoided this uncertainty is unknown, but nevertheless somehow, I believe that I have 'come through' the process. However, I also recognise that the process and output may not yet be polished and that the research journey in many regards is not yet complete.

13.8 FINAL THOUGHTS AND EVALUATION OF THE WORK

Although the approach may have been convoluted and chaotic, and the journey has been steeped in frustration and despair, looking at the research phase of my work and the results I am very proud of what I have achieved. This is especially the case since I have been 'left to my own devices' and pushed to make my own way and develop my own approach. Whilst this may not have been the most efficient learning approach, I have nevertheless done it and achieved a result that I am truly delighted with in terms of my own understanding and learning.

At the same time, I recognise that some 'hardened' organisational ecologists may take issue with some of my approaches and presentations. However, the relative scarcity of critical vital events (founding, growth and failure rates) within the data set that was available, despite the data set having 2,000 power plant and 8,000 generator vital events, provided a significant constraint.

This is particularly relevant because tests of many of the hypotheses originally constructed had to be abandoned due to lack of observations or collinearity of the variables. This meant that I had to adopt alternative mechanisms to draw inference and value from the available data. I make no apology for this and would highlight that after having viewed the literature, I believe that my techniques and approaches create new knowledge and insight into an under researched field by use of techniques that have never previously been applied to the evaluation and impact of public energy policy.

In conclusion, I am of the view that the research I have undertaken in terms of the development of the theories, hypotheses and the testing frameworks has been a significant and rewarding challenge in an area that is under researched.

The most definitive and important conclusion is that the work has proven that research techniques based on organisational ecology can be used very effectively to understand the impact of policy, technology change and industry response to public policy measures promoted and mandated by government, certainly in the electricity generation industry and quite possibly more widely. This is the greatest achievement and benefit from three years of in-depth endeavour by the author. From my viewpoint at least, I am delighted with the results and insights that I have gained.

14. BIBLIOGRAPHY

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