Growth Rates of State-owned and Private Enterprises in China and Their Innovation Strategies

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Finance

Durham University Business School

University of Durham

2015

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Abstract

Based on Schumpeterian model, new models are constructed to analyse growth rates of SOEs, LPEs and SMEs and their innovation strategies. Average growth rates of each type firms are divided into two parts: (1) increase rates of each type firms' scale; (2) technology-led growth rates. The order of average growth rates of each type firms is determined by whether their superiorities in some determinants of growth rates could prevail over their inferiorities in other determinants. And proportion in total production of firms with the highest growth rate increases over time, whilst proportion of firms with the lowest growth rate decreases over time. Proportion of firms with medium growth rate decreases over time if the difference between the highest growth rate and the medium growth rate is larger than the difference between the medium growth rate and the lowest growth rate. In terms of innovation strategy, at the early stage of development, imitating advanced technology from technology frontier is a better choice than undertaking R&D activities for each type firms. For one certain type firms, if the required least advantage in technology research capability to cover per unit of differences in technology gap can be satisfied, the imitation rate of this type firms is lower. In addition, if technology-led growth rates of each type firms are up to a certain level and innovation research capability could satisfy the lowest requirement, imitation rates will decrease in order to improve technology-led growth rates. Based on the model with endogenous step size of technology improvements, trends of preferences of imitating advanced technology is generally determined by technology gap and research labour.

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SOEs	State-Owned Enterprises
PEs	Private Enterprises
LPEs	Large-sized Private Enterprises
SMEs	Small-medium-sized Private Enterprises
IPR	Intellectual Property Right

Declaration

The content of this doctoral dissertation is based on the research work completed at Durham University Business School, UK. No material contained in the thesis has previously been submitted for a degree in this or any other university.

Acknowledgement

I would like to express my gratitude to all those who helped me during my PhD studies.

First, my deepest gratitude goes to Professor Guido Cozzi, my supervisor who, with constant guidance and extraordinary patience, gave me great help in all stages of my thesis writing by providing me with suggestions of great value and inspiring new ideas. Without his help, this thesis could not have been completed.

Second, I would like to give sincere gratitude to Dr. Thomas Renstrom, who reviewed the process of my research. I am also pleased to acknowledge Dr. Angus Chu, who gave me valuable advice when I lost my research in the early stages of my PhD.

I would like to give my thanks to my beloved parents for their consistent encouragement and great confidence in me. Without their support, I could not have finished my PhD.

To My Parents

Chapter 1 Introduction

In last 30 years, China has experienced miraculous economic growth, however, the sustainability of this growth is questioned because of its lower growth in factor productivities (Krugman, 1999). In fact, after maintaining the highest economic growth in the world for 30 years, China now is considered to be entering the 'New Normal' by officials, which means that China's economic growth is at a medium-high speed rather than previous high speed. The economic reform is regarded as a new engine of China's economic development in 'New Normal' in the *Report on the Work of the Government 2014.* In fact, economic reform began China's high-speed economic growth 30 years ago.

The privatisation of state-owned enterprises (SOEs) is an important part of China's economic reform that happened in third phase (after mid-1990s) (Liu, 2010). In this phase, the policy 'grasping the large and letting go of the small' was implemented. SOEs in less important sectors and small SOEs were privatised. However, in strategic sectors, SOEs function as an indirect tool that allows the government to manage the economy through their market power. Large SOEs dominate the domestic market and are more competitive in the worldwide market (Eilliot and Zhou, 2013; Hsueh, 2011).

In general, privatisation is one of three core concepts of the fundamental institutional reform that caused China's high economic growth (Xu, 2011). Private enterprises (PEs) have greater productivity than SOEs (Jefferson et al., 2000; Sachs and Woo, 1997; Plane, 1992, 1997; Su, 2006) and play an important role in China's economic growth (Allen *et al.,* 2005; Huang, 2008). And in the same time, SOEs still contribute a lot to China's economy because of their externality effects.[1]

Nowadays, China's government is preparing for the second reform of SOEs. In the Jinlin Province in 2014, President Xi Jinping provided standards for judging the reform of SOEs which are known as 'three benefits to': (1) maintaining and increasing the value of state-owned capital to society; (2) increasing the competitiveness of SOEs; (3) enhancing the effects of state-owned capital on society. According to the 'three benefits to' standards, the objective of the second SOE reform is to improve the competitiveness of SOEs in the market, particularly the international market, and increase their effects on China.

Another important impact of the 'New Normal' is that China's economy is increasingly driven by innovation, which is gradually replacing blind input and investment. The importance of innovation to economic growth is stressed by the government in official occasions. There is a trend in China of transitioning from

[1] Such as Ram, 1986; Jefferson, 1998; Jalilian and Weiss, 1997; Doamekpor, 1998: Bai *et al.,* 2000, 2006; Lin *et al.,* 1998, 2003; Hirschman, 1958; Holz, 2011.

imitation to innovation (Guan *et al.,* 2009).

But in terms of firm level, the strategies for technology improvement of SOEs and PEs are different because of their ownership. The government and firms innovate for different reasons. The government cares more about the long-term influence of technology while enterprises chase short-term profit (Chang *et al.,* 2006). Therefore, due to state-owned ownership, SOEs more prefer to undertake more R&D activities compared to PEs, and SOEs have benefits to encourage R&D activities and improve technology (Choi *et al.,* 2011; Guan *et al.,* 2009).

Because of China's unique historic and political characteristics, the impact of ownership cannot be ignored and it is necessary to analyse its effects on economic growth. And this thesis focus on impacts of technology improvements on China's economy.

In fact, production factor inputs especially capital inputs are a main engine of China's growth in past 30 years. However, now China enters into 'New Normal', which means China's economy will grow in mid-high speed rather than high seed as before. And China will gradually change itself from investment-driven economy to innovation driven economy. In other words China want to develop itself as innovative economy. Innovation will be a key factor that could determine whether China can keep a significant growth in long term.[2] Therefore, base on China's reality, the study about which factors can influence research activities and growth of firms in China are important.

In addition, this thesis does not model the impacts of human capital accumulation directly. But it does not mean that this thesis neglect the impacts. With the accumulation of human capital, the investment in labour increase and gradually, China is no longer competitive in cheap labour. And some labour-intensive industries are moved from China to Southeast Asia such as Indonesia. China has a motivation to update its economy structure, from labour-intensive and capital-intensive to technology-intensive. And human capital accumulation could positive influence step size of technology and effectiveness of research activities, which could affect technology improvements, and thus the growth of outputs.

The most novelty of this thesis is that this thesis, not as previous studies which discuss impacts of ownership and size effect separately, consider the ownership and size effect together in the model: firms in China are divided into three types, state-owned enterprises (SOEs), large private enterprises (LPEs) and small-medium private enterprises (SMEs).

2 China government work report in 2014,2015 and 2016

In addition the economic growths of these three types of firms are divided into two parts: (1) the growth rate of employees and (2) the growth rate of productivity, also known as the technology improvement causing growth rate. Imitating advanced technology and undertaking R&D activities could both lead to increases in the technology improvement causing growth rate. In the following chapters this structure will be used to discuss economic growth.

There are three main research questions in this thesis:

(1) Which factors will determine the growths of SOEs, LPEs and SMEs based on Schumpeterian model?
(2) Which type of firms will grow most and what are the conditions?
(3) For SOEs, LPEs and SMEs, how does the strategy of technology development, imitation or innovation, change over time?

These research questions are answered in Chapter 4, Chapter 5 and Chapter 6:

In Chapter 4, based on the Schumpeterian model, the growths of SOEs and PEs in China are studied and compared. Due to discrimination against PEs in banking sector (Brandt and Li, 2003; Cull and Xu, 2003), financial friction is considered in the model. In addition, there are three types of firms in China market: SOEs, LPEs and SMEs. In comparison to SOEs, with the development of the banking sector, LPEs are also welcome in lending market (Firth *et al.,* 2009). The final section of this chapter discusses the contributions of SOEs, LPEs and SMEs to total production.

Following Chapter 5, Chapter 6 focuses on the technology improvement causing the growth rate. It supposes that each type of firm must determine a strategy of technology development: imitating advanced technology or undertaking R&D activities. A model is constructed to describe the different strategies of SOEs and PEs.

Chapter 6 is an extension of Chapter 5. In Chapter 6, the endogenous step size of technology improvements, trend of preference for imitation and the influence of this trend on technology causing the growth rate are analysed.

Chapter 2 Background: China

2.1 China's Growth

China is a germane case study of the impact of institutions on economic growth. China has experienced significant economic growth since the reforms dating from 1978. China's reform is unique to that of Central and Eastern Europe and the former Soviet Union. Specifically, China did not endure radical political reform. Cogently with Acemoglu and Robinson (2002), domestic political pressure and international competition may bring about economic reform, as was the reason behind China commencing economic reform (reforming and opening-up policy).[3]

Before 1979, China practiced the Soviet model of developing an economy (planned economy). The overt advantage of planned economy is that the government can mobilise the resources to develop priority sectors. Indeed, the industrialisation of China has benefited from planned economy. However, it cannot be denied that Soviet-style economy is inefficient because (1) comparative advantages are not granted sufficient attention when determining industrial structure; (2) managers cannot motivate workers to improve their

[3] During the rule of Mao Zedong, China had achieved much with the economy (for example the first 'five-year plan'). Indeed, these achievements, such as the state-owned enterprises founded during this period and some significant projects in communications and transport, are the basis of China's industrialisation. However, in The Great Proletarian Cultural Revolution, China is thought to have suffered losses in the economy by most researchers, including Li (1984). It was under these circumstances that China created the reforming and opening-up policy.

productivity. (Lin *et al.,* 2003)

In agriculture, ownership of rural areas transferred from commune system to household responsibility system (HRS). Lin (1992) researches this agricultural institutional system change in China, and the findings suggest that between 1978-1984, the growth of agricultural outputs resulted from institutional change.

The role of the government in economic reform is significant. Lin (1989) has emphasised that government policy plays an important role in economic growth. The government can provide the structural stability. Based on the structural stability, the economy can be effectively built, and there will be measured economic behaviour. A shrewd government is able to guide individuals' investment motivation. The government offers an institutional arrangement that is a system, which successfully defines and protects the property rights in goods, production factors and intellectual property. Due to this kind of institutional arrangement, individuals are encouraged to seek profit opportunity.

According to the research of Liu (2010), there are three phases in China's economic reform. In the first period (1980s), individuals' small businesses were allowed to open. In the second phase (completed by 1993), prices were determined by demand and supply. This period is called 'price marketisation'. The third phase (since the mid-1990s) is the phase of state-owned enterprises' reform. In 1997[4], the government created the 'grasping the large and letting go of the small' policy. Moreover, large-size state-owned enterprises[5] (SOEs) have market power in important industries in China, such as the railways, telecommunication, electricity, military and mineral industries[6]. Additionally, small state-owned enterprises have been privatised in various forms.

Sachs and Woo (1997) summarise the theories explaining China's fast economic growth after the economic reform in 1978. They argue that there are two schools: the experimentalist school and the convergence school. The experimentalist school attributes China's economic growth to market reform, which leads to a unique China economic model. China is changing to a 'socialist market economy with Chinese characteristics' from planned economy. However, the experimentalist school is concerned that the reforms will cause more social instabilities and more inappropriate policies may be implemented due to less experiments. (Naughton, 1995; Rawski, 1994; Nolan and Ash, 1995; Lin *et al.*, 1994) The convergence school considers convergence with non-socialist market economies, especially those in East Asia. The coastal provinces (prosperous areas in China) have increased rapid growth compared to inner areas (poor areas in

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[4] At the 15th National Congress of Chinese Communist Party the 'grasping the large and letting go of the small' policy was formulated.

[5] According to the definition of SOE in China, there are there types of SOEs. The first one is the state-owned individual proprietorship enterprises that the State owns 100% of the shares. The second one is state-holding enterprises that State owns more than 50% shares in or owns less than 50% but has more shares than other shareholders. The last one is state-joining enterprises that State holds less than 50% shares in and less shares than other shareholders. Most researches use the acronym SOEs to refer to the first two types.

[6] China Enterprise Confederation/China Enterprise Directors Association publishes the 'China Top 500 enterprises' list every year. According to 'China Top 500 enterprises in 2011', there are 316 SOEs in Top 500. The ratio of SOEs is more than 60% with all of top 10 enterprises as SOEs.

China) because of the faster convergence and deeper market reform. Therefore, the experimentalist school prefers the gradualism strategy, while the convergence school does not favour gradualism. The convergence school tends to alter the economic structure and utilise the comparative advantages of China.

Sachs *et al.* (2000) attempt to evaluate these two schools of thought via an empirical study of transition economies. They find that privatisation is not sufficient to improve the efficiency of public enterprises. The objectives of firms must reflect profit maximisation. The soft budget constraints should be changed to hard budget constraints, which means the government cuts the subsidies and tax alleviation for SOEs. Furthermore, managers can be effectively monitored and controlled by the owners of enterprises. Thus, enterprises can run with efficiency, and economic growth can be better promoted.

The unique characteristics of China's economic reform lie not so much in opening the market to the world as in the changes of ownership. Due to China's former planned economy, despite private enterprise and other non-SOEs contributing a lot to economic growth, SOEs are still important for China, especially in capital-intensive industries. Since the SOEs' reform in 1995, the government no longer directly controls and manages SOEs, however the government now is the biggest shareholder in SOEs[7].

[7] Details about the structure of the SOEs in China in Appendix 1

2.1.1. SOEs and Private Enterprises

It is agreed by researchers that China's SOEs had poor financial performance compared with other forms of enterprise. For example, Jefferson *et al.* (2000) find that the productivity of private and collective enterprises were significantly higher than the enterprises in other ownership forms, after examining the productivity of enterprises in all major ownership forms including the private foreign-linked, State and collective enterprises during the period 1980-1996. The empirical results of Sachs and Woo (1997) display similar findings about the productivity of SOEs.

Plane (1997) has highlighted that private enterprises are more efficient in maximising profits than public firms. Private firms have a heightened ability to maximise profits. Plane (1992) posits that subsidies and tax alleviation for inefficient public corporations might lead to a heavy financial burden for the government. Privatisation is necessary under these circumstances.

Lardy (1998) conjectures that China's economic reform is not successful in the sector controlled by SOEs. Moreover, Yusuf *et al.* (2006) and Jefferson and Su (2006) suggest that the SOEs in China should consider being privatised because of poor performance, as privatization of SOEs could lead to improvements. However, if circulation taxes and capital intensity are presumed to be at the same level, the industrial SOEs may have better profitability than non-state enterprises (Holz, 2002, 2003)

Private enterprises are not more effective than public firms when the market is a perfect competition market, information asymmetries do not exist and contracts are successfully completed (Shapiro and Willing, 1990). However, in the real market, incentive problem result from asymmetric information and incomplete contracting. Thus, public corporations suffer inefficiency problem. (Sachs *et al.*, 2000)

Agency problem is a cause of advances of private enterprises. In private enterprises, managers can be effectively monitored since private enterprises are in the market to set prices and fear bankruptcy (Vickers and Yarrow, 1990). On the other hand the goal of private firms is profit maximisation, but public corporations, in some instances, have to consider policy burdens (Shleifer and Vishny, 1996). Especially during planned economy in China, the government decided the allocation of inputs and production of outputs. Managers in SOEs did need to have talent to manage works, care for the productions and sales. Under these conditions, it was hard to distinguish effective managers from ineffective managers. (Lin *et al.*, 1998)

2.1.2 Externality effects of SOEs

Low efficiency of SOEs does not mean the impacts of SOEs are negative on economic growth. Research on effects of SOEs on economic growth should consider direct effects and indirect effects (externality effects of SOEs).

Ram (1986) creates a two-sector model (government sector and private sector) to describe the externality effects of government size on economic performance and growth. In his two-sector model, the government-produced public goods input into private sectors. The data of 115 developing countries suggests that externality effects of government were positive.

Plane (1992) disagrees with Ram's (1986) theory. He critiques that Ram inverts the causality relation. Government size becomes large with the growth of economy. Therefore, the economic growth causes the expansion of government size. In the empirical analysis of Ram (1986), government consumption expenditures are employed as the proxy indicators for output of public goods considered the demand effects of public goods rather than supply effects. Furthermore, Plane (1992) uses the data of 45 developing countries to examine the external effects of SOEs on economic growth, producing a negative result.

Jefferson (1998) proffers that the externality effects of SOEs on China's economic growth are negative. He views SOEs as a form of impure public goods, which means nonexcludability and nondiminishability are two characteristics of SOEs. Additionally these two characteristics are the causes of externalities that give rise to low efficiency of SOEs in financial performance. As public goods, SOEs are over consumed by the society (workers, managers and public officials). With soft budget constraints, fiscal and/or financial subsidies are used to replenish the loss of economic efficiency caused by overconsumption, with inflation resulting. Furthermore, investment and employment in non-state sectors will be negatively affected by budget constraints and financial policies avoiding externalities of inflation. Therefore, externalities of SOEs are negative.

However, the study of Jalilian and Weiss (1997) does not support the negative effects of SOEs on economic growth. However, their research only considers the direct relation between SOEs and growth, and does not considered the indirect effects. Doamekpor (1998) similarly does not consider the externality effects of SOEs. However, he uses an alternative methodology named 'residual analysis method'. His analysis shows that in developed countries the externality effects of SOEs are negative, but in developing countries are positive.

The main reason why SOEs in China occupy disadvantaged positions among the enterprises in other ownership forms are policy-determined burdens: distorted output prices, high capital intensity and heavy social burdens (Lin *et al.,* 1998, 2003). In other words, SOEs have positive social externalities. Lin *et al.* (1998) suggest that in order to make SOEs more effective, policy burdens should be removed. However, his suggestion omits the SOEs' positive social externality effects (especially, linkage effects and social welfare) on economic growth.

Hirschman (1958) argues that SOEs have linkage effects on private enterprises. There are two kinds of linkage effects. One is the 'backward linkages': Supply bottlenecks resulting from concentrating investments in key industries by the government create profit opportunities for private enterprises in upstream industries. The other is 'forward linkages': The outputs of a certain industry may go to downstream industries rather than the final demand, which also creates opportunities for private enterprises.

Based on Hirschman's linkage effect theory, Holz (2011) attempts to discover whether China's SOEs in high-linkage sectors play an important role in fast economic growth. His research shows that the linkage effects of SOEs have a significantly positive impact on economic growth. The retention or expansion of SOEs should be profit-creating rather than profit-seeking. However, the government, in terms of province level, does not recognise the positive linkage effects of SOEs on economic growth, and does not concentrate SOEs in high-linkage sectors.

Bai *et al.* (2000, 2006) propose a multifaceted theory of SOEs. They state that when there is no high quality independent social security system, SOEs have incentives for production and maintaining social stability, while non-SOEs only have strong incentives for production. Consequently, non-SOEs benefit from the responsibility of SOEs for social stability, which provides a positive macroeconomic environment. Noticeably, Bai *et al.* (2000) believe that there are divergent interests between China's central and local government in SOEs; China's central government has enhanced incentives to maintain social stability compared to local governments.

Since SOEs have to bear the cost of maintaining social stability, Lo (1999) believes that the performance of China's industrial SOEs is underestimated, especially large and medium-scale enterprises following the reappraisal of the performance of China's state-owned industrial enterprises from 1980-1996. Large and medium-size enterprises play an important role in generating economy.

The literature on privatisation and externality effects of SOEs demonstrates that ownership of enterprises has non-negligible influences of ownership on China's economic growth. However, this literature proves the influence by empirical analysis or logic theory. Fewer theoretical models are provided to describe China's growth with regard to private enterprises (PE) and sate-owned enterprises.

Song et al. (2011) supposed that SOEs and PEs both invest in the labour-intensive sector, SOEs only invest in capital-intensive because the productivity of SOEs is lower than PEs; SOEs are crowded out of the labour-intensive industry. All workers are employed by PEs. Entrepreneurs continue to invest their savings in the labour-intensive sector. However, because of the decrease in the marginal product of labour, entrepreneurs will gradually stop investing in the labour-intensive sector and decide to invest in capital-intensive industry. If the marginal return of capital in capital-intensive industry is larger than labour-intensive industry, PEs will invest in capital-intensive industry and SOEs will be crowed out of capital-intensive industry. Otherwise, if PEs only invest in labour-intensive industry, eventually the marginal capital decreases.

Overall, this section reviews China's economic reform in 1980s. Following economic reform, SOEs and PEs are both active in the market and their effects are emphasised. Even though SOEs are less efficient than PEs, SOEs' external effects on society should not be ignored.

2.2 Strategy of Technology Improvements in China

Following economic reform, China achieved remarkable economic growth based on its advantages in population and lower labour cost. In the past 30 years, China optimised these advantages and created policies to attract foreign investors, along with learning advanced technology for economic growth. However, China now gradually transforms into an aged society and the advantage in lower labour cost simultaneously disappears. China is currently under pressure to change its economic structure.

China claims its economy now enters into 'new normal'. President Xi Jinping in APEC 2014 explained what 'new normal' means. One of the important characteristics of 'new normal' is to change China's economy from production factor driven and investment driven, to innovation driven.

Without considering the cost of imitation, the models of Romer (1986, 1990) indicate that developing countries could catch up to developed countries by technology imitation over a sustained period. Lin (2012) similarly believes imitating advanced technology from developed countries is a better way for less developed countries. However, empirical results (Barro, 1991; Williamson, 1991) do not support Romer's (1986, 1990) claims.

Apart from learning advanced technology from developed countries, domestic innovation is also necessary for developing countries and is compatible with learning foreign technology (Fu *et al.*, 2011). This opinion is supported by empirical findings (Hu *et al.*, 2005) stating that the return of firms in China is positively influenced by domestic innovation, while technology spill over is also affected by domestic capability of research and development (R&D).

Prior to economic reform, China's government centralised control and over protected the innovation system (Cai and Tylecote, 2008). Post reform, an open policy is also applied to the innovation system. Science and technology outsourcing activities are significantly active, as is foreign multinational corporations' involvement (Liu and White, 2001).

It should be noted that governments and enterprises have different intentions for innovation. Compared with enterprises, governments care more about the long term impacts of science and technology, and make long term plans for domestic innovation. These plans affect the R&D activities of firms in the market positively. (Chang et al., 2006) In addition, government will encourage firms' R&D activities by providing sources required (Johnson, 1982; Amsden, 1989; Haggard, 1994).

SOEs that are more easily affected by government because of their ownership, compared with private enterprises, a majority of SOEs prefer to undertake R&D activities rather than imitating advanced technology. Business groups in China, which are mainly conducted by SOEs can significantly enhance technology and encourage R&D activities (Choi et al., 2011). Differences between SOEs and private enterprises in strategies of technological improvements are described in empirical study (Guan et al.). This states how objectives for innovation by SOEs and non-SOEs are significantly different in terms of the importance of 'introducing niche products of technology'; 'improving existing technology' to reduce reliance on imported equipment/technology and 'reducing energy consumption' when compared with private enterprises.

In summary, there is a transition of strategy regarding technological improvement, from imitating advanced technology from developed countries to undertaking domestic R&D activities. Due to ownership, SOEs and private enterprises have divergent preferences for strategies focusing on technological improvements. In contrast to SOEs, private enterprises frequently opt for imitation.

Chapter 3 Literature Review

3.1 Endogenous Imitation

According to Schumpeterian theory, both imitation and innovation will lead to technology improvements.

Helpman (1993) consider imitation to be exogenous, and stronger intellectual property right (IPR) protection will lead to decline in imitation rate. And strengthening IPR protection in Northern countries has negative impacts on growth rates of Southern countries.

With exogenous imitation, Lai (1998) thinks that if the production is transferred from North to South by FDI, a policy of strengthening IPR protection will lead to increase of innovation rate. However, with endogenous imitation, Mondal and Gupta (2008) have an opposite finding to Lai (1998).

Glass and Wu (2007) also constructed an exogenous imitation model. In their model, Northern firm could engage in innovation and production transfer happens from Northern countries to Southern countries by FDI. And Southern firm will imitate products of foreign affiliates of Northern firms. Stronger IPR protection will reduce imitation rate, and then decrease FDI and innovation that could improve quality of products. Therefore, Northern firms prefer to undertake innovation for new products rather than quality improvements.

Southern firms are usually are considered to be imitator, however, in the model of Glass and Saggi (2002) where imitation is endogenous, Southern firms could also be innovator not only imitator under extremely special situation. Southern firms will innovate if it is impossible for Southern firms to imitate products immediately. Northern firms are also exposed to imitation if further innovation is prohibitive costly. Southern firms could imitate products of Northern firms and multinationals in South. But only innovation could improve quality level. Northern firms are separated into quality leader and follower. And imitation of Southern firms is the motivation of Northern quality leader to undertake further innovation. In their model, stronger IPR protection leads to higher cost of imitation, and rate of imitating multinational firms decreases, but relative rate of imitating multinational firms to imitating Northern firms increases, And FDI and innovation are both reduced.

In the endogenous imitation model of Parello (2008), only Northern firms are thought as innovator again. In the model, developing and developed countries are both engaged in R&D, but only R&D firms in developed countries could raise productivity level, while R&D firms in South can acquire knowledge from abroad, and then absorb these knowledge and implement them. They found that IPR protection has negative impacts on imitation rate long term and is ineffective to absorb technology knowledge if technology level in South is low.

Dinopoulos and Segerastrom (2010) also consider Southern firms as imitators. However, they divided the global economy into three categories: Northern quality leader, foreign affiliates of Northern quality leader in South and Southern firms. Any industry could switch randomly across these three categories. Technology transfer happens if foreign affiliates of quality leader could successfully hire Southern workers to engage in adaptive R&D. Southern workers could be hired by multinational firms to engage in adaptive R&D or by Southern firms to engage in imitating. This model shows stronger IPR protection has permanent positive effects on technology transfer and temporary positive influences on innovation rate of Northern quality leader.

Chu et al. (2014) consider Southern firms as innovators and imitators. And there are two kinds of imitators, (1) effective imitators who were domestic innovation in South and could adapt to more advanced technology, and (2) ineffective imitator who are able to imitating existing technology. Effective imitators and foreign affiliates of Northern firms are competitive for monopolistic position in intermediate sector. Ineffective imitator only can steal market share from foreign affiliates. Chu et al. (2014) think that growth of developing countries is driven by innovation, FDI and imitation. And monopolistic position in intermediate sector could be occupied by a domestic innovator, a domestic effective imitator or a foreign affiliate. In developing countries, the optimal IPR protection is stage dependent. At the early stage of development, it is more effective to imitate advanced foreign technology by implementing weaker IPR protection. However, at later stage, government should strengthen IPR protection to encourage domestic innovation.

3.2 Schumpeterian distance-to-frontier models

According to Howitt (2000), divergence of growth in the world is not only caused by physical capital accumulation but also caused by technology gap. Based on Howitt (2000), Howitt and Mayer-Foulkes (2005) modified the model, and they think Northern firms undertake 'modern R&D' while Southern firms 'implement' new technology. Firms with 'modern R&D' have a higher technology level. It is concluded that 'modern R&D' is the main cause of divergence of growths.

Acemoglu et al. (2003) assume that managers of firms have to be in concurrently charge of innovation and production, which create managerial overload. To alleviate managerial overload, managers will outsource production activities. If firms are closer to technology frontier, mangers will more prefer innovation and outsourcing of production.

Acemoglu et al. (2006) extends the model of Acemoglu et al. (2003), they divided manager into high-skill and low-skill. And both these two type managers involve in innovation and adoption of existing technologies from technology frontier. Managers with high skill will be continually hired if they succeed in innovation. And high-skill managers will replace managers who are reveled to be low skill.

Skills of manager are more important for innovation than imitation or adoption. Because of financial friction, insider managers could do better investment. Therefore, dismissing low-skill managers may cause loss in investment return but success of innovation activities. The selection of high-skill managers and firms is more important if countries are closer to technology frontier and pursue innovation-strategy. However, at the earlier stage of development, countries will pursue investment-strategy policy that affects economy negative in long term. Under this situation, countries will trap in investment-strategy and can not reduce the distance to technology frontier.

Not as Acemoglu et al (2003, 2006) those address the importance of managers in distance to technology frontier, Aghion et al (2005) focus on the impacts of financial development. Financial development determined whether a country could converge the growth rate of technology frontier. If financial development of countries could be up to some a certain level, these countries could catch up technology frontier while rest of countries will still more slowly grow in long term.

Except the factor mentioned above, which could directly or indirectly affect innovation activities, openness (Gersbach and Schneider, 2013), human capital (Romer, 1990) and IPR protection (Eicher and Garcia-Penalosa, 2008) are also considered to affect convergence to growth rate of technology frontier in the world.

3.3 Endogenous step size

According to Romer (1990), production of new knowledge or technology is determined by research labour input and accumulated technology level, and therefore the step size is only affected by research labour input. And there is scale effect in this model that increase in research labour input will cause greater step size and higher the growth rate of economy. However this is not proved by empirical study of Jones (1995) that there were no scale effects in OECD countries after the Second World War. And Solow (1994) and Temple (2003) think the model does not correspond to reality without thinking of impacts of accumulated technology level on step size.

Jones (1995), Kortum (1997) and Segerstrom (1998) constructed models to solve problems mentioned. New technology production is still determined by research labour and accumulated technology level, but the power of accumulated technology level in the function of new technology production is no more assumed to be 1. If the power is lower than 0, fishing out effect exists which means it is more difficult to obtain more advanced technology. If the power is over than 0, externality of new knowledge production will positively influence economy. However, in the model the power of accumulated technology level is supposed to be smaller than 1, which is proved to be reasonable by Jones (1995). Under this condition, step size is positively affected by research labour input but negatively influenced by accumulated technology level, which means it is more difficult to get higher step size if current accumulated technology level is greater.

Research labour input is replaced by R&D expenditure in the new knowledge production models of Rivera-Batiz and Romer (1991) and Jones and Willams (2000). Cheung and Lin (2004) consider R&D expenditures as capital input in the production of new technology.

In the empirical study of Yan et al. (2010), new knowledge production is determined by research larbour input, capital input and accumulated technology level. Yan et al. (2010) use province level data from 1998 to 2007 to estimate new knowledge production in China. In their estimation model, they also consider impacts of FDI, importing production facilities from abroad, accumulated technology level in other provinces. Their empirical results show that power of accumulated level is strictly smaller than 1. 'Raising the bar effects' in provinces are more significant than 'spillover effects'. In terms of FDI, which is similar with Porter and Stern (2000). In terms of FDI, 'spillover effects' on knowledge production in China are more significant than 'crowding out effects' they caused. Overall, empirical results of Yan et al. (2010) support the theory of Jones (1995) that there is no scale effect in the knowledge production and the power of accumulated technology is lower than 1.

Chapter 4 Model of Factors Affecting China

4.1 Introduction

China has experienced remarkable economic growth since the implementation of fiscal reforms in 1978. In the last decade, China's average annual growth rate is 10%, and the country is now recognised as the engine of the global economy.

Indeed, the country's prominence in economic terms has increased since the Asian financial crisis in 1997 and worldwide financial crisis in 2008. Today, however, economic progress has stalled. The growth rate of 7.3% in 2014 was the lowest in recent years; however, it was still the highest in the world. The country's leaders (such as President Xi Jinping and Prime Minister Li Keqiang) have publically emphasised the fact that this dip in growth is entirely normal. In order to maintain the country's economic stability and development, President Xi Jinping identified three key areas for attention: (1) ensure reasonable higher economic growth (around 7%); (2) update the country's economic structure; (3) change the emphasis on input and investment to innovation. After years of incredible growth, China has entered a new period of development. The Chinese economy no longer has the same characteristics as before the 1978 reforms. Furthermore, China has paid enormous environmental and societal costs for its rapid growth and development. These costs include air and soil pollution, labour protection issues, food security, and even the disintegration of the traditional Chinese family structure and ethics. In 2014, the government recognised that the country needed to assess its achievements, consider the costs of development and look to the future. As a result, China has taken steps to once again reform its economy[8].

[8] In *Report on the Work of the Government 2014*, deepening economic reform is considered as the engine of development of the Chinese economy.

Scholars, academics and experts agree that economic reforms have been the catalyst of China's development since the 1980s. It is also widely acknowledged that further reforms are needed to support the continued development of the economy in the future. To fully understand the Chinese economy, it is necessary to review the reforms that took place in 1979.

Before 1979, China adopted a Soviet approach to the development of its economy. Known as a 'planning economy', its obvious advantage was that the government could mobilise resources to construct priority sectors. Indeed, the industrialisation of China is the result of this planning economy. In Mao's time, China made a number of significant achievements, such as the first 'five-year plan'. These achievements, which also included the establishment of state-owned enterprises (SOEs) and large communications and transport projects, form the basis of China's industrialisation. However, this Soviet-type economy does have many disadvantages. It is not efficient because: (1) comparative advantages are not paid much attention to when determining the industrial structure; (2) managers cannot motivate workers to improve their productivity (Lin *et al.,* 2003). Furthermore, many eminent researchers, including Li (1984), suggested that China suffered heavy losses during The Great Proletarian Cultural Revolution. According to Acemoglu and Robinson (2000), domestic political pressure and international competition eventually brought about economic reform. After The Great Proletarian Cultural Revolution, the government was under significant pressure to change its economic policy and structure to improve China's development. Under these circumstances, China amended its approach and established an opening-up policy. It is important to point out, however, that China's reform differed from the countries of Central and Eastern Europe and the former Soviet Union.

Liu (2010) suggests that China's economic reform took place in three phases. In the first period (1980s), a number of small businesses were allowed to open. In the second phase (finished by 1993), prices were determined by supply and demand. This period is called 'price marketisation'. The third phase (since the mid-1990s), saw the reform of state-owned enterprises. In 1997[9], the government developed its 'grasping the large and letting go of the small' policy. This saw large-sized state-owned enterprises[10] (SOEs) dominating market power in important industries such as railways, telecommunications, electricity, military and mineral industries[11]. At the same time, small-sized state-owned enterprises were privatised in various forms.

Sachs and Woo (1997) have summarised China's sudden economic growth after

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[9] In the 15th National Congress of Chinese Communist Party, 'grasping the large and letting go of the small' policy was formulated.

[10] According to the definition of SOE in China, there are three types of SOEs. The first one is the state-owned individual proprietorship enterprises where the state owns 100% shares of enterprises. The second are state-holding enterprises where the state owns more than 50% or less than 50% of shares, but has more shares than other shareholders. The last is a state-joining enterprise where the state holds less than 50% shares and fewer shares than other shareholders. Most researchers refer to SOEs as the first of two types.

[11] China Enterprise Confederation/China Enterprise Directors Association publishes the 'China Top 500 enterprises' list every year. According to the 'China Top 500 enterprises in 2011', there are 316 SOEs in the top 500. The ratio of SOEs is more than 60%, and all of the top 10 enterprises are SOEs.

economic reform in 1978. They point out that the experimentalist school attribute the country's growth to market reform that changed China to a 'socialist market economy with Chinese characteristics' from a planning economy; however, the convergence school considers a convergence with a non-social market economy, which changed the country's economic structure and utilised the comparative advantages of China's position in East Asia.

The most significant change after 1978 was China's transformation from a planning economy to a market economy. This helped to open up the country's domestic market to the world and attract foreign investment. Privatisation of SOEs is also an important aspect of the reform. Xu (2011) attributed the remarkable economic growth in China to fundamental institutional restructuring, which featured three core concepts: privatisation; political decentralisation and regional centralisation; and competition. In fact, today, private enterprises (PEs) in China are considered to have contributed the most towards China's unprecedented economic growth (Allen *et al.*, 2005; Huang, 2008).

However, SOEs should be considered in any assessment of the Chinese economy. Indeed, the creation of SOEs is an indirect tool for governments to manage the economy, especially in strategic industries. Since the reform of SOEs in 1995, the government no longer directly controls and manages SOEs; instead, it is the biggest shareholder in these types of companies[12]. Large-sized Chinese SOEs have dominant influences on domestic markets, and the role of Chinese SOEs on international markets is also increasing (Elliot and Zhou, 2013; Hsueh, 2011). In 2013, the government owned 77 domestic firms out of a total of 85 listed on the Fortune 500. It should be noted that, in a number of stylised, non-strategic sectors, such as textiles, papermaking and catering, Chinese SOEs are still active after privatisation reform (Du and Liu, 2012).

Whilst it is generally accepted that private firms are more productive and profitable, (Jefferson *et al.,* 2000; Sachs and Woo, 1997; Plane, 1992, 1997; Su, 2006), questions about the externality effects of SOEs remain (Ram 1986). Indeed, there is an on-going debate about whether the externality effects of SOEs are positive. Empirical results produced in Plane's 1992 study show that externality effects are negative. Similarly, Jefferson (1998) argued that, in China, externality effects of SOEs negatively affected economic growth. Jalilian and Weiss (1997) hold opposite views. Furthermore, Doamekpor's analysis (1998) shows that externality effects are positive in developing countries. In addition, SOEs have to take strong social responsibility (Bai *et al.*, 2000, 2006) and suffer heavy social burdens (Lin *et al,* 1998, 2003). Positive linkage effects between SOEs and private enterprises (Hirschman, 1958; Holz, 2011) also influence economic growth.

[12] Details about the structure of the SOEs in China can be found in Appendix 4.1

In summary, PEs and SOEs have made a considerable contribution to China's economic growth. It is therefore necessary to consider the wider impacts of SOEs and PEs in order to fully analyse China's economy. After the financial crisis of 2008, a phenomenon termed 'Guo Jin Min Tui' (the state advances, the private sector retreats) arose. One cause of this phenomenon was financial friction towards PEs. There is discrimination against PEs in the Chinese banking sector (Brandt and Li, 2003; Cull and Xu, 2003), as SOEs benefit from advantages in the lending market and are placed under fewer controls by the government. In *Report on the Work of the Government 2015,* Premier Li Keqiang said that the government should support small and medium-sized firms and reduce the difficulties they face in the lending market. The majority of small and medium-sized businesses in China are PEs. However, large-sized private enterprises (LPEs), such as Alibaba, Huawei, Baidu and Shagang Group, are more competitive than SOEs. Banks are also receptive to LPEs in the lending market (Firth *et al.*, 2009). Therefore, in any analysis of PEs, the size of the organisation should be considered.

Overall, PEs and SOEs are two important parts that make up China's economy. The ownership of firms should not neglect to analyze China's growth. The novelty of this chapter is that firms in China are divided into three types (SOEs, LPEs, and SMEs) based on reality in China. Previous studies about China are only focus on ownership of firms or size effect separately. Less of research considered ownership and size effect together in the model. However, with the development of PEs in China, important characteristics of LPEs and SMEs, which will affect the growth of outputs are significant different with each other, for example the interest rate in the lending market and research capabilities. Therefore, this chapter considers both impacts of the ownership and size effect on the outputs.

In addition, as the explanations in Chapter 1, base on Schumpeterian Model, this chapter only focuses on how technology improvements will affect the growth of these three types of firms in China.

The research questions are followings in this chapter:

(1) Which factors and how these factor will affect technology improvements of SOEs, LPEs and SMEs, and thus affect their growth?
(2) Which type of firms will grow most, and under which kinds of situation?
(3) How the contribution of these three types of firms to total gross productivity will change?

This chapter is divided into three sections. The first section examines statistics about SOEs, LPEs and SMEs with reference to employment, speed of expansion and financing costs. In the second part, the study focuses on growth models of the three types of organisation, which have been developed based on the

Schumpeterian framework, Ex Ante Screening model and Ex Post Monitoring, and Moral Hazard model. In this part, determinants influencing growth rates and their relationships are discussed. Finally, the third section explores each type of businesses' production volumes.

4.2 Stylised facts

4.2.1 Employment

The proportion of the urban population employed by state-owned enterprises (SOEs) was 35% in 2000, but this decreased significantly to 16.6% in 2013. The urban employment share of foreign enterprise (FEs) was lower than 4% during the same period, and its increase was gradual. In 2013, the number of people employed by FEs was still the lowest at around 8%. The urban employment share of private enterprises (PEs) was slightly higher than FEs (5.5%); however, the sector experienced significant growth during the period between 2000 and 2013. Today, 21.6% of the working population are employed by PEs. PEs' contribution to urban employment is growing year on year. In China, therefore, PEs and SOEs are the two major contributors to urban employment.

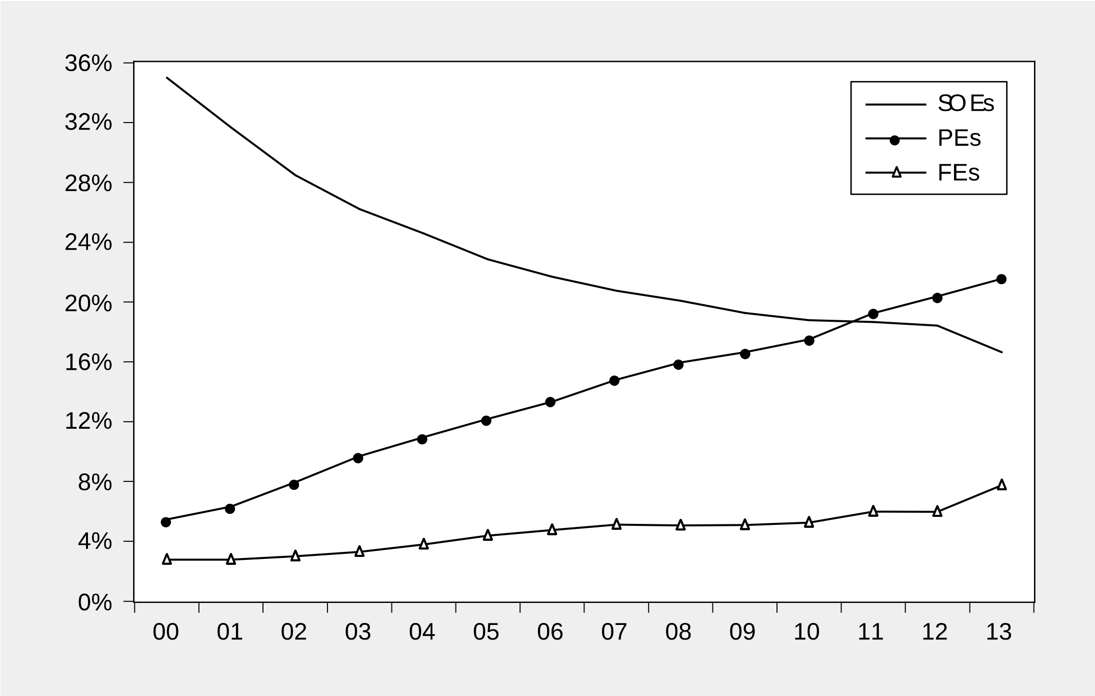


Figure 4.1 THE RATIO OF URBAN EMPLOYMENT BY STATUS OF REGISTRATION

Note: The figure shows urban employment ratios in foreign enterprises (FE), private enterprises (PE) and state-owned enterprises (SOE) from 2000 to 2013. FEs include enterprises invested in by foreign countries, Hong Kong, Taiwan and Macao

Source: China Statistics Database

The employment rate of PEs jumped from 12.8% in 2001 to 25.6% in 2002. After a one-year period of stability, the rate of increase dropped from 26.1% to 16.7% in 2004. The decreasing trend was maintained until 2007. In the years that followed, employment rates remained stable, ranging from around 9% to 10%. The rate of employment in SOEs fluctuated from 2001 to 2012, and in 2013 the increase rate slumped to -6.9%, which is even lower than the rate in 2001 (-5.75). The increase rate of SOEs has generally been below 0, with the exception of three years between 2010 and 2012. Figure 4.2 shows that the increase in numbers of employees in PEs is larger than that in SOEs.

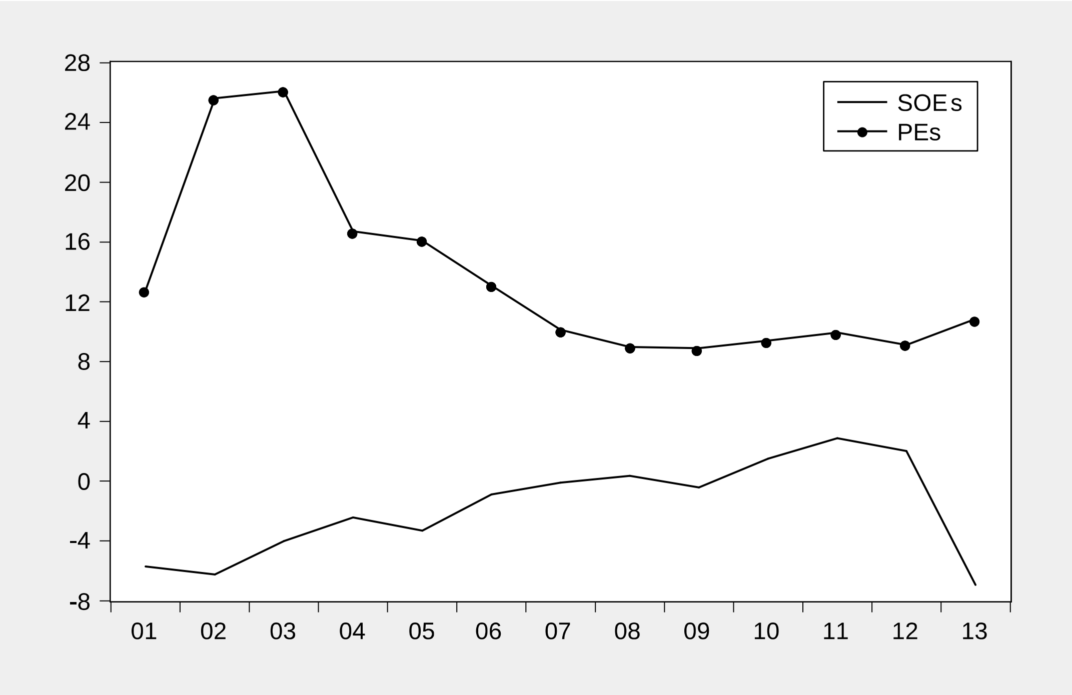


Figure 4.2 INCREASE RATES OF EMPLOYEES IN SOES AND PES FROM 2001 TO 2013

Source: China Statistics Database

Figure 4.3 shows that there is no particular trend in terms of the increase in numbers of SOEs, PEs, large-sized enterprises, small and medium-sized enterprises between 2001 and 2013. However, the growth in the number of SOEs is slower than the rise in PEs. There are two spikes in the number of LPEs in 2003 and 2011. Excluding these two values, the average increase rate of SMEs (10.4%) is larger than LPEs (7.3%).

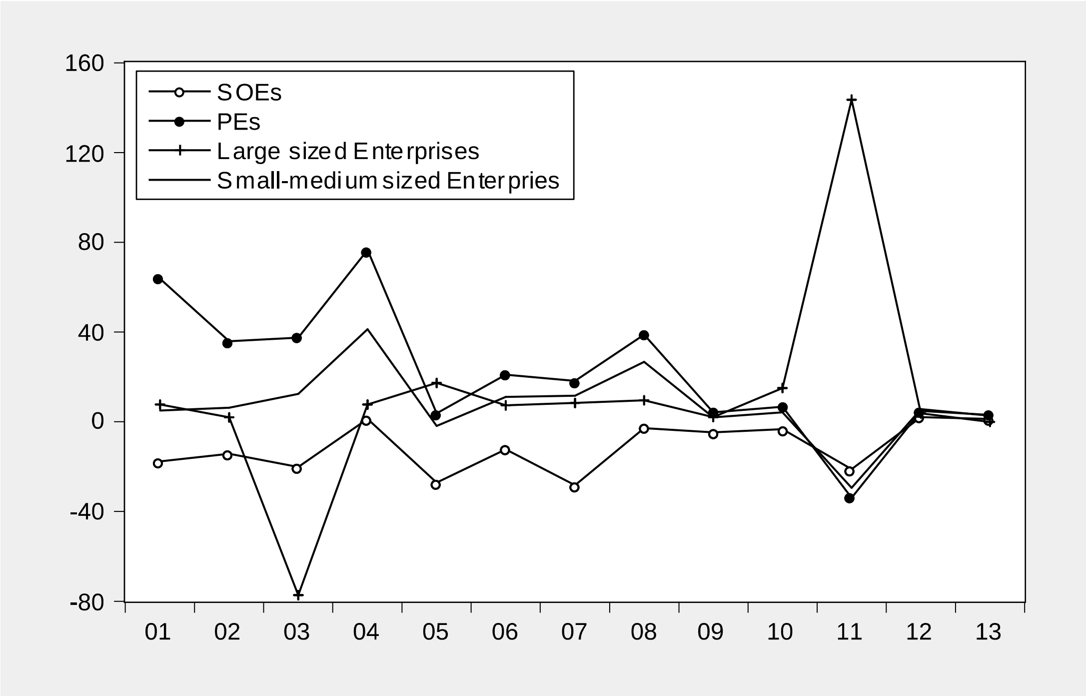


Figure 4.3 INCREASE RATES OF NUMBERS OF SOES, PES, LARGE-SIZED ENTERPRISES AND SMALL AND MEDIUM-SIZED ENTERPRISES

Source: China Statistics Database

4.2.2 Bank lending to private enterprises

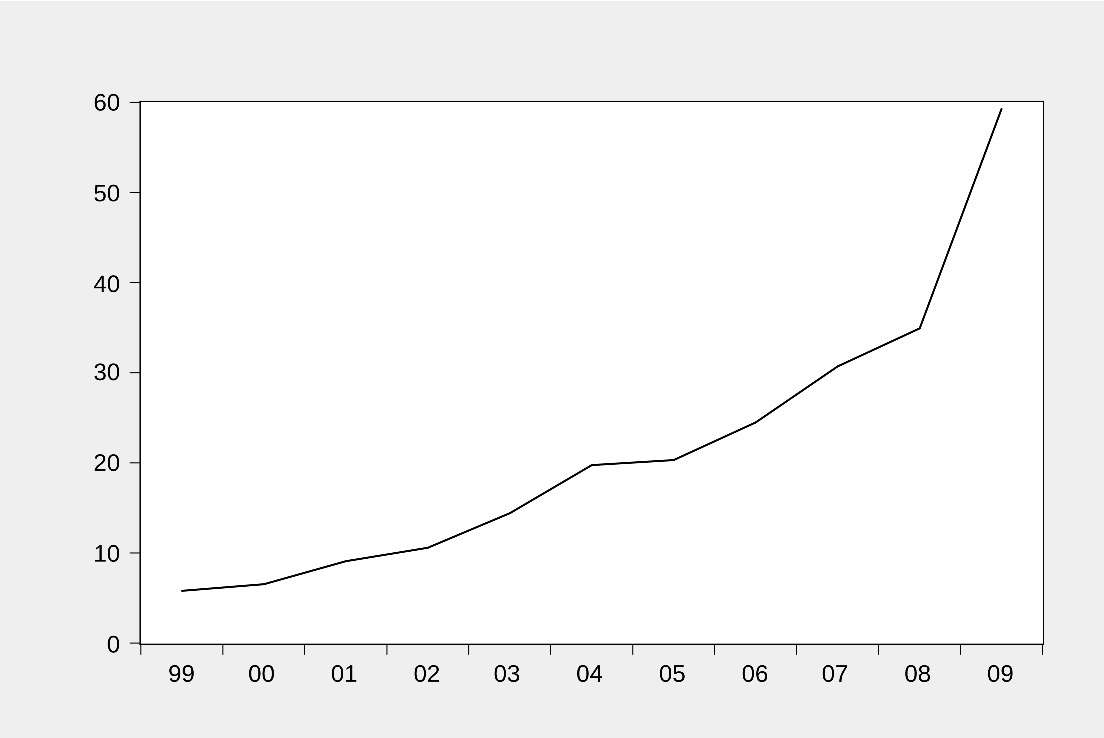


Figure 4.4 SHORT-TERM LOANS TO PRIVATE ENTERPRISES AND SELF-EMPLOYED INDIVIDUALS FROM 1999 TO 2009

Source: China Statistical Year Book 2000-2010

In the period 1999 to 2009, short loans to PEs and self-employed individuals jumped from 579.1 million Yuan to 5926.6 million Yuan. Similarly, the proportion of short-term loans to PEs and self-employed individuals increased from 0.9% to 5%. This percentage is still, however, relatively low. Furthermore, despite financing support for private enterprises gradually increasing, PEs still faced a number of financial frictions.

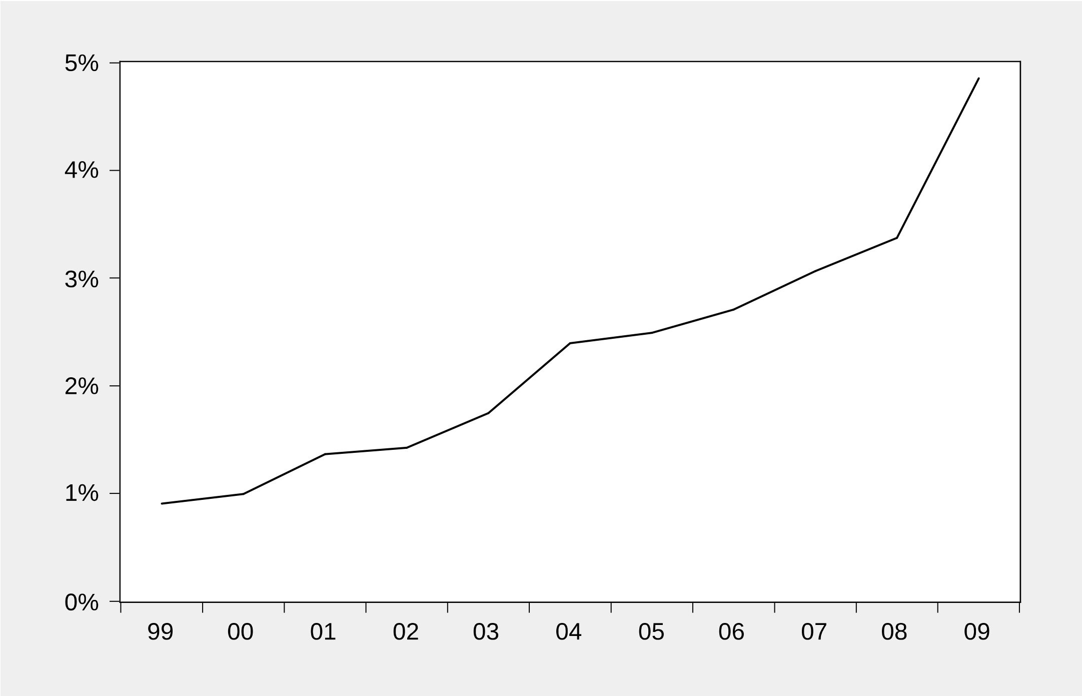


Figure 4.5 THE PERCENTAGE OF SHORT-TERM LOANS TO PRIVATE ENTERPRISES AND SELF-EMPLOYED INDIVIDUALS IN TOTAL SHORT-TERM LOANS FROM 1999 TO 2009

Source: China Statistical Year Books 2000-2010

4.2.3 Data for SOEs, LPEs and SMEs

Standards of SOEs, LPEs and SMEs

The official file 'Interim Provisions on Standards for Medium and Small Enterprises'[13] was issued on 18th June 2011. This document set the standards for small and medium-sized enterprises across a range of industries and sectors. This chapter uses these standards, which are outlined in Table 1 below.

13 'Interim Provisions on Standards for Medium and Small Enterprises (2011), http://www.gov.cn/zwgk/2011-07/04/content_1898747.htm

	Large-sized enterprises	**Small and medium-sized enterprises**
Number of Employees	≥1000	<1000
Operating Revenue (RMB)	≥400 million Yuan	<400 million Yuan

Table 4.1 THE STANDARDS FOR LARGE-SIZED ENTERPRISES AND SMALL AND MEDIUM-SIZED ENTERPRISES

The criterion for LPEs is over 1,000 employees and operating revenue of no less than 400 million Yuan. SMEs are categorised as employing fewer than 1,000 people and having operating revenue less than million Yuan.

Bank borrowings and interest rates for SOEs, LPEs and SMEs

Table 4.2 shows the number of SOEs, LPEs and SMEs that are publicly issued firms listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange since 1st January 2008. There are 636 publicly issued SOEs, 441 publicly issued LPEs and 424 publicly issued SMEs. None of these firms have changed their ownership type since 1st January 2008.

	SOEs	LPEs	SMEs
Number of Firms	441	636	424

Table 4.2 THE NUMBER OF PUBLICLY ISSUED FIRMS OF SOES, LPES AND SMES IN CHINA FROM 1ST JANUARY 2008 TO 30TH MAY 2013

Source: CSMAR Database

A summary of the interest rates and bank borrowings of publicly issued SOEs, LPEs and SMEs is presented in Table 4.3. There are 63 SOEs and 37 LPEs with banking loans and interest rates information, whilst only 22 SMEs have provided this information. According to the interest rate information declared by these 122 publicly issued firms, SOEs enjoyed the lowest average interest rate (about 6.94%). SMEs have the highest average interest rate, which is approximately 10.76%. The average interest rate paid by LPEs is 8.82%. According to Table 3, SMEs face the harshest financial frictions in China.

	Number of Firms	Average Interest Rate (%)	The Amount of Loans (million Yuan)
SOEs	63	6.94	31181.04
LPEs	37	8.82	17186.80
SMEs	22	10.76	9338.00

Table 4.3 SUMMARY OF INTEREST RATES AND BANKING LOANS OF PUBLICLY ISSUED FIRMS OF SOES, LPES AND SMES IN CHINA FROM 1ST JANUARY 2008 TO 30TH MAY 2013

Source: CSMAR Database

The statistics outlined in this section prove that SOEs and PEs are two important sectors within the Chinese economy. However, LPEs contribute the most in terms of employment and the expending speed of PEs is larger than SOEs. Evidence also shows that the number of SOEs in China is decreasing. In addition, the average increase rate in the total number of small and medium-sized firms is slightly higher than large-sized firms. Data also shows that PEs are subject to greater financial penalties than other types of businesses. PEs are discriminated against by the banking sector, particularly with regard to interest rates, which are higher than those paid by SOEs. However, size also determines financing cost. The financing cost of LPEs is lower than that of SMEs. Characteristics highlighted by these stylised facts are discussed further in terms of their influence on SOEs, LPEs, and SMEs.

4.3 The model

In China, state-owned enterprises (SOEs) and private enterprises (PEs) make an important contribution to China's economy. However, PEs face a number of financial restrictions and penalties, which place them at a disadvantage to SOEs. The banking sector, for instance, consider size when assessing the credit of PEs. Whilst it is widely accepted that the majority of small and medium-sized firms are in fact privately owned, large-sized PEs, such as Huawei, Alibaba, Tencent, China Wanda Group, Shagang Group, are treated differently by the banks. In this chapter, ownership of firms and the issues of size are both considered in relation to the growth of Chinese firms within a closed market with financial restrictions.

As discussed, there are three types of businesses in China. They are state-owned enterprises (SOEs), large-sized private enterprises (LPEs) and small and medium-sized private enterprises (SMEs). LPEs and SMEs have the same ownership structure, which differs to that of SOEs. However, SMEs are discriminated against by the credit market, which imposes financial restraints on their operations. LPEs, which also receive financial penalties, are, however, not impacted as much by these financial frictions. Banks in China, most of which are state-owned, are less interested in the ownership of firms, but more interested about their size, perspective and profitability. Banks are typically more willing to provide loans to enterprises with good credit and valuable projects.

The total production in the market is,

$$Y = y_{St} + y_{Lt} + y_{Mt} \tag{4.1}$$

S, L and M represent SOEs, LPEs and SMEs respectively. Y is the total production in the market. y_{St}, y_{Lt}, y_{Mt} are the total production of SOEs, LPEs and SMEs.

Schumpeterian model describes intermediate products and labour are inputs of production of final goods, and final goods are used for consumption and also inputs of R&D and production of intermediate goods. And monopolists in an intermediate sectors charge the price of intermediate goods. Average productivity of production of final goods is accumulation of productivity across all intermediate sectors. In non-innovating sectors, productivity keeps same as last period.

For each type firms, the production of final goods is

$$y_{it} = (N_i L_i)^{1-\alpha} \int_0^1 A_{it}^{1-\alpha}(j) X_{it}^{\alpha}(j) dj$$

where $i \in \{S, L, M\}$, $j \epsilon [0,1]$ presents intermediate sector j, L_i presents the average effective labour inputs per firm for each type of firm. $\widetilde{E_i} = N_i L_i$ indicates employees of SOEs, LPEs and SMEs.

Entrepreneurs would like to maximise their profit and the relative price of intermediate goods to final goods is

$$Price_t(j) = \alpha A_{it}^{1-\alpha}(j)(N_i L_i)^{1-\alpha} X_{it}^{\alpha}(j)$$

And equilibrium quantity of intermediate goods is

$$X_{it}^{\alpha}(j) = \alpha^{\frac{2}{1-\alpha}} A_{it}(j)(N_i L_i)$$

The optimal production for each type of firm is,

$$y_{it}^{*} = \Pi_{it} A_{it} \tag{4.2}$$

where $\Pi_i = N_i L_i \widetilde{\pi_i}$. N_i is the number of each type of firm. L_i presents the average effective labour inputs per firm for each type of firm. $\widetilde{E_i} = N_i L_i$ indicates employees of SOEs, LPEs and SMEs. $\widetilde{\pi_i} = \alpha^{\frac{2\alpha}{1-\alpha}}$ is the constants indicator. A_{it} presents the average level of productivities of each type of firm. Equation (4.2) shows the optimal output of each type of enterprise in relation to the growth in productivity A_t. It can be concluded that the growth of each type of firm is related to the growth in productivity, which is determined by innovation.

There is μ opportunity for innovation, which leads to $A_t = \tilde{\gamma} A_{t-1}$. If there is no innovation, the productivity remains $A_t = A_{t-1}$. Therefore, the expected productivity at time t is,

$$E(A_t) = \mu\tilde{\gamma} A_{t-1} + (1-\mu) A_{t-1}$$

By the law of large numbers, the growth rate of average productivity for each type of firm is,

$$\frac{A_{it}}{A_{it-1}} - 1 = \frac{\mu\tilde{\gamma} A_{it-1} + (1-\mu) A_{it-1}}{Ai_{t-1}} - 1 = \mu(\tilde{\gamma} - 1)$$

The growth rate of employees at each type of enterprise is

$$\frac{\widetilde{E_{it}}}{\widetilde{E_{i(t-1)}}} - 1 = \widetilde{e_{it}} - 1$$

The growth rate g_i of outputs is determined by growth rates of productivity and employees,

$$g_i = \left(\frac{A_{it}}{A_{i(t-1)}}\right)\left(\frac{\widetilde{E_{it}}}{\widetilde{E_{i(t-1)}}}\right) - 1 = [\mu_i(\widetilde{\gamma_i} - 1) + 1]\widetilde{e_{it}} - 1 \qquad (4.3)$$

In this chapter, g_i is the average growth rate of each type of firm.

As discussed in the previous section, the growth in the number of people employed by SOEs is lower than that of PEs. Moreover, the growth rate of the total number of SOEs is lowest. The average effective labour inputs of each type of firm in each period are constant. Only the total amount of each type of enterprise changes over time.

$$\frac{\widetilde{E_{\iota t}}}{\widetilde{E_{\iota(t-1)}}} = \frac{N_{it}L_i}{N_{i(t-1)L_i}} = n_{it}$$

The change rates in the total numbers of SOEs, LPEs and SMEs could also present change rates in the number of employees in each type of firm.

The reform of SOEs brought with it a change in focus, from sectors such as labour-intensive, manual industries to high-tech, economic and political security industries. Merger, consolidation and regrouping between SOEs also became increasingly common. For example, CSR Corporation and CNR Corporation consolidated into CRRC Corporation in order to become more competitive in the international rail market. Therefore, the change rate in the total number of SOEs is the lowest among the three types of firms. The change rate in the number of LPEs is considerably less than SMEs. This is because – in a competitive market – achieving growth in large-sized firms is more difficult than in small and medium-sized firms.

$$n_M > n_L > n_S$$

As the market is comprised of SOEs, LPEs and SMEs, the growth rate of the whole market is,

$$G = \frac{y_{st}}{Y_t} g_s + \frac{y_{lt}}{Y_t} g_l + \frac{y_{mt}}{Y_t} g_m \tag{4.4}$$

4.3.1 Research activities

In *The Economics of Growth* (Aghion and Howitt, 2009), the possibility of innovation occurring μ is positively related to the amount spent on research R_t but is negatively related to $\check{A}_t = \gamma A_{t-1}$ which is the productivity when research is successful. When technological advances become more complex, the improvement is harder to achieve.

$$\mu_t = \lambda_i \left(\frac{R_t}{\check{A}_t}\right)^{\sigma} \qquad 0 < \sigma < 1 \tag{4.5}$$

where λ_i presents the effectiveness of innovation activities of each type of firm. And based on the Equation (4.5), the amount spent on research R_t is expressed as,

$$R_t = \widetilde{A}_t (\frac{\mu_t}{\lambda_i})^{\frac{1}{\sigma}} \qquad 0 < \sigma < 1 \tag{4.6}$$

4.3.2 Growth rates of SOEs, LPEs and SMEs with financial frictions

In reality, research activities involve significant capital outlay. One of the notable constraints that can be placed on innovative activities is financial friction. There are two main models that describe financial frictions for economic growth in the Schumpeterian framework. They are: Ex Ante Screening model and models with Ex Post Monitoring and Moral Hazard.

Models with Ex Ante Screening

According to King and Levine (1993), banks have to determine whether or not a given project/research is feasible before lending money. In this equation, fR_t is the screening cost and θ $(0 < \theta < 1)$ is the possibility that the project is feasible. It is supposed that P is the repayment that borrowers pay the banks. When the research project is feasible, banks will receive the repayment P. However, there is $1 - \theta$ possibility that the bank will receive nothing. The expected repayment is

$$\theta P + (1 - \theta) * 0 = \theta P$$

The expected profit of the bank is,

$$\theta P - fR_t$$

The expected profit should be equal to or larger than 0. If $\theta P \geq fR_t$, and the repayment of borrowers P is,

$$P \geq \frac{f}{\theta} R_t$$

In reality, there is not perfect competition in the banking sector. In this situation, a mark-up is added to the expected profit (that is thought to be 0 in a perfectly competitive banking sector), which is assumed as exogenous,

$$P = \left(\frac{f}{\theta} + \varepsilon\right) R_t$$

where ε is an exogenous mark-up in the banking sector.

The benefit from the research activity is written as,

$$Q = \lambda \left(\frac{R_t}{\check{A}_t}\right)^{\sigma} \tilde{\pi} \check{A}_t - R_t \left(1 + \frac{f}{\theta} + \varepsilon\right)$$

To maximise the benefit from innovation research, the optimal research input is worked out as,

$$R_t = \check{A}_t \left(1 + \frac{f}{\theta} + \varepsilon\right)^{\frac{1}{\sigma - 1}} (\sigma \lambda \tilde{\pi})^{\frac{1}{1-\sigma}}$$

In a non-perfect competitive banking market, based on Function (4.5), the possibility of technological improvement occurring is,

$$\mu_t = \left(\frac{\tilde{\pi}\sigma}{1 + \frac{f}{\theta} + \varepsilon}\right)^{\frac{\sigma}{1-\sigma}} \lambda^{\frac{1}{1-\sigma}}$$

Therefore, in a non-perfect competitive banking market, the average production growth rate of each type of firm is,

$$g_i = \left[\left(\frac{\pi\sigma}{1 + \frac{f_i}{\theta_i} + \varepsilon}\right)^{\frac{\sigma}{1-\sigma}} \lambda_i^{\frac{1}{1-\sigma}} (\tilde{\gamma_i} - 1) + 1\right] \widetilde{e_{it}} - 1 \qquad (4.7)$$

As ε is an exogenous mark-up in the banking sector, the average growth rate of each type of firm in the capital-intensive sector is negatively related to its financing cost parameter f/θ and positively related to the effectiveness of innovation activities λ and technical improvement $\widetilde{\gamma_i}$.

Impacts of financing costs on growth rates

When taking into account financial frictions, the financing cost actually determines the growth rate of each type of firm if two conditions hold that: (1) the effectiveness of innovation activities of each type of enterprise is the same ($\lambda_S = \lambda_L = \lambda_M = \lambda$); (2) the technical improvements caused by research activities of SOEs, LPEs and SMEs are at the same level ($\widetilde{\gamma_S} = \widetilde{\gamma_L} = \widetilde{\gamma_M} = \tilde{\gamma}$). According to Function (4.7), the average growth rates in production of SOEs, LPEs and SMEs are negatively related to their financing cost parameters f/θ. In addition, the growth in the number of employees within each type of firm is the same ($\widetilde{e_S} = \widetilde{e_L} = \widetilde{e_M}$).

In China, discrimination against private firms exists in the lending sector (Brandt and Li, 2003; Cull and Xu, 2003). Lending for research activities usually take the form of a medium to long-term loan. When undertaking a credit assessment for this type of loan, lenders check the background of debtors. Following the reform of SOEs in the 1990s, SOEs – particularly small and medium-sized enterprises – were eliminated from the market. In spite of this, the majority of SOEs survived, and play an important role in the economic and political security of China today. In general, however, these successful SOEs are large-sized and wield significant economic power in market. In these circumstances, investment projects involving SOEs are more attractive to creditors as they are perceived as having a higher feasible probability.

Information possessed by creditors in regard to loan applicants may lead to discrimination against certain groups of businesses (Arrow, 1998; Fafchamps, 2000). Indeed, the assessment of loan applicants' characteristics is based on whether it is costly for banks to acquire information of their creditworthiness (Schwab, 1986; Arrow, 1998; Darity and Mason, 1998; Yinger, 1998). In China, banks[14] normally have a mutually beneficial relationship with SOEs, and have existing channels for obtaining credit information (Brandt and Li, 2003). Whilst state ownership and business connections with the government still carry weight in banks' lending decisions in China, commercial judgements, such as an enterprise's size, profitability, cooperate governance, and location are also important determinates (Firth *et al.*, 2009).

Overall, it is more feasible for banks to undertake research into SOEs because of their economic strength and political connections. Based on commercial judgements, LPEs are a more attractive proposition to banks than SMEs.

$$\theta_S > \theta_L > \theta_M$$

[14] There are five important banks in China. They are: Industrial and Commercial Bank of China, Bank of China, Agricultural Bank of China, China Construction Bank and Bank of Communications. These banks were previously sole funded by the state. The government owned 99.45% of the ten largest banks in China (La Porta *et al.*, 2002). After 2004, they were transferred to state-holding banks. More details about the banking sector in China can be found at http://www.cbrc.gov.cn/chinese/jrjg/index.html.

When considering the cost to a bank of acquiring information about a company's creditworthiness, SMEs are at a disadvantage in comparison to SOEs and LPEs. This is because SOEs normally have a history of long-term cooperation with the banks, and the channel for obtaining information already exists. LPEs have a size advantage and cooperative governance, and the screening cost is less than with SMEs. Indeed, it is costly for a bank to obtain information about SMEs.

$$f_S < f_L < f_M$$

Broadly speaking, the financing cost of SMEs is higher than LPEs and SOEs. In addition, the financing cost of SOEs is the lowest.

$$\frac{f_S}{\theta_S} < \frac{f_L}{\theta_L} < \frac{f_M}{\theta_M} \tag{4.8}$$

In reality, interest rates could supersede the financing costs of each type of firm. In fact, SOEs have a large advantage when it comes to interest rates on loans[15]. Inequality (4.8) is proven by the average interest rates of SOEs, LPEs and SOEs showed in Table 4.3.

According to Function (4.7) and Inequality (4.8), it can be concluded that the production growth rate of SOEs in a capital-intensive industry is highest, while the average growth rate of SMEs is the lowest,

$$g_M < g_L < g_s$$

State-owned and commercial banks will perceive a LPE with a strong credit

[15] Table 4.3 shows that SOEs have the lowest banking interest rate.

history and innovative, effective projects as equally attractive as a SOE. In this circumstance, the production growth rates of LPEs with good credit and promising projects may be close to or even equal to that of SOEs.

Differences in the technical research capabilities of SOEs, LPEs and SMEs

This section is focused exclusively on the impact of financial frictions on growth rates. The role of technical capabilities is not discussed; indeed,, the effectiveness of innovation activities and technical improvement through research differs between each type of enterprise. This section will therefore explore the differences in the technical research capabilities of SOEs, LPEs and SMEs, and discuss the subsequent influence on growth rates.

The number of applications for patents by state-owned manufacturing enterprises in 2012 and 2011 averaged 2.03 and 1.44 per firm, which is significantly higher than applications lodged by private manufacturing enterprises (0.21 and 0.16 respectively). In 2011, outputs directly linked to R&D activities in state-owned manufacturing enterprises was about 0.16 billion Yuan per firm, whilst the outputs of private manufacturing enterprises was only 7.85 million Yuan. The average ratio of outputs to inputs in terms of R&D activities from 2008 to 2009 in large and medium-sized private enterprises was 19.39. The figure for large and medium-sized state-owned enterprises was 17.22.[16] On this basis, it is safe to assume that innovation activities in SMEs are the least effective and LPEs are most effective ($\lambda_M < \lambda_S < \lambda_L$).

The average value of production per new product development project of large and medium-sized SOEs from 2008 to 2010 was 33.99 million Yuan, whilst the average value of LPEs was 35.52 million Yuan. In 2011, the figure for state-owned enterprises was 42.56 million Yuan; in contrast, privately owned enterprises average value was less than 21 million Yuan. It can be concluded that technical improvements (or an increase in productivity) as a result of research activities conducted by SOEs is less than LPEs; however, the gap is not especially large. Technical improvements made by SMEs are the smallest ($\gamma_M < \gamma_S < \gamma_L$).[17]

It is supposed that $\Omega_\mathrm{i} = \lambda_i^{\frac{1}{1-\sigma}}(\widetilde{\gamma_i} - 1)$. Ω_i presents the technical research capabilities of SOEs, LPEs, and SMEs. In addition, $\mathrm{T}_i = \Omega_\mathrm{i}\left(\frac{\widetilde{\pi}\sigma}{1+\frac{f_i}{\theta_i}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}} + 1$ presents the joint effects of the financing cost and technical research capabilities of each type of firm. As a result, Function (4.7) can be transformed into,

$$g_i = \mathrm{T}_i n_i - 1$$

According to the statistics, the technical research capabilities of SMEs are the lowest, whilst LPEs are the highest. The technical research capabilities of SOEs

[16] Data sourced from the China Statistics Database
[17] Data sourced from the China Statistics Database

are lower than LPEs, but the difference is not significant.

$$\Omega_L > \Omega_S > \Omega_M$$

Based on Function (8), the technical research capability of each type of firm (Ω_i) positively affects growth rates. However, financing costs are negatively related to growth rates.

The technical capabilities of SMEs are the lowest, but their financing costs are highest. It can be concluded that the combined impact of financing cost and research capability on SMEs is the least significant. The technical capabilities of SOEs are lower than LPEs, and financing costs of SOEs lower than LPEs. The combined impact of financing cost and research capabilities of SOEs and LPEs can be determined by SOEs' advantages in financing costs and LPEs' advantages in technical research capabilities. If the advantages of LPEs in technical research capabilities do not outweigh the disadvantages in financing costs [$\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} < \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}$], the combined effects of financing cost and research capabilities are less than SOEs ($T_S > T_L$). However, if the advantages of SOEs in financing cost are not larger than the advantages of LPEs in technical research capabilities [$\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} > \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}$], the combined impact of financing cost and research capabilities of SOEs is smaller than LPEs ($T_S < T_L$).

It is more complex to compare the growth rates of SOEs, LPEs, and SMEs. If $\left(\frac{\Omega_L}{\Omega_S}\right) < \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}$ $and \frac{T_S}{T_L} > \frac{n_L}{n_S}$, the average growth rate of SOEs is higher than LPEs. If the strengths of SOEs in terms of financing cost prevail over their weaknesses in technical research capability, the combined impact of research capabilities and financing costs on SOEs is more significant than the effect on LPEs. Moreover, if SOEs' strengths outweigh disadvantages in the growth rates in the total number of firms, the average growth rate of SOEs is larger than LPEs.

If $\frac{T_S}{T_M} > \frac{n_M}{n_S}$, the average growth rate of SOEs is larger than SMEs. On the basis that SMEs have the lowest combined results in terms of technical research capabilities and financing costs, and the advantages of SOEs in joint effects are more significant than the inferiorities in SOEs' total labour inputs, SOEs will – on average – grow more rapidly than SMEs. Similarly, the average growth rate of LPEs is higher than SMEs, if LPEs' advantages in joint effects are higher overall ($\frac{T_L}{T_M} > \frac{n_M}{n_L}$).

***Proposition 4.1*: In the Ex Ante Screening model, average growth rates of SOEs, LPEs and SMEs are determined by their technical research capabilities, financing costs and the growth rate in the total number of each**

type of firm. The order of growth rates is determined by whether their superiorities in certain determinants outweigh their weaknesses in other determinants.

Models with Ex Post Monitoring and Moral Hazard

Aghion, Banerjee and Piketty (1999) suppose that banks make the decision to lend money, but borrowers make the choice to default. hR_t $(0 < h < 1)$ is the default cost of to the borrower. h indicates the financing development and the ability of banks to monitor borrowers. When financing development is high and the ability of banks to monitor the borrowers is great, h is higher. This means that the default costs faced by borrowers is higher and there is less possibility that they will choose to default on their loans.

It is supposed that Γ is the interest factor and μ is the possibility of innovation occurring. The expected repayment is $\mu\Gamma L_t$. When the expected repayment is larger than the default cost, borrowers choose to default，

$$\mu\Gamma L_t > hR_t$$

Banks will lend money to borrowers only when the expected repayment equals the total amount of the loan (there is no time cost, and so there is no discounted factor),

$$\mu\Gamma L_t = L_t$$

With the restriction $0 < h < 1$, the lower bond of research activities (input R_t) is

$$R_t > \frac{1}{1-h}(R_t - L_t) = \nu(R_t - L_t) = \hat{R}_t \tag{4.9}$$

where the credit multiplier $\nu = 1/(1-h)$ and $\nu > 1$.

It is supposed that $\Lambda_t = R_t - L_t$, and Λ_t is the amount of funds spent on research projects. Whenever Inequality (4.9) holds, the borrowers choose to default. The equilibrium growth rate is obtained by substituting the constrained investment $\hat{R}_t = \nu\Lambda_t$ into the innovation production Function (4.6). Thereby the growth rate of production is

$$g_i = \left[\Omega_i \left(\frac{\nu_i \Lambda_{it}}{\check{A}_{it}}\right)^{\sigma} + 1\right] n_i - 1$$

$\check{A}_t$ is target productivity/technology level, and the technology level in the last period is $\check{A}_t = \bar{\gamma}\check{A}_{t-1}$. The productivity level in the first period is assumed to be $\check{A}_1 = \bar{\gamma}\ (A_0 + \varsigma)$. $\bar{\gamma}$ is the geometric average value of technological improvements throughout the entire period. A_0 is the initial productivity that occurs as a result of the technical improvements and is assumed to be the same for each type of firm. Initial productivity A_o can be understood as the average productivity level of industries entered into by enterprises during an initial period. It is therefore supposed that $A_0 = 1$. ς is the productivity achieved by effective management. The function $\check{A}_t$ of $\bar{\gamma}$ is,

$$\check{A}_t = \bar{\gamma}^t(1 + \varsigma)$$

where $\bar{\gamma}^t$ presents an accumulated technical improvements during the entire period.

The average growth in production rates of SOEs, LPEs and SMEs are presented as

$$g_i = \left\{ \Omega_i \left[\frac{\nu_i \Lambda_\mathrm{i}}{\Phi_i (1 + \varsigma_i)} \right]^\sigma + 1 \right\} n_i - 1 \qquad (4.10)$$

where $\Phi_\mathrm{i} = \bar{\gamma}_i{}^t$ is an accumulated technical improvements of each type of firm.

It is supposed that $\mathbb{C}_i = \Omega_i \left[\frac{\nu_i \Lambda_\mathrm{i}}{\Phi_i (1+\varsigma_i)} \right]^\sigma + 1$, which indicates the combined effect of technical impacts, default costs, and management effectiveness.

In this chapter, only a formal channel of financing is referred to; that is, debtors borrow funds from banks in order to conduct research. In this model, Λ represents only the firms themselves.

On the basis of Function (4.10), it can be concluded that: (1) average growth rates of SOEs, LPEs and SMEs are positively related to their technical research capabilities, default costs, funds assigned to research activities and the growth rates of the number of each type of enterprise; (2) the accumulated technical improvements and the effectiveness of management influence average growth rates negatively.

In the model, h is the default cost, and presents the effectiveness of the banks monitoring the firms. The effectiveness of monitoring SOEs, LPEs and SMEs is determined by whether it is costly for banks to obtain accurate information about each type of firms' investment projects and creditworthiness.

As a result of established channels and practices between banks and SOEs (Brandt and Li, 2003), SOE monitoring is the most effective (h_s). LPEs have a larger h because banks can obtain more detailed information about the projects and firms, and owners of LPEs can less easily escape any ramifications should they choose to default. If the owners of LPEs do choose to default and seek to escape punishment, however, banks are able to acquire fixed and other assets to decrease the losses caused by default. If a LPE chooses to default, therefore, banks can effectively punish them. However, financial information about SMEs and their projects is less easy to obtain and evaluate (as a result, SMEs typically have lower credit). Owners of SMEs can more easily evade punishment if they choose to default. Furthermore, even if the owner(s) of a SME are caught, they can, for example, transfer money or assets to family members or other relations. Banks therefore find it difficult to acquire assets to cover their losses. Consequently, the default cost h of LPEs is larger than SMEs. Overall, banks are most effective in their monitoring of SOEs, whilst SMEs have the lowest default cost $(h_s > h_l > h_m)$. This means the credit multiplier of SOEs is the largest and SMEs the smallest.

$$\nu_S > \nu_L > \nu_M$$

The average per-firm cost of state-owned manufacturing enterprises' R&D input in 2011 and 2012 is approximately 11.63 million Yuan. In contrast, the outlay of private manufacturing enterprises is only 0.51 million Yuan. Considering the size effects of PEs, small and medium-sized private manufacturing enterprises' R&D inputs are presumed to be less than large-sized private manufacturing enterprises.

$$R_S > R_L > R_M$$

On this basis, it is assumed that SOEs spend the most on R&D activities, which is presented as Λ_S. The outlay of SMEs is the lowest.

$$\Lambda_S \geq \Lambda_L \geq \Lambda_M$$

Ignoring the external effects determiner (Lin *et al.*, 1998, 2003; Bai *et al.*, 2000, 2006; Holz, 2011), SOEs in China are less effective than PEs in terms of financing performance (Jefferson *et al.*, 2000; Lardy, 1998; Plane, 1997; Sachs and Woo, 1997). For example, managers in PEs can be effectively monitored since PEs seek profit maximisation and are open to financial takeovers (Vickers and Yarrow, 1990). By contrast, SOEs have policy burdens and tend to be less effectively managed (Shleifer and Vishny, 1996). Therefore, the effective management indicator of SOEs (ς_S) is smallest, and LPEs are the most effective in terms of management.

$$\varsigma_L > \varsigma_M > \varsigma_S$$

The accumulated technical improvements of LPEs (Φ_L) are highest. SMEs are weakest at accumulated technical improvements (Φ_M) because of the technical research capabilities of this type of firm. The average number of patent applications by state-owned manufacturing enterprises in 2012 and 2011 is 2.03 and 1.44 respectively. The number of applications by private manufacturing enterprises is 0.21 and 0.16. Therefore, the accumulated technical improvements of SOEs, LPEs and SMEs is presented as,

$$\Phi_L > \Phi_S > \Phi_M$$

In summary, SOEs have a distinct advantage due to the amount of research activities they invest in. However, the default costs of SOEs are the highest. SOEs perform better than SMEs but worse than LPEs both in terms of technical research capability and accumulated improvements. However, because management of SOEs is less effective, the indicator of productivity through effective management is the lowest. In comparison to SOEs and SMEs, LPEs are the most effective in their technical innovation and management. Default costs of LPEs are higher than SMEs but lower than SOEs. Similarly, the level of investment in self-funding research activities is greater than SMEs but less than SOEs. The combined impact of default costs and the total funds paid by LPEs for research activities are mid-range in comparison to SOEs and SMEs. Despite better performance than SOEs with regards to effectiveness of management, SMEs are lowest in all determinants of growth rates.

According to Function (4.10), it is difficult to order the growth rates of SOEs, LPEs and SMEs. Pairwise comparison of each type of firms' growth will be outlined later in the study.

If $\left(\frac{\Lambda_S}{\Lambda_L}\right)^{\sigma} > \frac{\Omega_L}{\Omega_S}\left(\frac{\nu_L}{\nu_S}\right)^{\sigma}\left(\frac{1+\varsigma_S}{1+\varsigma_L}\right)^{\sigma}\left(\frac{\Phi_S}{\Phi_L}\right)^{\sigma}$ *and* $\frac{\mathbb{C}_S}{\mathbb{C}_L} > \frac{n_L}{n_S}$, the average growth rate of SOEs is greater than LPEs. On this basis, if the superiority of SOEs in terms of levels of research investment prevails over disadvantages in default costs, management effectiveness, technical research capabilities and accumulated technology improvements, then the combined effects of technological impacts, default cost and management effectiveness are better than LPEs. In this situation, the advantages of SOEs outweigh the disadvantages caused by the low growth rate in the total number of SOEs.

If $\frac{\Omega_S}{\Omega_M}\left(\frac{\Lambda_S}{\Lambda_L}\right)^{\sigma}\left(\frac{\Phi_M}{\Phi_S}\right)^{\sigma} > \left(\frac{\nu_M}{\nu_S}\right)^{\sigma}\left(\frac{1+\varsigma_S}{1+\varsigma_M}\right)^{\sigma}$ *and* $\frac{\mathbb{C}_S}{\mathbb{C}_M} > \frac{n_M}{n_S}$, the average growth rate of SOEs is more rapid than SMEs. The superiority of SMEs in terms of default costs and management effectiveness is negated by SOEs' advantages in technical research capabilities, accumulated technology improvements and self-funding research investment. The joint effects of technology impacts, default cost and management effectiveness are therefore more significant in SOEs than SMEs. In this circumstance, the superiority of SOEs in terms of combined effects prevails over their inferiority in total labour input growth.

If $\frac{\Omega_L}{\Omega_M}\left(\frac{\Lambda_L}{\Lambda_M}\right)^{\sigma}\left(\frac{1+\varsigma_M}{1+\varsigma_L}\right)^{\sigma}\left(\frac{\Phi_M}{\Phi_L}\right)^{\sigma} > \left(\frac{\nu_M}{\nu_L}\right)^{\sigma}$ *and* $\frac{\mathbb{C}_L}{\mathbb{C}_M} > \frac{n_M}{n_L}$, the average growth rate of LPEs is higher than SMEs. On this basis, LPEs' weaknesses in default costs are outweighed by their technical research capabilities, level of self-funding innovation inputs, management effectiveness and accumulated technology improvements. As a result, the combination of technology impacts, default cost and management effectiveness on LPEs are more obvious than on SMEs. Taking into account the fact that LPEs' combined advantages are more significant than their inferior growth rate, the average growth rate of LPEs is actually larger than that of SMEs.

Proposition 4.2: **Average growth rates of SOEs, LPEs and SMEs are positively determined by technical research capabilities, default costs, level of self-funding research inputs and total number of each type of firm, but negatively influenced by accumulated technology improvements and management effectiveness. If superior determinants prevail over inferior determinants in comparison to the other types of firms, the average growth rate of this type of enterprise is higher.**

Summary

The average growth rates of SOEs, LPEs and SMEs and their determinants are discussed in this section. In both the Ex Ante Screening model and the Ex Post

Monitoring and Moral Hazard model, two components determine the average growth rates of each type of firm. One is the growth rate of the total amount of each type of firm; the other is the growth rate caused by technical innovation. If one type of enterprise is dominant due to its technical advantages, the scale of this type of firm should be limited so that the expansion speed is slower than the other two types of firm. However, if one type of firm is disadvantaged in terms of technical growth rate (such as SMEs), the government could issue a policy that encourages an increase in the number of this type of business so that, when compared to the other two types firms, the average growth rate will not as low.

Other factors, such as financial frictions, technology, management effectiveness and self-funding capital investment in technology, also determine the growth rates of SOEs, LPEs and SMEs. According to the Ex Ante Screening model, financing cost and technical research capabilities are two such determinants. The average technology-led growth rate of SMEs is the lowest because SMEs are at a disadvantage in terms of technical research capabilities and financing cost. The rate of technology-led growth in SOEs and LPEs is determined by whether the superiority of SOEs in terms of financing cost is more significant than their inferiority in technical research capabilities. In the Ex Post Monitoring and Moral Hazard model, research capabilities, default cost and self-funding research investment positively affected the average technology-led growth rates of SOEs, LPEs and SMEs. However, the effects of accumulated technology and management effectiveness are negative. If one type of firms' advantages outweighs their inferiorities when compared to other types of firms, the average technical growth rate of this type firm is higher.

4.3.3 Weights of each type of firms in growth of total outputs

The determinants of average growth rates of SOEs, LPEs and SMEs have been examined and compared using the Ex Ante Screening model and Ex Post Monitoring and Moral Hazard model. In this section, the weights of SOEs, LPEs and SMEs in growth of total production are discussed.

Considering the order of average growth rate of SOEs, LPEs, SMEs, Function (4.1) is rewritten as

$$Y = y_{1t} + y_{2t} + y_{3t}$$

1, 2 and 3 in this function represent the firms with the highest average growth rate, with average growth rate in the middle range.

Similarly, according to the Schumpeterian model, the optimal production for each type of firm (Function (4.2)) is transformed into

$$y_{Ot}^{*} = \Pi_O A_{Ot}$$

where $O \in \{1, 2, 3\}$. And $\Pi_O = N_O L_O \pi_O$

The production at time t is,

$$y_{Ot} = (1 + g_O) * y_{O(t-1)}$$

$$y_{O(t-1)} = (1 + g_O) * y_{O(t-2)}$$

The output is optimal at any period. It is supposed that the optimal output at time 0 is,

$$y^*_{O0} = N_{O0} L_O \tilde{\pi}(A_0^O + \varsigma_O)$$

A_0^O is the initial productivity of each type of firm. It is assumed that $A_0^O = 1$. ς_O is an indicator of management effectiveness. Let $\varpi_O = N_{O0} L_O \pi(1 + \varsigma_O)$. Therefore, the output of each type of firm can be written as,

$$y_{Ot} = (1 + g_O)^t y^*_{O0} = (1 + g_O)^t \varpi_O \qquad (4.11)$$

In enterprises with the highest growth rate, the proportion of the total production increases over time. However, the weight of the type of firms with the lowest growth rate decreases over time. The trend found in the type firms with midrange growth is more complex. The relationship of the gap between first and second highest growth rates and the gap between the second highest and lowest growth rates determines the proportional change. When $\frac{g_1}{g_2} > \frac{g_2}{g_3}$, the weight of firms with the second highest growth rate in total production decreases over time.

Proposition 4.3: **Enterprises that are growing most slowly will gradually be forced out of the market, and their weight in the market will decrease**

overtime. At the same time, the proportion of firms with the highest growth rate will increase. Firms with an average growth rate in the middle range will see a decrease over time when $\frac{g_1}{g_2} > \frac{g_2}{g_3}$.

4.4 Quantitative Analysis:

In previous parts, it has been discussed that which factors could affect growths of SOEs, LPEs and SMEs and their orders. In this part, I will relate theoretical results in this chapter to the data reality.

4.4.1 Models with Ex Ante Screening

Based on theoretical results in previous part, in Ex Ante Screening model, it is known that technical research capabilities, financing costs and change rates of total number of each type firms will determine the average growths of SOEs, LPEs and SMEs and their orders.

In reality, financing cost could be presented by lending interest rate. And Table 4.3 shows from 2008 to 2013, average lending interest rates of the listed SOEs, LPEs and SMEs are 6.94% and 8.82% and 10.76% respectively. And these three numbers used to present the value of financing costs of each type firms in reality.

Technical research capabilities of SOEs, LPEs and SMEs in China are presented by the average value of ratios of new product sales incomes to expenditures on R&D from 2012 to 2014[18]. Higher new product sales income with per unit expenditure on R&D means higher research capability. However, I can not directly get data of LPEs and SMEs on new product sales income and expenditure on R&D. I use the ratio of large-sized firms to total firms to calculate the new product sales income and expenditure on R&D of LPEs and SMEs[19]. And average values of these ratios of SOEs, LPEs and SMEs from 2012 to 2014 are 11.09, 14.51 and 8.79 respectively.

The average change rates of total number of SOEs, LPEs and SMEs from 2012 to 2014 are 0.93, 1.03 and 1.09, which means during the period, total number of SOEs decreased while total number of LPEs and SMEs increased, but the increase rate of LPEs was smaller than SMEs.

Factor	**Method**	**Type of Firms**	**Value**
Financing Cost	Average lending interest rate of listed companies from 2008 to 2013	SOEs	6.94%
		LPEs	8.82%
		SMEs	10.76%
Research Capability	$\frac{new\ product\ sales\ income}{expenditure\ on\ R\&D}$	SOEs	11.09
		LPEs	14.51

[18] Data on innovation in china, in level of firms, are only available from 2011 to 2014. And change rates of total number of each type firms are referred in this model. Therefore, I use data from 2012 to 2014 to do quantitative analysis.

[19] The functions I used to calculate related data are $Data\ of\ LPEs = \frac{Data\ of\ large{-}sized\ firms}{Data\ of\ all\ firms} \times Data\ of\ PEs$ and $Data\ of\ SMEs = Data\ of\ PEs - Data\ of\ LPEs$

		SMEs	8.79
Chang rate of total number of firms	Average change rate of total numbers of firms from 2012 to 2014	SOEs	0.93
		LPEs	1.03
		SMEs	1.06

Table 4.4 VALUES OF FACTORS THAT DETERMINE GROWTH OF SOES, LPES AND SMES

Original Data Source: CSMAR Database and China Statistics Database.

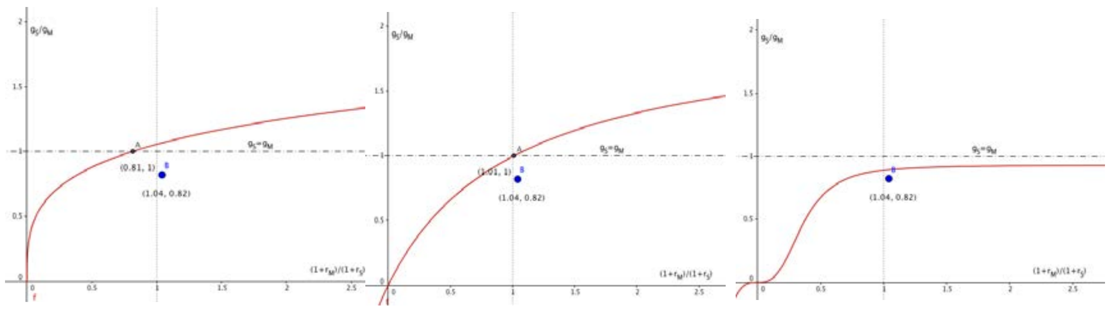
In addition, parameters are supposed to be 0.25, 0.5 and 0.75. And with each value of parameters $\tilde{\pi}$ and σ, impacts of research capability, financing cost and change rate of total number of firms on the order of growths of SOEs, LPEs and SMEs will be discussed respectively in the next.

Impacts of financing cost

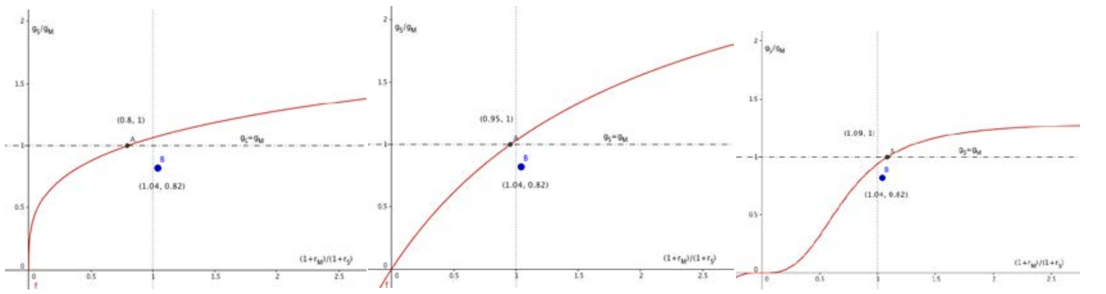
In this part, I will compare one type of firms with another one, and discus at exact what conditions, the relative growth with larger than 1.

Compared growth of SOEs to SMEs, by Graph 4.1, it clearly shows that there is a positive relationship between $\frac{1+g_S}{1+g_M}$ and $\frac{1+r_M}{1+r_S}$[20], which means relative growth of SOEs to SMEs (growth of SMEs is normalized to be one) should be more higher if the advantage of SOEs in lending interest rate, compared with SMEs, is more significant. And when $\tilde{\pi}$=0.25 and σ=0.75, the model fits reality better.

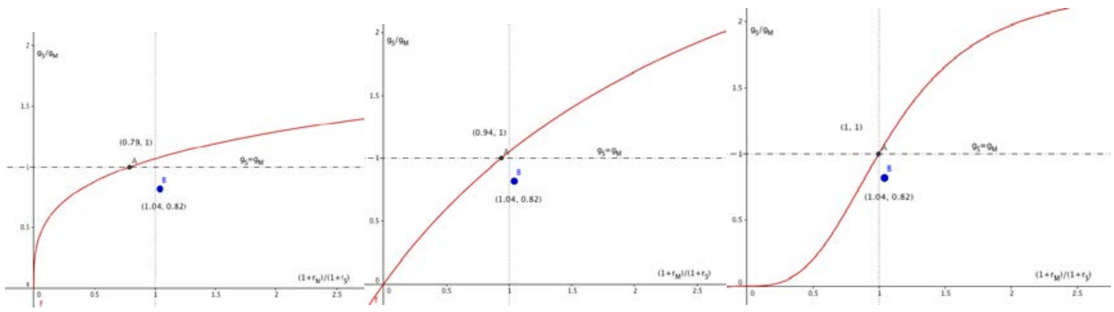
[20] r_S, r_L *and* r_M present lending interest rates of SOEs, LPEs and SMEs respectively.



$\tilde{\pi} = 0.25,\ \sigma = 0.25$ $\tilde{\pi} = 0.25,\ \sigma = 0.5$ $\tilde{\pi} = 0.25,\ \sigma = 0.75$



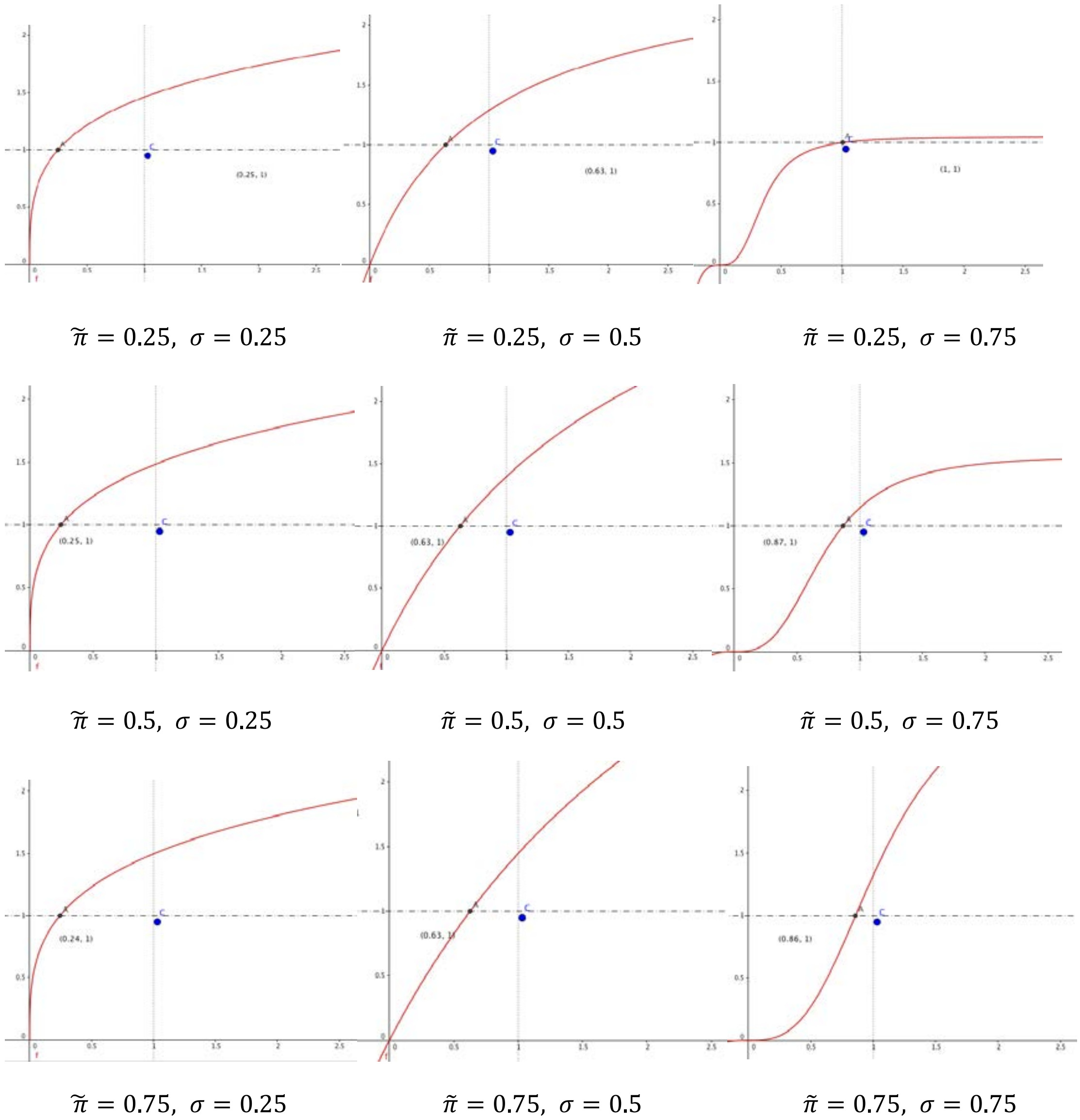
$\tilde{\pi} = 0.5,\ \sigma = 0.25$ $\tilde{\pi} = 0.5,\ \sigma = 0.5$ $\tilde{\pi} = 0.5,\ \sigma = 0.75$



$\tilde{\pi} = 0.75,\ \sigma = 0.25$ $\tilde{\pi} = 0.75,\ \sigma = 0.5$ $\tilde{\pi} = 0.75,\ \sigma = 0.75$

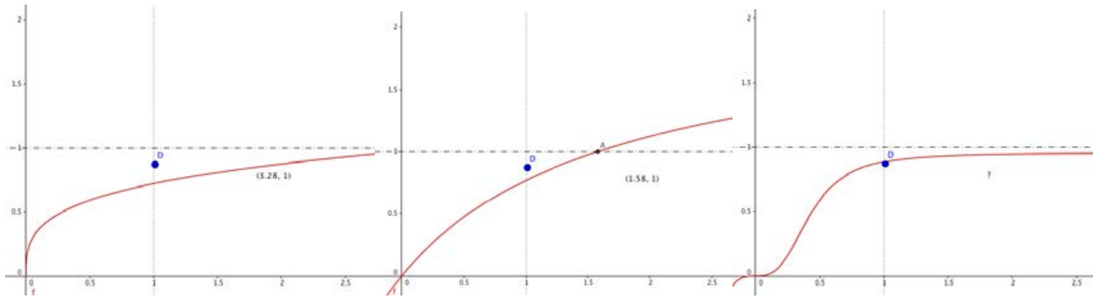
Graph 4.1 COMPARED GROWTH OF SOES TO SMES CONSIDERING IMPACTS OF FINANCING COSTS (LENDING INTEREST RATE)

By Graph 4.2, the relationship between relative growth of LPEs to SMEs and relative advantage of LPEs in lending interest rate is positive. Also when $\tilde{\pi}$=0.25 and σ=0.75, the model could describe reality better

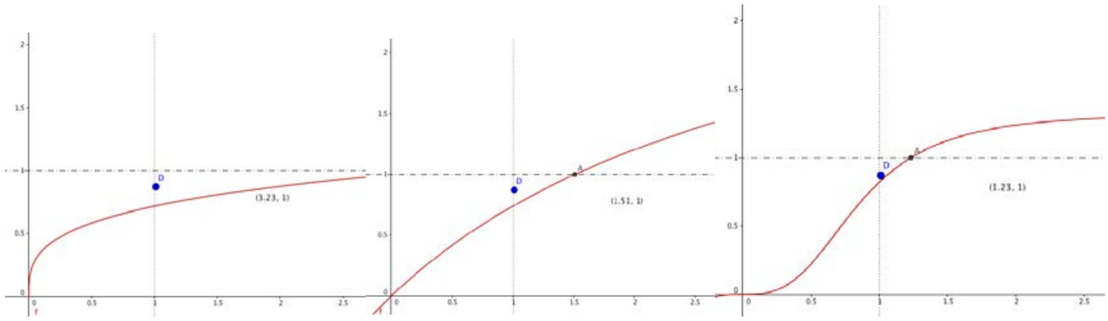


Graph 4.2 COMPARED GROWTH OF LPES TO SMES CONSIDERING IMPACTS OF FINANCING COSTS (LENDING INTEREST RATE)

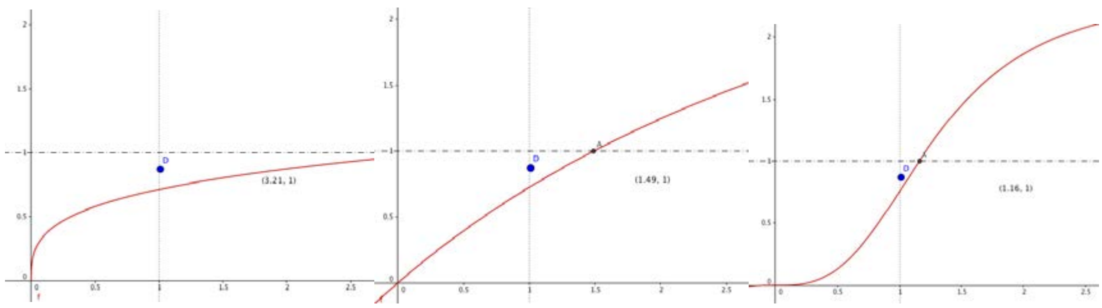
It is shown by Graph 4.3 that more significant advantage of SOEs in lending interest rates will lead to higher relative growth of SOEs to LPEs. And when $\tilde{\pi} = 0.25\ and\ \sigma = 0.75$, the model fits reality better.



$\tilde{\pi} = 0.25,\ \sigma = 0.25$ $\tilde{\pi} = 0.25,\ \sigma = 0.5$ $\tilde{\pi} = 0.25,\ \sigma = 0.75$



$\tilde{\pi} = 0.5,\ \sigma = 0.25$ $\tilde{\pi} = 0.5,\ \sigma = 0.5$ $\tilde{\pi} = 0.5,\ \sigma = 0.75$

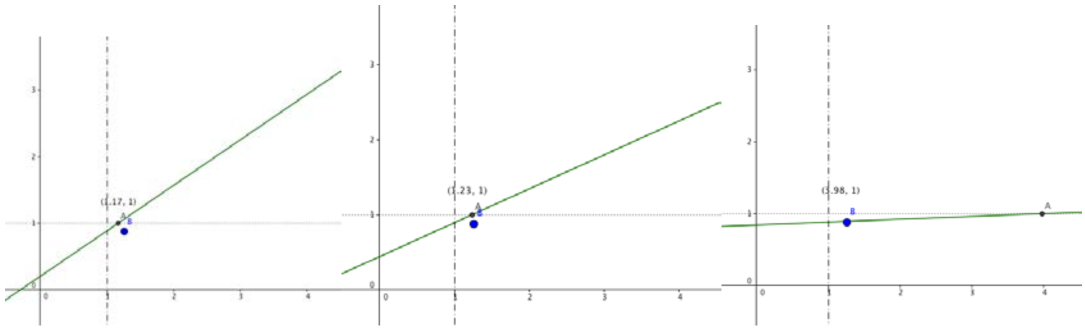


$\tilde{\pi} = 0.75,\ \sigma = 0.25$ $\tilde{\pi} = 0.75,\ \sigma = 0.5$ $\tilde{\pi} = 0.75,\ \sigma = 0.75$

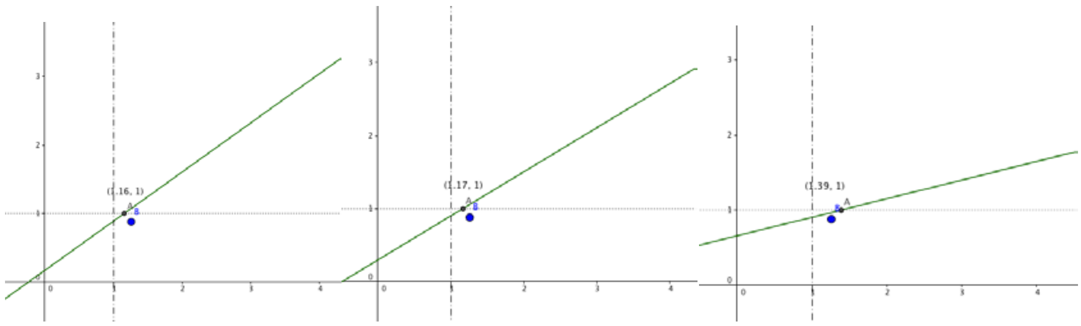
Graph 4.3 COMPARED GROWTH OF SOES TO LPES CONSIDERING IMPACTS OF FINANCING COSTS (LENDING INTEREST RATE)

Impacts of research capability

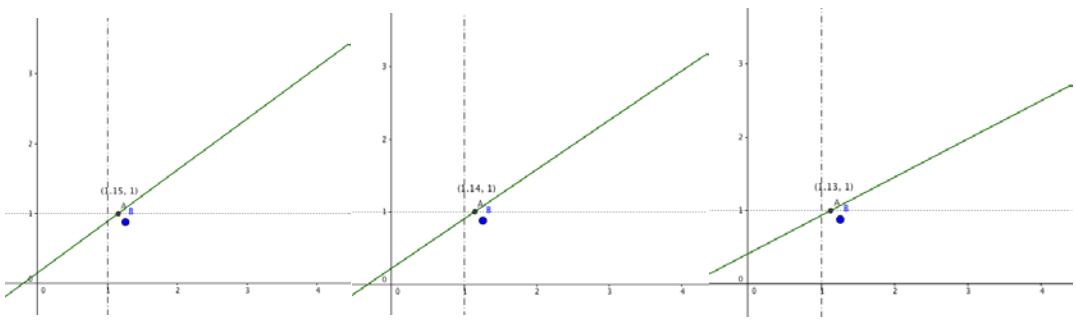
Compared growth of SOEs to SMEs, the relative growth of SOEs to SMEs is positively affected by relative research capability of SOEs to SMEs. The more significant advantage of SOEs in research capability will lead to higher relative growth of SOEs. And when $\tilde{\pi} = 0.25,\ \sigma = 0.75$, the model could explain reality better.



$\tilde{\pi} = 0.25,\ \sigma = 0.25$ $\tilde{\pi} = 0.25,\ \sigma = 0.5$ $\tilde{\pi} = 0.25,\ \sigma = 0.75$



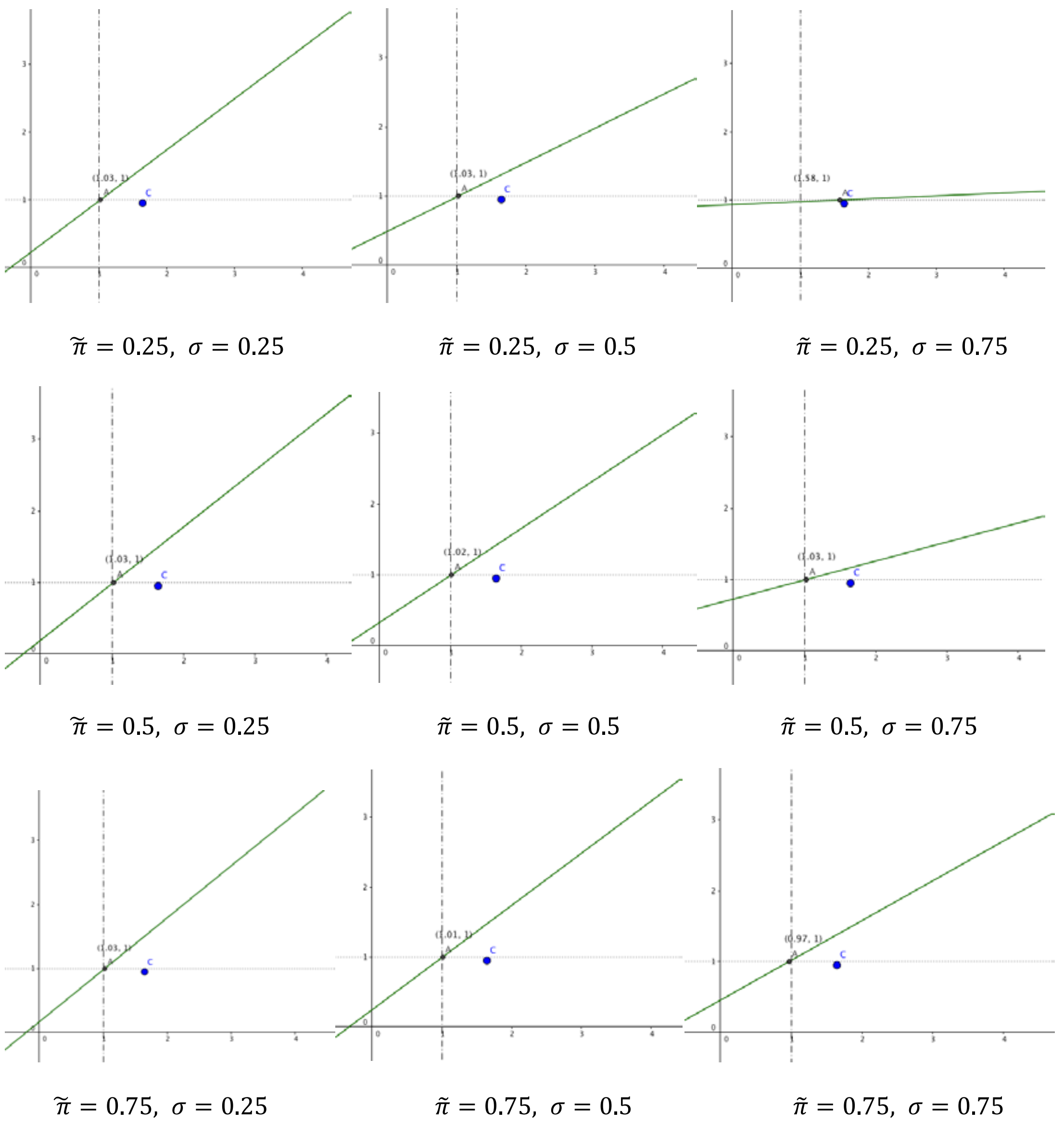
$\tilde{\pi} = 0.5,\ \sigma = 0.25$ $\tilde{\pi} = 0.5,\ \sigma = 0.5$ $\tilde{\pi} = 0.5,\ \sigma = 0.75$



$\tilde{\pi} = 0.75,\ \sigma = 0.25$ $\tilde{\pi} = 0.75,\ \sigma = 0.5$ $\tilde{\pi} = 0.75,\ \sigma = 0.75$

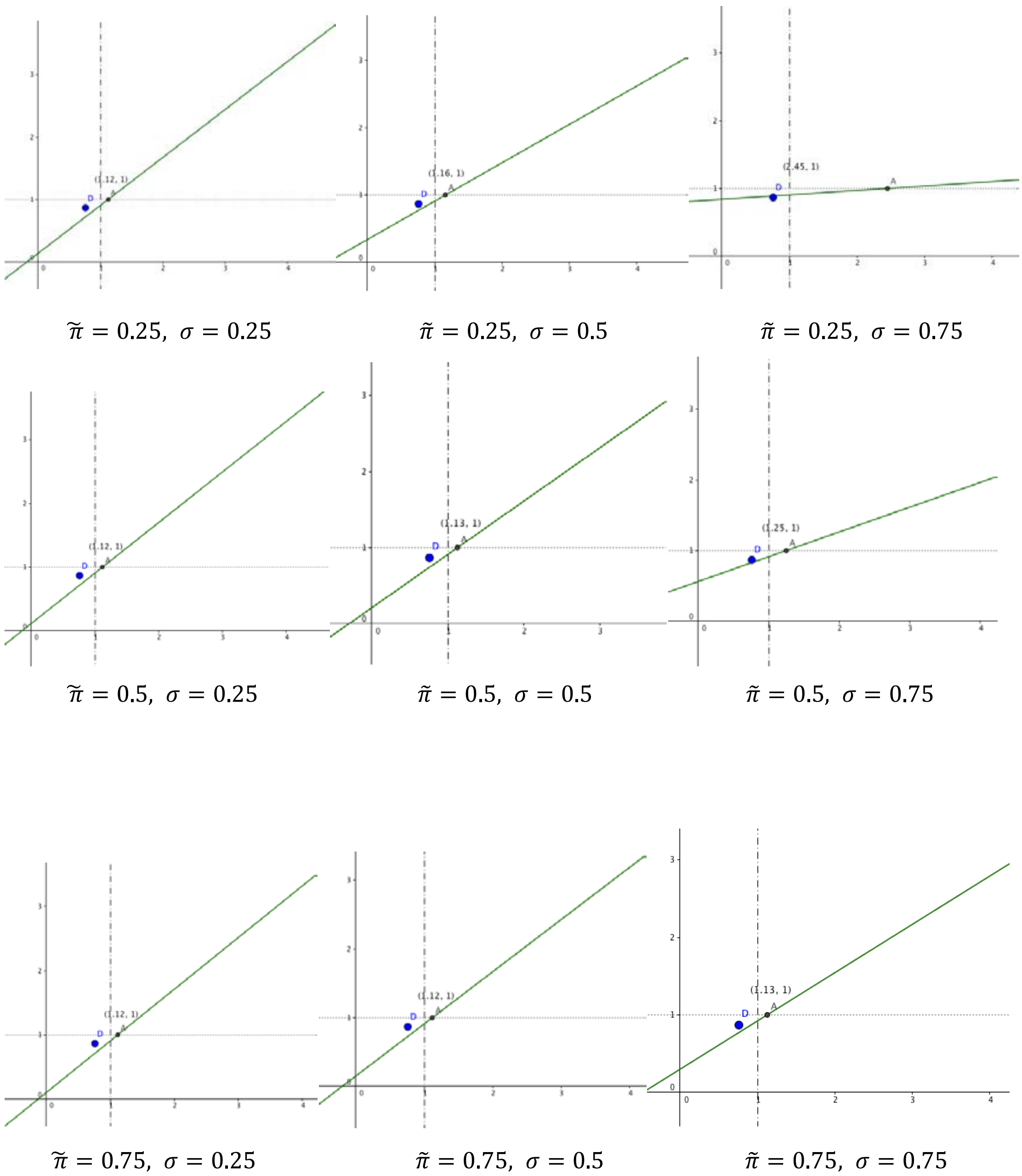
Graph 4.4 COMPARED GROWTH OF SOES TO SMES CONSIDERING IMPACTS OF RESEARCH CAPABILITIES

Graph 4.5 shows that relative growth of LPEs to SMEs is positively related to advantages of LPEs in research capability than SMEs. And when $\tilde{\pi} = 0.25,\ \sigma = 0.75$, the model describe reality better.



Graph 4.5 COMPARED GROWTH OF LPES TO SMES CONSIDERING IMPACTS OF RESEARCH CAPABILITIES

In Graph 4.6, the influence of relative research capability of SOEs to LPEs on relative growth of SOEs is positive and the model in this chapter could better conform to reality when $\tilde{\pi} = 0.25,\ \sigma = 0.75$



$\tilde{\pi} = 0.25,\ \sigma = 0.25$ | $\tilde{\pi} = 0.25,\ \sigma = 0.5$ | $\tilde{\pi} = 0.25,\ \sigma = 0.75$

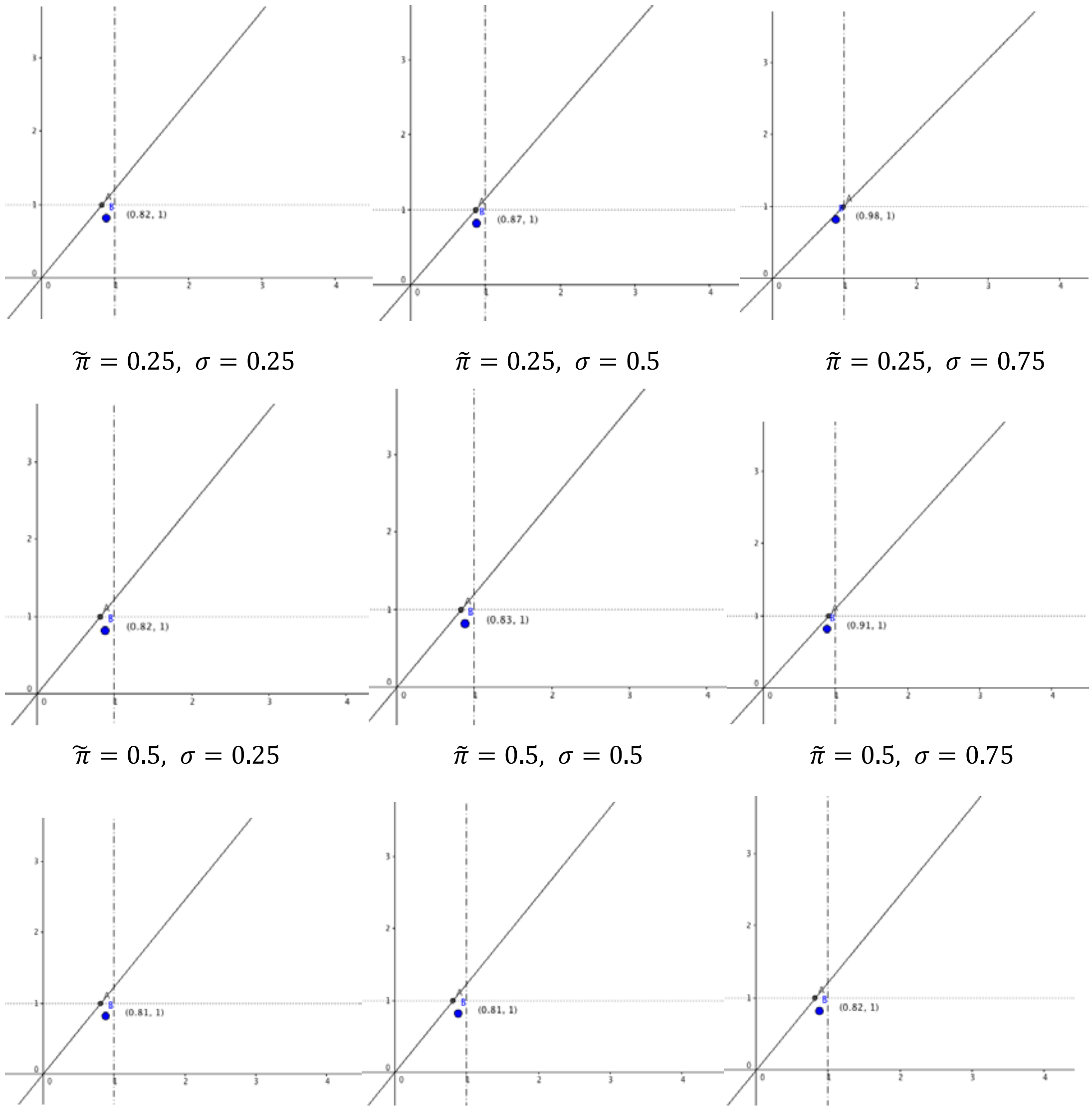
$\tilde{\pi} = 0.5,\ \sigma = 0.25$ | $\tilde{\pi} = 0.5,\ \sigma = 0.5$ | $\tilde{\pi} = 0.5,\ \sigma = 0.75$

$\tilde{\pi} = 0.75,\ \sigma = 0.25$ | $\tilde{\pi} = 0.75,\ \sigma = 0.5$ | $\tilde{\pi} = 0.75,\ \sigma = 0.75$

Graph 4.6 COMPARED GROWTH OF SOES TO LPES CONSIDERING IMPACTS OF RESEARCH CAPABILITIES

Impacts of change rates of total number of each type firms

The relative growth of SOEs to SMEs is positively affected by relative change rate of total number of SOEs to SMEs, which is presented by Graph 4.7. And the model could explain reality better when $\tilde{\pi} = 0.25,\ \sigma = 0.75$



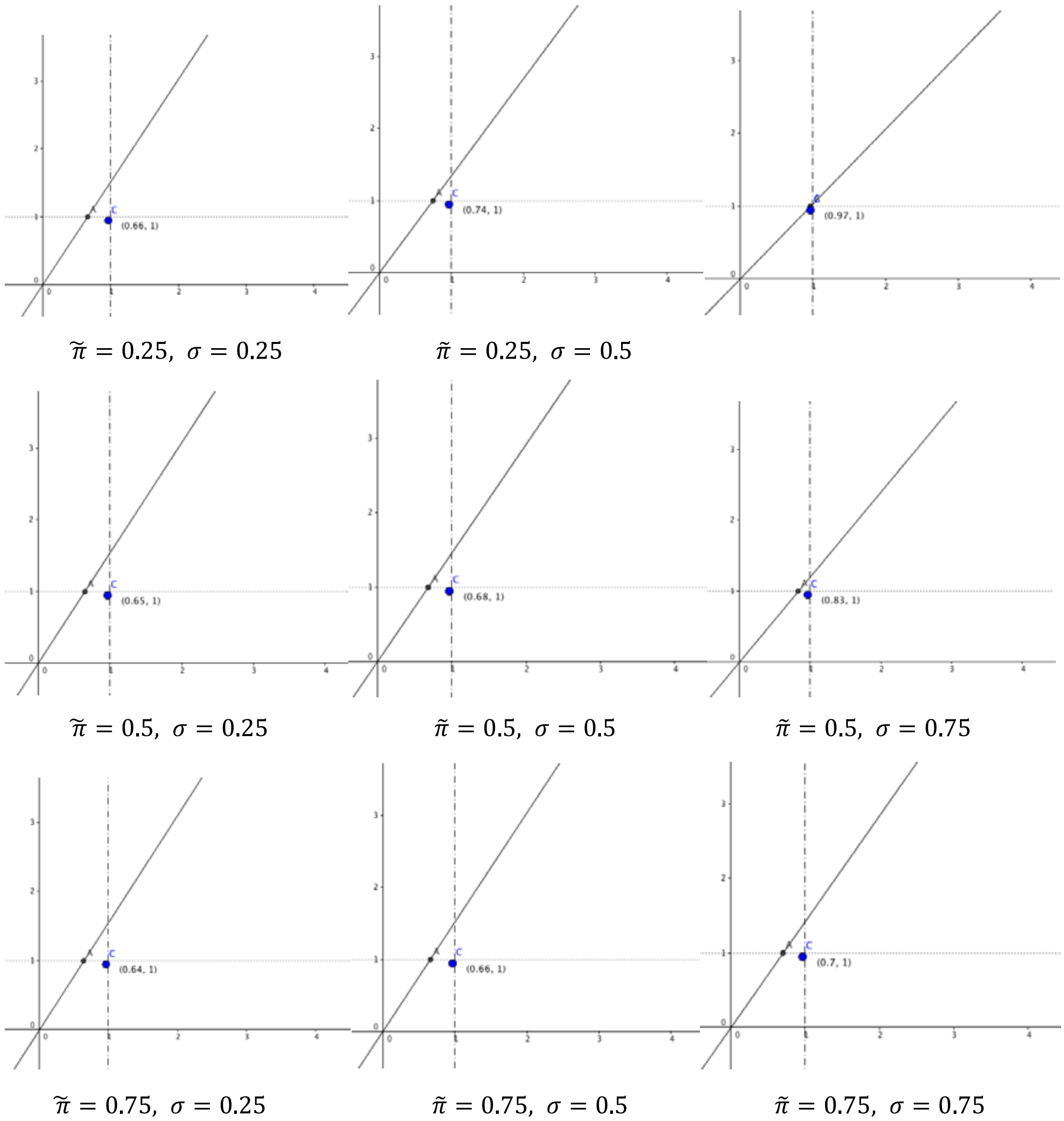
$\tilde{\pi} = 0.25,\ \sigma = 0.25$ $\tilde{\pi} = 0.25,\ \sigma = 0.5$ $\tilde{\pi} = 0.25,\ \sigma = 0.75$

$\tilde{\pi} = 0.5,\ \sigma = 0.25$ $\tilde{\pi} = 0.5,\ \sigma = 0.5$ $\tilde{\pi} = 0.5,\ \sigma = 0.75$

$\tilde{\pi} = 0.75,\ \sigma = 0.25$ $\tilde{\pi} = 0.75,\ \sigma = 0.5$ $\tilde{\pi} = 0.75,\ \sigma = 0.75$

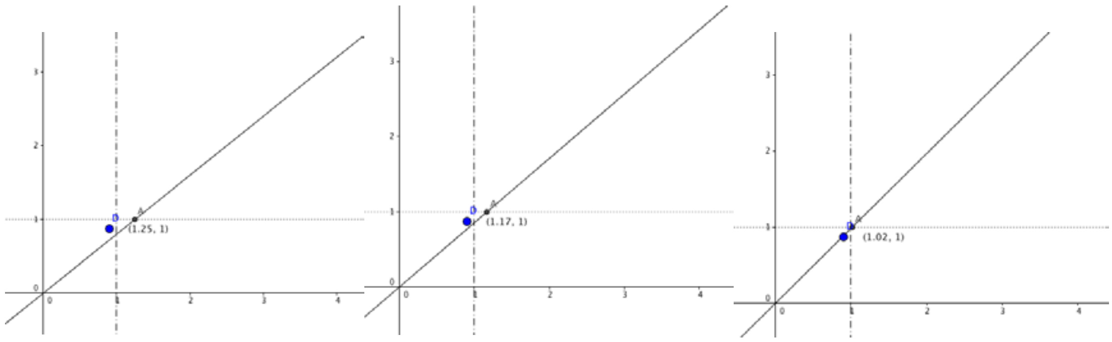
Graph 4.7 COMPARED GROWTH OF SOES TO SMES CONSIDERING IMPACTS OF CHANGE RATES OF TOTAL NUMBER OF EACH TYPE FIRMS.

Graph 4.8 indicates that the relative growth of LPEs to SMEs is higher if the disadvantage of LPEs in growth of total number of firms is less significant, compared with SMEs. Also the model could describe reality better if $\tilde{\pi} = 0.25$, $\sigma = 0.75$.

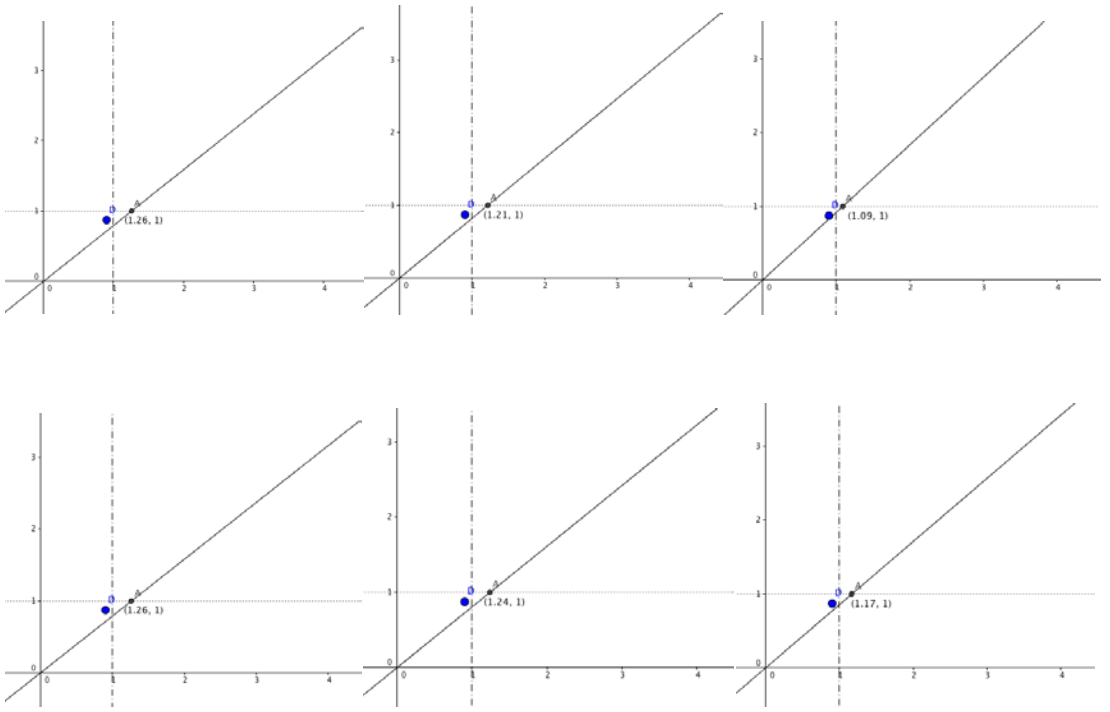


Graph 4.8 COMPARED GROWTH OF LPES TO SMES CONSIDERING IMPACTS OF CHANGE RATES OF TOTAL NUMBER OF EACH TYPE FIRMS.

It is clearly shown by Graph 4.9 that relative of growth rate of SOEs to LPEs is positively affected by relative change rate of total number of SOEs to LPEs. And the reality can be better explained when $\tilde{\pi} = 0.25,\ \sigma = 0.75$



$\tilde{\pi} = 0.25,\ \sigma = 0.25$ $\tilde{\pi} = 0.25,\ \sigma = 0.5$ $\tilde{\pi} = 0.25,\ \sigma = 0.75$



$\tilde{\pi} = 0.75,\ \sigma = 0.25$ $\tilde{\pi} = 0.75,\ \sigma = 0.5$ $\tilde{\pi} = 0.75,\ \sigma = 0.75$

Graph 4.9 COMPARED GROWTH OF SOES TO LPES CONSIDERING IMPACTS OF CHANGE RATES OF TOTAL NUMBER OF EACH TYPE FIRMS.

Summary

It has been clearly shown that when $\tilde{\pi} = 0.25,\ \sigma = 0.75$, the model could explain the reality better. Under this circumstance, to have higher growth than the other two types of frims, the required least relative values of lending rates, research capabilities and change rates of total number of one certain type of firms are presented by Table 4.5

Factors/Growth	$g_S > g_M$	$g_L > g_M$	$g_S > g_L$
Lending rates	$None$	$\frac{1+r_M}{1+r_L} > 1$	$None$
Research Capability	$\frac{\Omega_S}{\Omega_M} > 3.98$	$\frac{\Omega_L}{\Omega_M} > 1.58$	$\frac{\Omega_S}{\Omega_L} > 2.45$
Change rate of total number of firms	$\frac{n_S}{n_M} > 0.98$	$\frac{n_L}{n_M} > 0.97$	$\frac{n_S}{n_L} > 1.02$

Table 4.5 REQUIRED LEAST RELATIVE VALUES OF LENDING RATES, RESEARCH CAPABILITIES AND CHANGE RATES OF TOTAL NUMBER OF FIRMS.

Holding research capabilities and change rates of total number of each type firms as constants ($\Omega_S = 11.09, \Omega_L = 14.51, \Omega_M = 8.79, n_S = 0.93, n_L = 1.03$ and $n_M = 1.06$), the growth of SOEs should be worse than LPEs and SMEs. Compared with SMEs, the disadvantage of SOEs in total number of firms prevails over their advantage in lending interest rates. And compared with LPEs, SOEs have disadvantages both in research capability and total number of firms, and advantage of SOEs in lending rates are not significant as their disadvantages. In terms of comparison of growths of LPEs and SMEs, LPEs have disadvantage in total number of firms but their research capabilities are in dominant position, compared with SMEs. Under this situation, growth of LPEs will be higher than SMEs, if the lending rate of SMEs is higher than LPEs, which is true in reality.

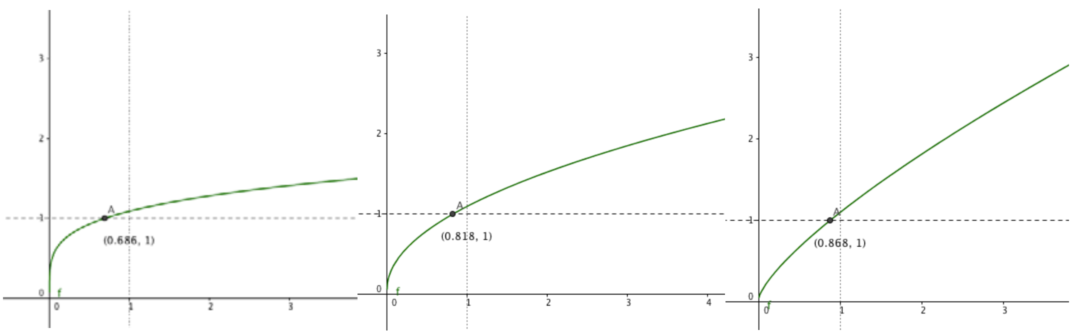
However, if lending rates and change rates of SOEs, LPEs and SMEs are considered as constants ($r_S = 6.94\%, r_L = 8.82\%, r_M = 10.76\%, n_r = 0.97, n_L = 1.03, n_M = 1.06$), growth of SOEs will be higher SMEs if relative research capability of SOEs to SMEs is lager than 3.98 and also higher than LPEs if relative research capability of SOEs to LPEs is more than 2.45. And growth of LPEs is better than SMEs if relative research capability of LPEs to SMEs is over than 1.58.

In addition, focus on impacts of change rates of total number of SOEs, LPEs and SMEs, ($r_S = 6.94\%, r_L = 8.82\%, r_M = 10.76\%, \Omega_S = 11.09, \Omega_L = 14.51\ and\ \Omega_M = 8.79$), if SOEs would like to get higher growth than SMEs and LPEs, the relative change rates of total number of SOEs to SMEs and LPEs should be larger than 0.98 and 1.02 respectively. And if relative change rates of total number of LPEs to SMEs is larger than 0.97, growth of LPEs will be over than SMEs, which means compared wit SMEs, the relative disadvantage of LPEs in total number of firms should less significant.

4.4.2 Model with Ex Post Monitoring and Moral Hazard

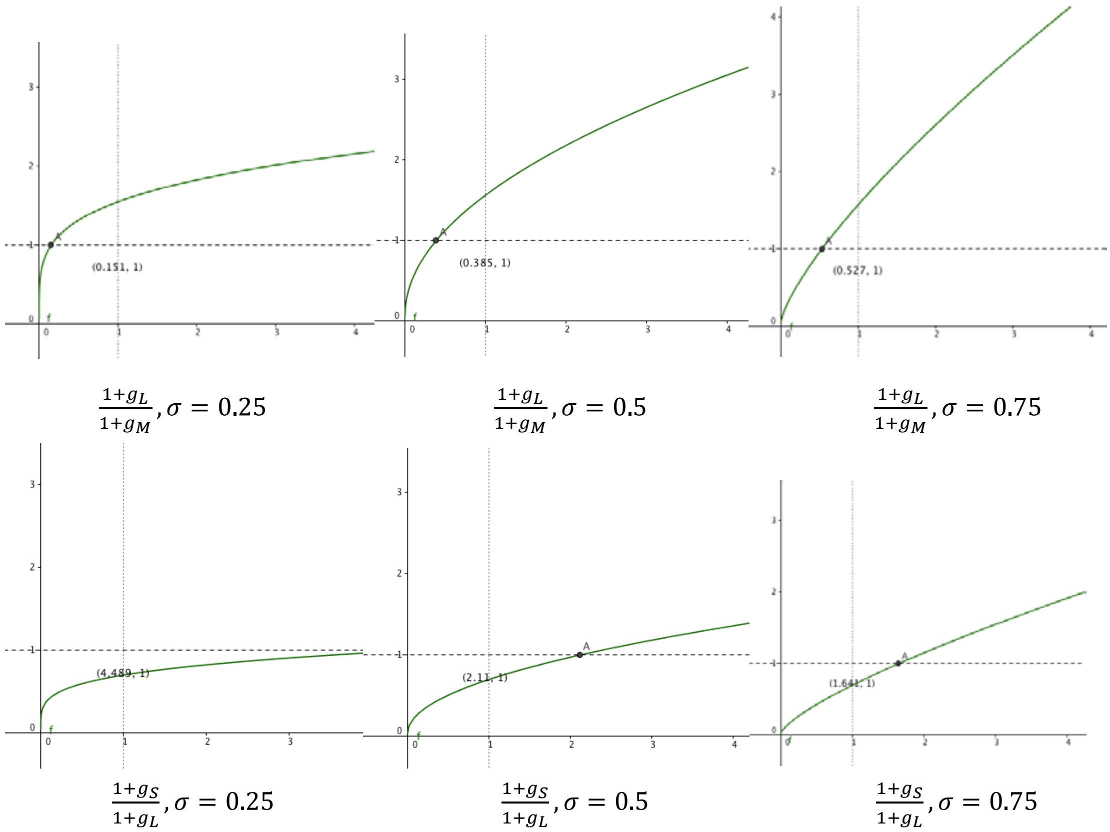
It has been discussed that, based on models with Ex Post Monitoring and Moral Hazard, growths of SOEs, LPEs and SMEs are determined by their research capabilities, change rate of total number of firms. Default costs, level of self-funding research capital inputs, accumulated technology improvements and management effectiveness. And in the model, the joint effects of level of self-funding research capital inputs, accumulated technology improvements and management effectiveness present self-funding research capital inputs per unit accumulation technology level. And in the model, v_i inversely presents the default costs of each type firms. And lending rates of each type firms also could measure the value of v_i[21]. The value of v of SOEs, LPEs and SMEs are 1.935, 1.926 and 1.901 respectively. And parameter σ is assumed to be 0.25, 0.5 and 0.75.

Graph 4.10 shows that for one certain type of firms, the relative growth of this type firms to the other two types is positively related to relative self-funding research capital inputs per unit accumulated technology level. This means that if the advantage of one certain type firms in self-funding research capital inputs is more significant, growth of this type firms will be higher.



$\frac{1+g_S}{1+g_M}, \sigma = 0.25$ $\frac{1+g_S}{1+g_M}, \sigma = 0.5$ $\frac{1+g_S}{1+g_M}, \sigma = 0.75$

[21] $v_i = \frac{1}{r_i} + 1$



Graph 4.10 IMPACTS OF SELF-FUNDING RESEARCH CAPTIAL INPUTS PER UNIT ACCUMULATED TECHNOLOGY LEVEL.

Table 4.6 shows the required lest relative self-funding research capital per unit accumulated technology level of each type firms when $\sigma = 0.25$, $\sigma = 0.5$ and $\sigma = 0.75$.

When $\sigma = 0.25$, growth of SOEs will larger than SMEs and LPEs if the relative self-funding research capital per unit accumulated technology level of SOEs to SMEs and LPEs are more than 0.686 and 0.868 respectively. And growth of LPEs is higher than SMEs if the relative self-funding research capital per unit accumulated technology level of LPEs to SMEs is over than 0.818.

When $\sigma = 0.5$, the relative self-funding research capital per unit accumulated technology level of SOEs to SMEs and LPEs should more than 0.151 and 0.527 respectively, in order to get higher growth of SOEs than SMEs and LPEs. And the growth of LPEs will more than SMEs if the relative self-funding research capital per unit accumulated technology level of LPEs to SMEs is higher than 0.385.

When $\sigma = 0.75$, SOEs will have better growth than SMEs and LPEs if relative self-funding research capital per unit accumulated technology level of SOEs to SMEs and LPEs are over than 4.489 and 1.641 respectively. In addition, the growth of SMEs is worse than LPEs when the self-funding research capital per unit accumulated technology level of LPEs is more than twice than SMEs.

	$\boldsymbol{g_S > g_M}$	$\boldsymbol{g_L > g_M}$	$\boldsymbol{g_S > g_L}$
$\boldsymbol{\sigma = 0.25}$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_M}{A_M}} > 0.686$	$\frac{\frac{\Lambda_L}{A_L}}{\frac{\Lambda_M}{A_M}} > 0.818$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_L}{A_L}} > 0.868$
$\boldsymbol{\sigma = 0.5}$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_M}{A_M}} > 0.151$	$\frac{\frac{\Lambda_L}{A_L}}{\frac{\Lambda_M}{A_M}} > 0.385$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_L}{A_L}} > 0.527$
$\boldsymbol{\sigma = 0.75}$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_M}{A_M}} > 4.489$	$\frac{\frac{\Lambda_L}{A_L}}{\frac{\Lambda_M}{A_M}} > 2.11$	$\frac{\frac{\Lambda_S}{A_s}}{\frac{\Lambda_L}{A_L}} > 1.641$

Table 4.6 REQUIRED LEAST RELATIVE SELF-FUNDING RESEARCH CAPITAL PER UNIT ACCUMULATED TECHNOLOGY LEVEL

4.5 Conclusion

In this chapter, models are discussed, which is used to examine the average growth rates of SOEs, LPEs, and SMEs in China. The model in this chapter follows the structure of classic multifactor Schumpeterian model, the main differences between this model and existing model are:

1. Based on Schumpeterian model, model in this chapter is used to analyze growth of three type firms (SOEs, LPEs and SMEs) in first, and then indirectly to analyze China's economy that is mainly made up of these three types of firms.
2. The scale effect of labour is not sidestepped in this model. Empirical studies of Barro and Sala-i-Martin (1995) and Laincz and Peretto (2006) show that growth rate of economy is not significantly related to population based on cross-country data. However, according to Dinopoulos and Thompson (1999), even though scale effects may not exist in cross-country analysis, in manufacturing industry, there may be scale effects. In this chapter, growths of outputs of SOEs, LPEs and SMEs in China are compared, and the theoretical results show that scale effect of labour (it is presented by total number of firms in this chapter) indeed determine growths of each type firms, especially for SMEs that are disadvantaged by research capability and financing cost.

The analysis found that two key elements determine the average growth rates of

SOEs, LPEs and SMEs in China. The first is growth rate caused by technology; the second is an increase in the total number of enterprises.

Financial frictions, technology, management effectiveness, self-funding research investment and increases in scale affect the average growth rate of SOEs, LPEs and SMEs. Evidence shows that SOEs face the least financial frictions. In comparison, SMEs have the most serious difficulties, due to higher scrutiny over their creditworthiness, difficulty in monitoring and high financing costs. In terms of technology, LPEs are more effective than SOEs and SMEs. Based on this criterion, SMEs perform the worst. Analysis has also found that the management effectiveness of SOEs is the worst and LPEs the best. This is due to the nature of ownership and organisational scale.

In the Ex Ante Screening model, without considering the effectiveness of innovation，the growth rate caused by SOEs' technical advancement is higher than LPEs and SMEs. This is also because fewer financial frictions are imposed on SOEs than other types of firms. Because of the high financing cost, the average technology-led growth rate of SMEs is the lowest.

However, with considering the effectiveness of innovation， there are more circumstances that impact on the technology-led growth rate of these businesses. In the Ex Ante Screening model, SMEs' average growth rate caused by technology is the smallest because SMEs are both disadvantaged through financial restrictions and technical research capabilities. Furthermore, if $\frac{\Omega_L}{\Omega_S} < \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}++\varepsilon}\right)^{\sigma}$], the average growth rate of SOEs is larger than LPEs. This is because the role played by the financial frictions determiner is greater than that of research capabilities.

If the impacts of default costs, management effectiveness, technical research capabilities and accumulated technology improvements are less significant than self-funding research investment, the average growth rate of SOEs is larger than LPEs. Interestingly, the growth rate of LPEs is smaller than SMEs if the positive impacts from innovation activities and financial frictions are less than the negative impacts from management effectiveness. Unlike SMEs, technical research capabilities, accumulated technology improvements and self-funding research investment can negate SOEs' inferiorities in default costs and management effectiveness. This in turn increases the average technology-led growth rate, meaning it is higher than that of SMEs. In addition, LPEs' superiority in terms of technology research capabilities, amount of self-funding innovation inputs, management effectiveness and accumulated technology improvements means their average technology-led growth rate is higher than SMEs.

Where one type of firm has a superior average technology-led growth rate but an inferior rate in the increase in the total amount firms (and the superiority is more pronounced than the inferiority) this type of firm's average growth rate is higher than the others.

This chapter also considers changes in the number of each type of firm over time. Using a defined model, the weights of each type of firm are determined by their growth rate. The weight of firms with the highest growth rate increases over time, whilst the weight of firms with the lowest growth rate decreases over time. The weight of firms with medium growth rate decreases over time if the difference between the highest growth rate and the medium growth rate is larger than the difference between the medium growth rate and the lowest growth rate.

The models discussed in this chapter have a practical effect on policy making. If one type of firm is disadvantaged in terms of its technological growth rate, a policy could be established to increase the number of these type firms so that the average growth increases. In *Report on the Work of the Government 2015,* non-state-owned enterprises are considered to be the most important part of China's economy, and the development of private firms should be encouraged and supported by the government. In China, the majority of private firms are small and medium-sized businesses. In order to develop private enterprises, particularly privately owned small and medium-sized firms, the government could implement policies that tackle two core issues. The first relates to increasing the total number of SMEs and encouraging new business start-ups, in order to increase the total number of firms. The second is increasing the technology-led growth rate. Policies that reduce financing costs and encourage SMEs to invest in research would be hugely beneficial.

The main limitation of this model is that analysis of growth of SOEs, LPEs and SMEs are undertaken separately, and then compared their growth. Even though this model could explain growth of each type firms in reality, this model does not consider linkage effects[22] in these three types of firms, which may be studied in my future.

[22] Hirschman (1958) and Holz (2011) think that there are linkage effects of SOEs on private firms.

Chapter 5 R&D, Imitation and Economic Growth of China in terms of State-owned and Private Enterprises

5.1 Introduction

Since the reform and opening-up policy that began in the mid-1980s, the economy of China has grown at an incredible rate, with the average growth rate each year up to 10%. However, China gives the world an expression that a huge population and low-cost labour is one of the secrets of China's economic growth. In fact, labour-intensive sectors play a key role in China's growth in the early development stage. However, with the increase in labour cost, foreign investors gradually disinvest from China's mainland and start to cast their eyes on Southeast Asian countries such as Vietnam and Indonesia. On the other hand, environmental problems, inequality and other domestic issues are challenging China's central government. China has the stress of adjusting the economic structure for long-term development.

In the Report on the Work of the Government 2014, Premier Li Keqiang pointed out that innovation-driven development will be pursued and the reform of the science and technology management system will continue to be deepened. Reforming and promoting manufacturing industries and improving indigenous innovation capability are goals of the 12th Five-Year Program in China. At the same time, China tries to export it high techniques to other countries, for example high-speed rail. It seems that China wants to change from 'Imitation China' to 'Innovation China'.

Domestic research and development (R&D) or technology borrowing aboard (imitation) are two channels of product and process innovation. Developed countries such as the U.S.A, Germany and Japan prefer R&D, while developing countries tend to choose imitating advanced technology from advanced countries because of limited capital. In other words, technology borrowing abroad may be a better way for developing countries to catch up (Lin, 2012, pp13-16).

The research by Fu et al. (2011) shows that indigenous innovation and foreign technology are complementary for developing countries. Without proactive domestic innovation efforts, the developing countries cannot catch up with the developed countries. The foreign technology is static, which is normally presented as imported machines. There is a similar finding by Hu et al. (2005) that domestic innovation positively affected returns in Chinese firms. Domestic and foreign technology transfer is influenced by indigenous R&D capabilities, but the complementary relationship between foreign technology transfer and domestic innovation in the foreign sector is found to be weak.

Imitation is a process of learning advanced technology for developing countries, under the economic growth model with imitation and innovation by Mukoyama (2003), which makes it possible for developing countries to be an innovator in the next round of competition. If the amount of innovation in the equilibrium is too little, the better policy for government is providing a subsidy to imitate rather than R&D. A subsidy to R&D may result in monopoly distortion.

Before the economic reform, the innovation system in China was centralised planning and was over-protected by the government (Cai and Tylecote, 2008). After the mid-1980s, China's innovation system moved away from over-protection, and the science and technology outsourcing activities were evidently active. In addition, foreign multinational corporations' involvement (Liu and White, 2001) and a transition from imitation to innovation (Guan et al., 2009) were other trends of the innovation system in China.

However, the purpose of innovation for governments and enterprises is different. Governments set up long-term goals of science and technology, while enterprises are more concerned with short-term maximising profits. The long-term plans of domestic innovation by governments actually positively influence the R&D activities of enterprises (Chang et al., 2006), and government's support firms' innovation activities by providing sources (Johnson, 1982; Amsden, 1989; Haggard, 1994).

Compared to private enterprises, state-owned enterprises (SOEs) are more likely to engage in R&D activities than imitation. State-owned enterprises play a significant role in China's economic growth. SOEs have externality effects (Jefferson, 1998; Lin et al., 1998, 2003) on the society and economy, while private firms chase maximising profits. There is a lagged positive relationship between state-ownership and innovation performance (Choi et al., 2011). Reformed SOEs and other newly established firms lead to the high growth of business groups in China (Choi et al., 2011). Business groups evidently influence China's industrial development and technology advancement, (Lee and Hahn, 2005), and are also an important factor for enhancing technology and encouraging R&D activities (Choi et al., 2011).

Additionally, the study by Guan et al. (2009) whose sample is based on the enterprises in Beijing shows objectives of innovation for SOEs and non-SOEs are significantly different in terms of the importance of 'introducing niche products of technology', 'improving existing technology' to reduce reliance on imported equipment/technology and 'reducing energy consumption'. This study suggests SOEs have the responsibilities of long-term development and a national strategy in international markets. Because of these responsibilities, SOEs are more likely to carry out R&D activities than private enterprises.

Overall, the previous studies show that imitation and innovation are two channels to improve technology. And in China, SOEs because of their social responsibilities seem to more involve in innovation than PEs. However, there is less literature to model the difference between SOEs and LPEs in their preferences of imitation. The novelties of this chapter are:

(1) A model is constructed to describe the different choice of state-owned enterprises' and private firms' innovation strategies.
(2) As Chapter 4, size effect is also considered in this model because of the good performance of LPEs, such as Huawei, Xiaomi, Sany, on technology innovation. The firms in China are divided into three types: SOEs, LPEs and SMEs.

The model is built to answer the following questions:

(1) For all three types of firms (SOEs, LPEs and SMEs) in China, do they all prefer imitation rather than innovation all the time?
(2) Can imitation always improve the growth of productivities of production?
(3) Which type of firms is the most prefer imitation compared to the other two types of firms?

In this chapter, enterprises have to choose an innovation strategy, choosing between R&D activities and imitating advanced technology. At the early stage of corporation development, private enterprises and SOEs both prefer importing advanced technology abroad. However, the probability of technological borrowings decreases with the growth of firms, and owing to higher financing costs, it is more possible for private enterprises to choose technology borrowings abroad.

5.2 Stylised Facts

The central government in China considers that it is time for China to change its approach to economic growth[23] and encourage creation and innovation that is considered as the engine of the growth of China in the next few decades. Several plans and policies were issued for this purpose, for example the 11th and 12th Five-year Program.

5.2.1 Source of domestic expenditure on R&D activities in China

As seen in Figure 5.1, the gross domestic expenditure on R&D activities in China has kept moving ahead since 1991, and the growth increased rapidly after 2002. Business enterprises contribute most to R&D activities and provide most of the funds for R&D. Government is the second source of funds.

[23] This is written down in the Report on the Work of the Government 2014.

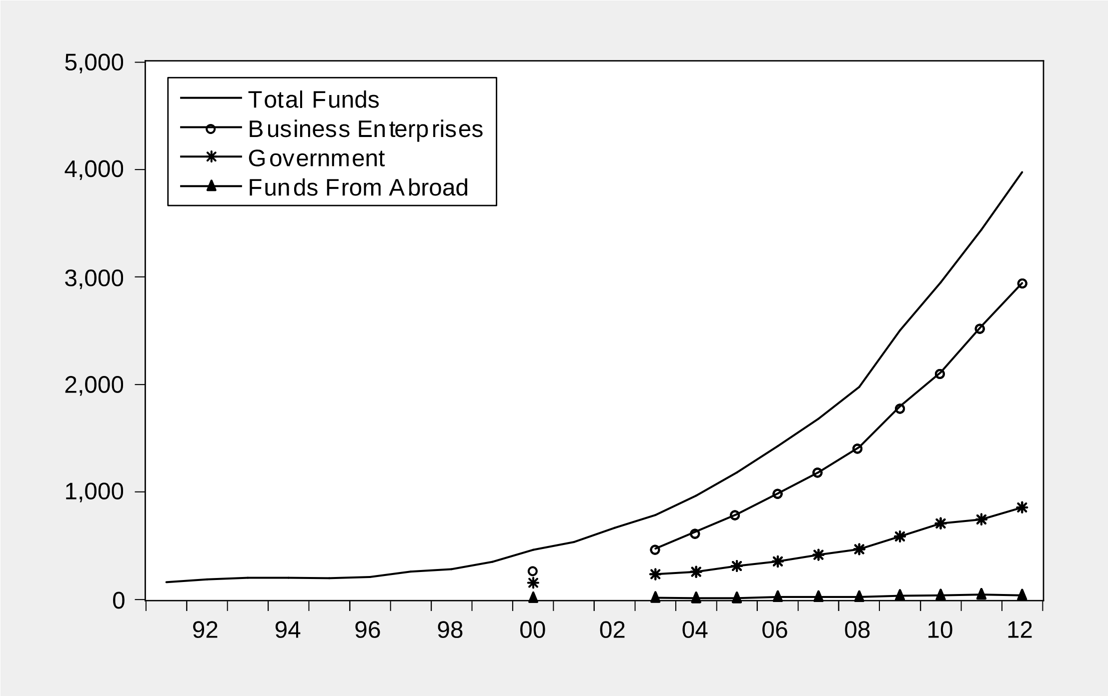


Figure 5.1 GROSS DOMESTIC EXPENDITURES ON R&D BY TOTAL INTRAMURAL AND SOURCEOF FUNDS

Unit: Million yuan

Source: OECD

Figure 5.2 show the source of funds for the R&D activities of business enterprises. The contribution of business enterprises is still the most prevalent. Funds from abroad and the government make up a small part of the domestic expenditures on R&D activities carried out by enterprises.

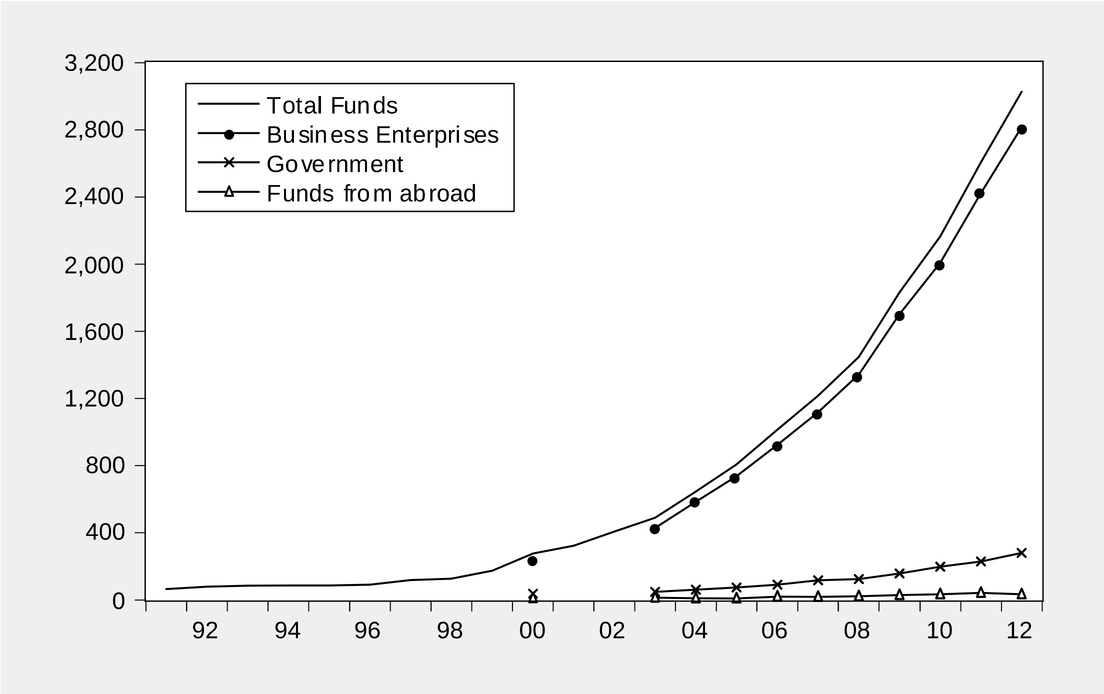


Figure 5.2 REAL GROSS DOMESTIC EXPENDITURES ON R&D BY BUSINESS ENTERPRISES AND SOURCE OF FUNDS

Unit: Million yuan

Source: OECD

5.2.2 Inputs and outputs of R&D activities in enterprises with different ownerships

According an official report[24]issued in 2010 concerning R&D activities in China, the total amount of expenditure on R&D in 2009 was about 580.21 billion yuan - that is 6.5 times the R&D expenditure in 2000. The average annual growth of R&D expenditures is 23%, whilst 17% of SOEs and 6.4% of private enterprises undertake R&D activities. 30.5% of large-medium sized firms and 6% of

24 The official report ' The report on the nation survey of R&D activities in China in second time' is posted on the website of National Bureau of Statistics of China: http://www.stats.gov.cn/tjsj/tjgb/rdpcgb/

small-sized firm works on R&D.[25] SOEs seem to have more willingness to carry out R&D activities than private enterprises. R&D seems to be more attractive for large-medium sized firms than small-sized enterprises.

Table 5.1 shows the amount of funds spent on R&D activities per firm in 2012 and 2011. The amount of expenditure on R&D activities per state-owned enterprise and the amount per private enterprise both increased from 2011 to 2012, and the amount of expenditure on R&D activities per state-owned enterprise is about twenty times the amount per private enterprise. It is indicated that state-owned enterprises prefer R&D activities to innovate new products and production processes than private enterprises.

The amount of inputs of R&D per enterprise (10 thousands yuan)	**2012**	**2011**
Total amount	209.46	184.08
State-owned manufacturing enterprises	1234.77	1090.44
Private manufacturing enterprises	65.85	52.27

Table 5.1 THE AMOUNT OF INPUTS OF R&D ACTIVITIES PER ENTERPRISE

Source: China Statistics Database

Table 5.2 shows the number of applications for patent rights by ownership. The

[25] These percentages are not showed in this official report, these numbers are calculated based on the data in this report

number of private firms' applications for patent rights is about twice the number of state-owned enterprises. It seems that private enterprises are more motivated to carry out R&D activities and have more output than state-owned enterprises. However, when the number of each type of firm is considered[26], the conclusion is different.

The number of application for patent right	**2012**	**2011**
Sate-owned manufacturing enterprises	16660	11611
Private manufacturing enterprises	39626	29210

Table 5.2 THE NUMEBER OF APPLICATION FOR PATENT RIGHT BY OWNESHIP

Source: China Statistics Database

Table 5.3 presents the number of applications for patent rights per firm by ownership, which is regarded as an indicator of the probability of R&D activities. In table 5.3, in 2012 and 2011, the number of applications for patent rights per state-owned enterprises is about ten times the number per private enterprise. It is can be concluded that the probability of state-owned enterprises carrying out R&D activities is larger than private enterprises. State-owned enterprises have more motivation than private enterprises to carry out R&D activities.

[26] The number of manufacturing state-owned enterprises and private enterprises are showed in Appendix.

The number of application for patent right per firm	2012	2011
Sate-owned manufacturing enterprises	2.03	1.44
Private manufacturing enterprises	0.21	0.16

Table 5.3 THE NUMBER OF APPLICATION FOR PATENT RIGHT PER FIRM

Source: China Statistics Database

Based on the data shown in Table 5.2 and Table 5.3, the R&D activities of private enterprises seem to be more effective than state-owned enterprises. The input of R&D activities per state-owned enterprise is twenty times the input per private enterprise; however, the number of applicants for patent rights per state-owned firm is only ten times the number per private firm.

Outputs Caused by R&D Activities per firm (10 thousands yuan)	2011
State-owned manufacturing enterprises	15812.46
Private manufacturing enterprises	785.04

Table 5.4 OUTPUTS CAUSED BY R&D ACTIVITIES PER FIRM BY OWNERSHIP

Source: China Statistics Database

Table 5.4 presents the average value of outputs caused by the R&D activities of state-owned enterprises and private enterprises. The average value of outputs of state-owned enterprises is about twenty times the average value of outputs of private enterprises in 2011. According to this data, state-owned enterprises and private enterprises are almost equally as effective on R&D activities.

5.2.3 Inputs and outputs of R&D activities in large-medium sized enterprises

Figure 5.3 shows that the inputs of R&D activities in state-owned large-medium sized enterprises are much higher than private large-medium sized enterprises from 2006 to 2010. During the period, inputs of R&D activities in both state-owned and private large-medium sized enterprises increased. Furthermore, the growth rate of inputs of R&D activities in state-owned firms is slightly higher than private firms.

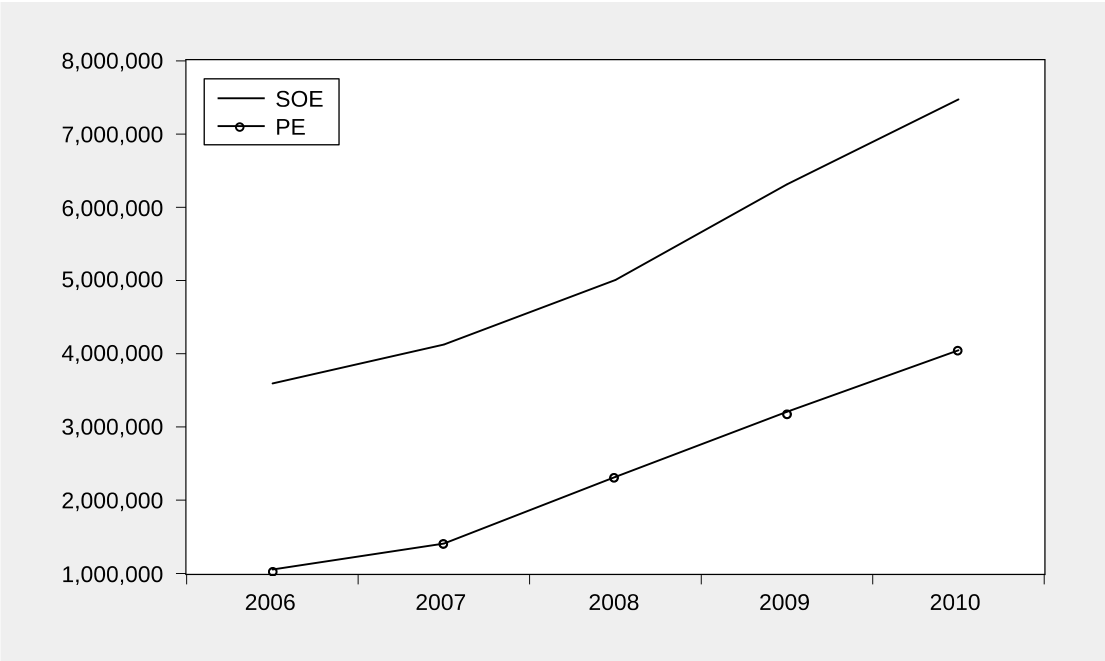


Figure 5.3 AVEARAGE REAL INPUTS OF R&D ACTIVITIES IN LARGRE-MEDIUM SIZED ENTERPRISE FROM 2006 TO 2010

Unit: 10 Thousands yuan

Source: China Statistics Database

The effectiveness of R&D activities in state-owned and private large-medium sized enterprises is compared in Table 5.5. Private large-medium sized enterprises are slightly more effective than state-owned. Private enterprises become more effective from 2008 to 2010. The effectiveness of state-owned enterprises declines.

The effectiveness of R&D activities（outputs/inputs) in large-medium sized enterprises	**State-owned enterprises**	**Private enterprises**
2008	17.90	19.30
2009	17.66	18.24
2010	16.10	20.64

Table 5.5 THE EFFECTIVNESS OF R&D ACTIVITIES IN STATE-OWNED AND PRIVATE LARGE-MIEDUM SIZED ENTEPRISES

Source: China Statistics Database

Figure 5.4 shows the trend of average inputs of R&D activities in large-medium sized enterprises from 2003 to 2012, which can indicate the probability of undertaking R&D activities in larger-medium sized firm. In general, the probability of carrying out R&D activities increased from 2003 to 2012. However, there was a decrease between 2010 and 2011. This may be caused by the jump of the number of large-medium sized enterprises in China, which leads to the decrease in average inputs.

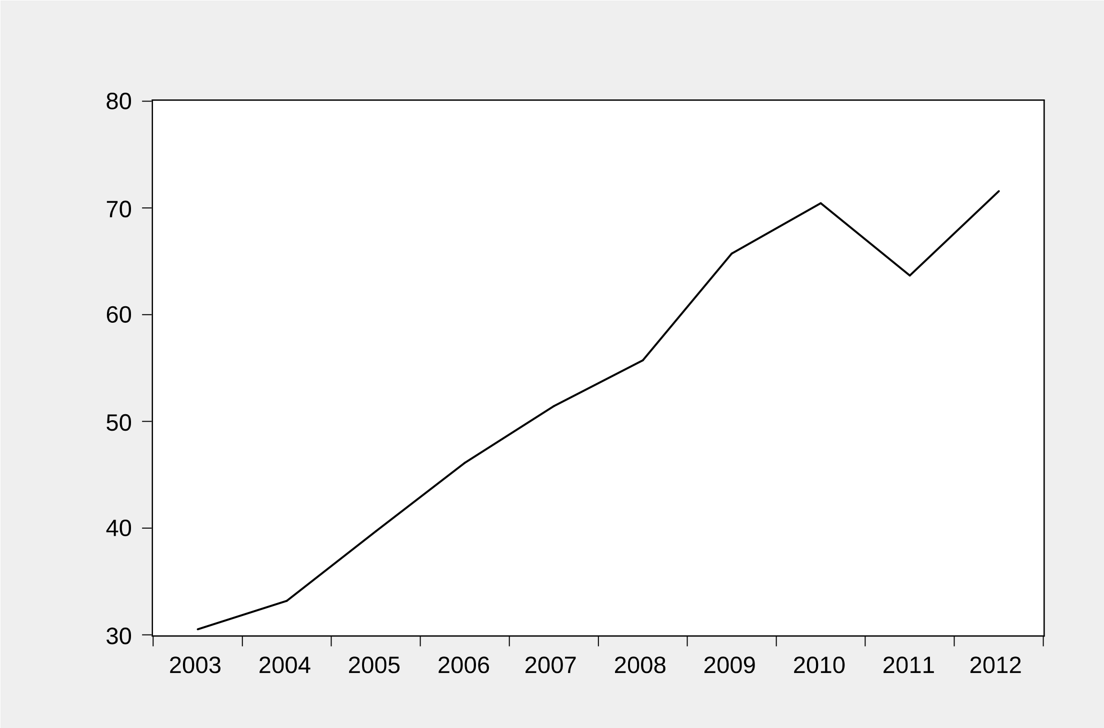


Figure 5.4 AVERAGE REAL INPUTS OF R&D ACTIVITIES IN LARGRE-MEDIUM SIZED ENTERPRISE PER FIRM FROM 2003 TO 2012

Source: China Statistics Database

Figure 5.5 shows the trend of the average number of applications for patent rights in large-medium sized enterprises, which can also indicate the probability of carrying out R&D and outputs of R&D. In general, the trend shown in Figure 5.5 is similar to the trend in Figure 5.4. Large-medium sized enterprises have increasing motivation to invest in R&D activities.

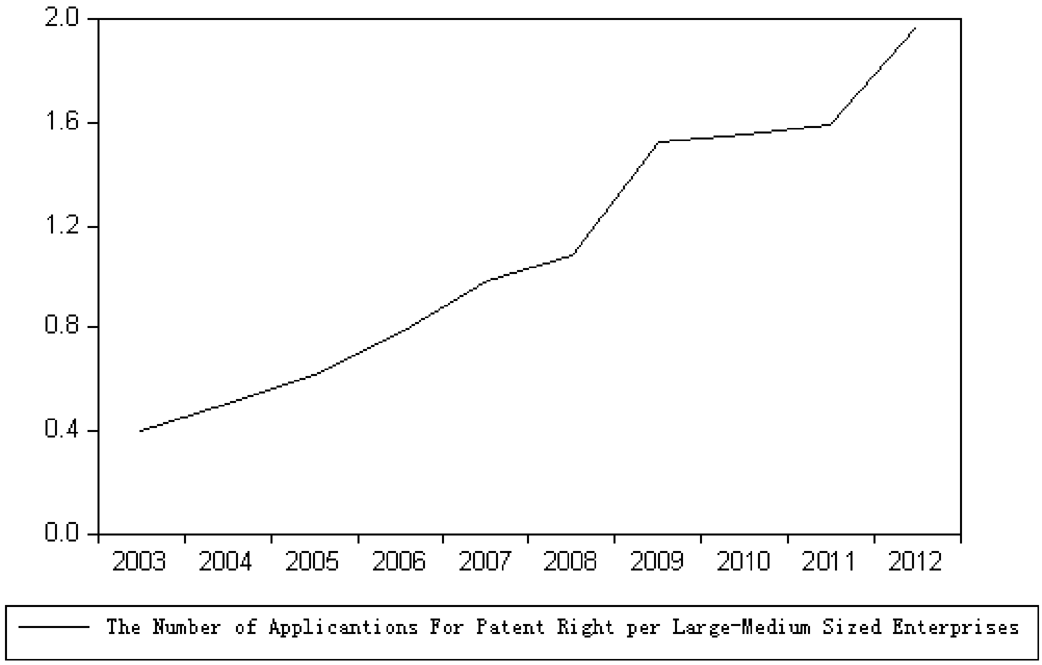


Figure 5.5 THE AVERGER NUMBER OF APPLICANTS FOR PATENT RIGHT IN LARGE-MEDIUM SIZED ENTERISES

Source: China Statistics Database

5.2.4 Expenditures on technology borrowings (imitation)

Table 5.6 shows the expenditure on technological borrowings. There is no particular trend of expenditure on imitation during the period from 2004 to 2012. However, comparing expenditures between 2004 and 2012, the total amount increased from 54.105 billion yuan to 75.244 billion yuan; the amount on technology borrowing slightly decreasing from 39.736 billion yuan to 39.391 billion yuan; and the amount on learning technology borrowed abroad and domestic technology borrowing increased from 6.121 billion yuan to 15.684 billion yuan, and from 8.248 billion yuan to 20.169 billion yuan respectively. In

2004, technology borrowing abroad was the most important channel of imitating advanced technology, however, the importance of technology borrowing abroad gradually declines. The effects of learning technology borrowed and domestic technological borrowings became stronger, and this indicates that the gap between domestic technology levels and world technology frontiers becomes narrower.

The amount of funds on technology borrowings (billion yuan)	**2012**	**2011**	**2009**	**2008**	**2004**
Total	75.244	87.168	80.758	77.391	54.105
Technology borrowing aboard	39.391	44.899	42.217	46.691	39.736
Learning technology borrowed aboard	15.684	20.217	18.2	12.27	6.121
Domestic technology borrowing	20.169	22.052	20.341	18.43	8.248

Table 5.6 THE AMOUNT OF EXPENDITURES ON TECHNOLOGY BORRWOINGS

Source: China Statistics Database

5.2.5 Types of Patents Right Applicants

According to Figure 5.6, most of the patent rights applicants are utility patents from 1995 to 2013, except the period from 2005 to 2010. From 2005 to 2010, design patents make up the majority of the total applicants. Before 2008, the percentage of utility patents in total applicants significantly decreases but after

2008, the number gradually climbs. By contrast, the percentage of design patents in total keeps increasing until 2008 and then declines. The percentage of invention patents steadily increased from 1995 to 2013, and its percentage was the lowest until 2013. In 2013, the percentage of invention patents was more than design patents, and became the second-most important source of patent rights. It is clearly shown that the most important technological improvement channel for China is improving existing techniques. Even though China are worse regarding their original techniques, the increasing improvement in the original techniques is obvious, and is now the second important channel of patent rights.

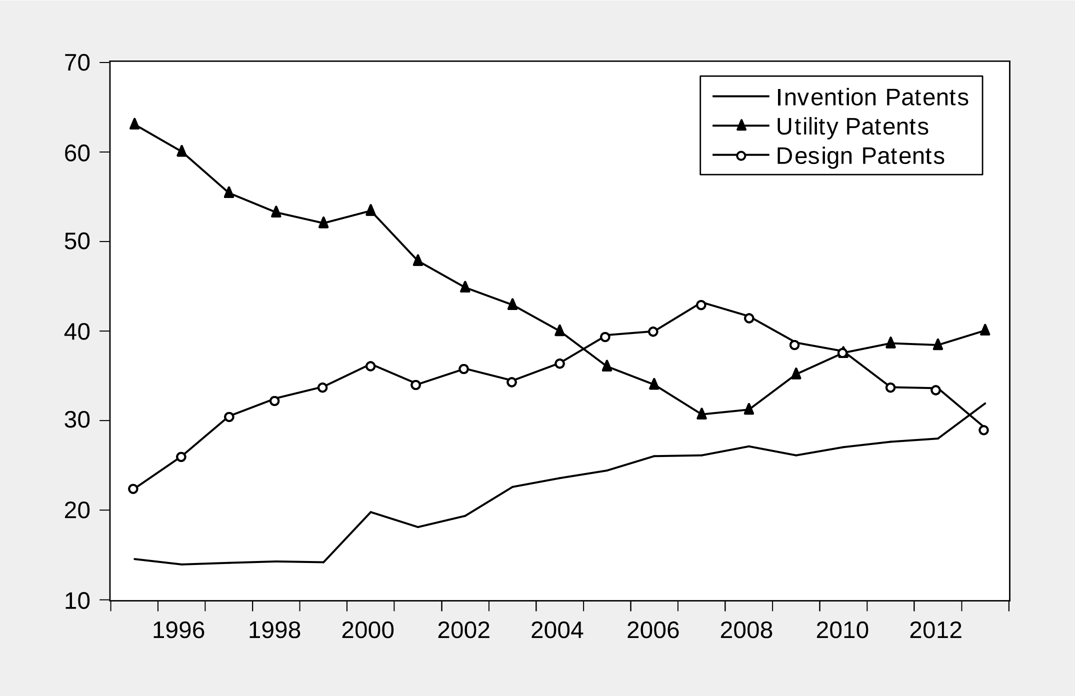


Figure 5.6 EACH TYPE PATENTS APPLICATIONS IN TOTAL PATENTS APPLICATIONS

Source: China Statistics Database

The data shown in this part demonstrates that with the development, the innovation strategy of China gradually changed from imitation to R&D. Moreover, state-owned enterprises have more motivations to carry out R&D activities than private enterprises. The size of enterprise also affects the innovation strategy - for example, large-medium sized enterprises are more likely to choose R&D activities.

5.3 The Model

In Chapter 4, determinants of growth rates of SOEs, LPEs and SMEs are discussed, as well as how these determinants affect growth rates in terms of the ownership of each type of firm. Growth rates are determined by two important factors, one is technology causing the growth rate; the other one is the growth rate of employees. In Chapter 4, in a simple case, the effective labour supplies per firm of each type of firm keeps constant at each period. Therefore, the growth rate of employees is presented by an increased rate of the total number of each type of firm, which is also the expending speed of each type.

However, in the last chapter, we saw the differences in innovation and imitation in terms of technology causing growth rate. This part will focus on how innovation and imitation activities could affect technology causing growth rate.

Similarly, in this chapter, it is still supposed that there are three types of firms in

China, and they are state-owned enterprises (SOEs), large-sized private enterprises (LPEs) and small-sized enterprises (SMEs). As this is concerned with technology causing growth rates, the impacts of employment increase rates are not referred to in this part. According to Schumpeter's framework, the technology causing growth rate of each type of firm can be written as,

$$P_i = \frac{A_{it}}{A_{it-1}} - 1$$

where $i \in \{S, L, M\}$. S, L and M present SOEs, LPEs and SMEs respectively.

To improve productivities, entrepreneurs have to choose one of two strategies: to borrow advanced technology (imitation) or to undertake R&D activities. It is supposed that the probability of choosing imitation is e_t. As Chu et al. (2014), g^* is the exogenous growth rate of advanced technology of technology frontier in world. A^*_{t-1} presents the productivity of technology frontier in world in last period, which is also an exogenous variable.

	Innovation	**Imitation**
Probability of Choosing R&D activities or Imitation	$1 - e_t$	e_t
Probability of succeeding in R&D activities or Imitation	μ_t	1
Technology improvement caused by R&D activities or Imitation	$\gamma_t A_{t-1}$	$g^* A^*_{t-1}$

Table 5.7 SUMMARY OF TECHNOLOGY IMPROVEMENT CAUSED BY R&D ACTIVIES OR IMITATION

It is clearly shown by Graph 5.1 that the process of entrepreneurs choosing their strategy of technology is improving. Entrepreneurs have a chance to import advanced technology, and the technology improvement arising from imitation is $g^* A^*_{t-1}$. Entrepreneurs can also choose to undertake R&D activities in order to innovate new products or processes. The chance of successful innovation is μ_t, and the gain is $\gamma_t A_{t-1}$. If entrepreneurs choose to undertake R&D research and unfortunately the R&D research fails, the current technology level is the same as in the last period and entrepreneurs will thus face the choice between innovation and imitation again. The expected technological improvement caused by R&D activities is $\mu_t \gamma_t A_{t-1}$. Therefore, the expected productivity of each type firms in time t is

$$E(A_t) = A_{t-1} + (1 - e_t)\mu_t \gamma_t A_{t-1} + e_t g^* A^*_{t-1} \tag{5.1}$$

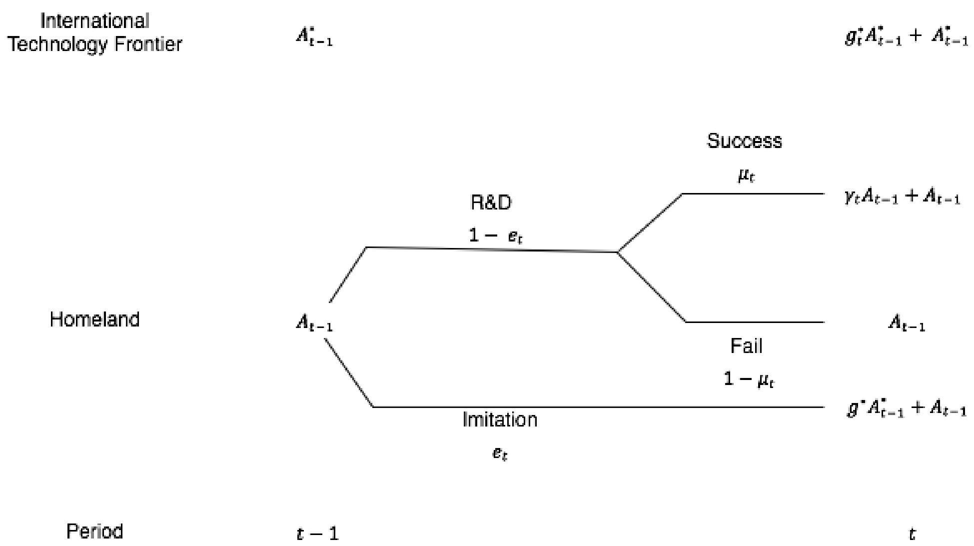
In the model of Chu et al. (2014), Southern firms could be innovators and imitators. And the monopolistic position of domestic innovator in intermediate sectors could be replaced by domestic effective imitators and multinational firms. Chu et al. (2014) focus on the interaction between imitation and innovation performed by two different firms (domestic innovative firms and foreign affiliates of Northern firms). In the model of this thesis, as Acemoglu et al. (2003, 2006), innovation and imitation are performed by the same firm. However, different from Acemoglue et al. (2003, 2006), imitation and innovation can not be undertaken in the same time. Because of credit constraints, entrepreneurs have to a strategy to improve technology of production: imitation or innovation. If innovative activities fail, the technology level keeps the same as previous, and entrepreneurs make a choice again of strategies of technology improvement in next period.

Simple quadratic cost functions used to present cost of R&D activities and imitation

$$R_t = \check{A}_{t-1}\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} \qquad \sigma_I > 1 \tag{5.2}$$

$$E_t = \frac{\check{A}_{t-1}(e_t)^{\sigma_E}}{\sigma_E \bar{e}}\Theta_t \qquad \sigma_E > 1 \tag{5.3}$$

R_t and E_t are the amount of investment in R&D activities and imitating advanced technology respectively. $\check{A}_{t-1}$ is the productivity before successful innovation or imitation occurring. λ is a research parameter. $\bar{e}$ is the imitation parameter. Θ_t presents the patent protection.



Graph 5.11 PROCESS OF CHOOSING TECHNOLOGY IMPROVING STRATEGY

5.3.1 Without Financial Frictions

Firstly, a simple case will be discussed where financial frictions of SOEs, LPEs, and SMEs are not considered. If there are no financial frictions, the expected input for enhancing technology improvement is

$$E(C_t) = (1 - e_t)R_t + e_t E_t \tag{5.4}$$

Because of patent right protection, imitating advanced technology is not free and E_t is the cost of imitating advanced technology from technology frontier.

This chapter only focus on the growth rate caused by technology, therefore, according to Schumpeterian model, the optimal production per labour input is

$$\widehat{y_t^*} = \pi A_t$$

The reward from R&D activities or/and imitation is,

$$\ddot{\Pi} = \pi E(\check{A}_t) - E(C_t)$$

To maximise the reward $\ddot{\Pi}$, and based on Function (5.1) and (5.4), the probability of successful innovation with optimal inputs of R&D activities is

$$\mu_t = \left(\frac{\pi \gamma_t \lambda^{\sigma_I}}{\sigma_I}\right)^{\frac{1}{\sigma_I - 1}} \tag{5.5}$$

Similarly, Equation (5.6) is calculated with optimal inputs of importing advanced technology.

$$\frac{\partial \ddot{\Pi}}{\partial e_t} = 0$$

$$\pi\left(-\mu_t \gamma_t \breve{A}_{t-1} + g^* A_{t-1}^*\right) + \breve{A}_{t-1}\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} = (\sigma_E + 1)\frac{\breve{A}_{t-1}(e_t)^{\sigma_E}}{\sigma_E \bar{e}}\Theta_t \tag{5.6}$$

In this chapter, the geometric mean of the growth rate of exogenous advanced technology improvements in each period is introduced to calculate frontier technology in the last period.

$$A_{t-1}^* = (1 + \bar{g}^*)A_{t-2}^*$$

$$A_{t-2}^* = (1 + \bar{g}^*)A_{t-3}^*$$

$$\vdots$$

$$A_1^* = (1 + \bar{g}^*)A_0^*$$

Therefore, $A_{t-1}^* = (1 + \bar{g}^*)^{t-1} A_0^*$. A_0^* is the international initial level of technology frontiers. It is supposed that the domestic initial level is linearly related to the world initial level $A_0^* = \mathrm{Z}A_0$. The gap between the domestic technology level and advanced technology level is,

$$\frac{A_{t-1}^*}{\breve{A}_{t-1}} = \frac{(1 + \bar{g}^*)^{t-1} A_0^*}{\breve{A}_{t-1}} = (1 + \bar{g}^*)^{t-1}\left(\frac{ZA_0}{\breve{A}_{t-1}}\right) = \frac{Z(1 + \bar{g}^*)^{t-1}}{a_{t-1}^0}$$

$a_{t-1}^0 = \frac{\breve{A}_{t-1}}{A_0}$ is the gap of domestic productivity in the last period to initial level.

Equation (5.6) then can be rewritten as

$$\pi\left[-\mu_t \gamma_t + Zg^* \frac{(1 + \bar{g}^*)^{t-1}}{a_{t-1}^0}\right] + \left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} = (\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E \bar{e}}\Theta_t \tag{5.7}$$

Based on Equation (5.5) and Equation (5.7), the probability of imitating advanced technology with maximising rewards from imitation and/or R&D

activities is,

$$e_t = \left\{ \frac{\left[\pi g^* Z \frac{(1+\bar{g}^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi \gamma_t}{\sigma_I} \lambda \right)^{\frac{\sigma_I}{\sigma_I - 1}} (\sigma_I - 1) \right] \sigma_E \bar{e}}{(\sigma_E + 1)\Theta_t} \right\}^{\frac{1}{\sigma_E}} \tag{5.8}$$

The larger accumulated technology increases, which is the ratio of existing productivity level to the initial level (a_{t-1}^0), leads to a lower probability of imitation e_t. The technology owned by the firms with a larger a_{t-1}^0 difference is more advanced than those with a lower difference and are closer to technology frontiers. Comparing them to the initial level, firms with more accumulated technology levels have less interesting estimations and have more motivation to undertake R&D research activities. Those firms are already in a leading position in the competition, and they are more likely to invent new products or innovate production processes to maintain their advantage. By contrast, those smaller a_{t-1}^0 enterprises are at a disadvantage technologically, and they desire to master the advanced technology as soon as they can in order to become competitive and catch up other competitors. Therefore, firms with smaller a_{t-1}^0 success are more likely to choose technology borrowing.

The larger step size of innovation technology γ_t, which is an exogenous variable, indicates the technology improvement caused by R&D activities is large. The R&D research effectiveness λ is negatively related to the probability of imitation. If R&D research is more effective, the probability of successful R&D activities is higher. Furthermore, the expected return generated by R&D activities is higher. Under these circumstances, the benefits created by R&D activities may be larger than those of imitation. The chance of imitating advanced technology decreases, and in addition, Θ_t is the patent protection. Higher Θ_t means the cost of imitation is larger, and so the probability of imitation also declines.

Impacts of Ownership of Enterprises

In Chapter 4, it is known that the technology research capabilities include step size of innovation and R&D research effectiveness ($\Omega_i = \lambda_i \gamma_i$) will affected by ownership of firms. The technology research capabilities of LPEs are best with SMEs being worst.

$$\Omega_L > \Omega_S > \Omega_M$$

Before China's economic reform in the 1980's, private enterprises were not allowed to exist. Privatisation of SOEs was one of the important concepts of economic reform and SOEs' reform. SOEs in less important sectors are privatised, which is one channel where LPEs in China emanate. The other channel is that SMEs gradually grow into LPEs in the market. Therefore, the initial technology level of SOEs is the best as SMEs have the worst initial technology level, if the initial period is regarded as the start of economic reform in China. Because of the two channels of LPEs, the initial technology level of LPEs is in the middle range, compared to SOEs and SMEs.

Constant gap indicators Z_i present gaps between the technology frontier and the technology levels of SOEs, LPEs and SMEs in the initial period. Owing to the highest initial technology level, the constant gap indicator of SOEs is the smallest. The constant gap indicator of LPEs is in the middle range, and the indicator of SMEs is the largest.

$$Z_S < Z_L < Z_M$$

Based on Function (4.8), if $\frac{\frac{Z_S}{a_{S(t-1)}^0}-\frac{Z_M}{a_{M(t-1)}^0}}{(\Omega_S-\Omega_M)^{\frac{\sigma_I}{\sigma_I-1}}} > \frac{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}{\pi g^*(1+\bar{g}^*)^{t-1}}$, the imitation probability of SOEs is larger than SMEs. If $\frac{\frac{Z_L}{a_{L(t-1)}^0}-\frac{Z_M}{a_{M(t-1)}^0}}{(\Omega_L-\Omega_M)^{\frac{\sigma_I}{\sigma_I-1}}} > \frac{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}{\pi g^*(1+\bar{g}^*)^{t-1}}$, the imitation probability of LPEs is larger than SMEs. And $\frac{\frac{Z_S}{a_{S(t-1)}^0}-\frac{Z_L}{a_{L(t-1)}^0}}{(\Omega_L-\Omega_S)^{\frac{\sigma_I}{\sigma_I-1}}} > \frac{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(1-\sigma_I)}{\pi g^*(1+\bar{g}^*)^{t-1}}$, the imitation probability of SOEs is larger than LPEs.

Compared with SOEs and LPEs, if the distance of SMEs to technology frontiers in the last period is larger than SOEs and LPEs, and the R&D research capability of SMEs is worse than SOEs and LPEs. Therefore, SMEs have less advantage in R&D, and SMEs are more interested in imitation.

However, if the distance of SOEs and LPEs to technology frontiers is larger than SMEs, there is a required least advantage in technology research capability of

SOEs and LPEs to cover per unit of longer distance of SOEs and LPEs to technology frontier than SMEs is $\frac{\pi g^*}{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}$. If SOEs and LPEs can satisfy this required least advantage, compared to SMEs, SOEs and LPEs are still better in R&D and have less probability to borrow technology. However, if SOEs and LPEs can't satisfy the least research capability, this means SOEs and LPEs don't have enough R&D research capabilities to cover up the longer distance to technology frontiers, and then SOEs LPEs will choose imitation with more probability than SMEs.

In the comparison between SOEs and LPEs, if the technology gap of SOEs is larger than LPEs, and SOEs do not have advantages in research capability, then SOEs more prefer imitation than LPEs. However, if the technology gap of SOEs is smaller than LPEs, there is also least required least advantage ($\frac{\pi g^*}{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}$) in technology research capability of LPEs to cover per unit of longer distance of LPEs to technology frontier than SOEs. If LPEs' advantages in research capability can satisfy this condition ($\frac{(\Omega_L)^{\frac{\sigma_I}{\sigma_I-1}}-(\Omega_S)^{\frac{\sigma_I}{\sigma_I-1}}}{\frac{Z_L}{a^0_{L(t-1)}}-\frac{Z_S}{a^0_{S(t-1)}}} > \frac{\pi g^*(1+\bar{g}^*)^{t-1}}{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}$), LPEs have less probability to borrow technology than SOEs. However, if LPEs don't have enough R&D research capabilities to cover up the longer distance to technology frontiers, LPEs will more prefer imitation than SOEs.

Proposition 5.1: **For one certain type firms, if the required least advantage $\left(\frac{\pi g^*}{\left(\frac{\pi}{\sigma_I}\right)^{\frac{\sigma_I}{\sigma_I-1}}(\sigma_I-1)}\right)$ in technology research capability to cover per unit of differences in technology gap, compared with another type firms, can be satisfied, this type firm will have less possibility to choose imitation.**

Change of imitation rate over time

In this chapter, a simple case $\sigma_I = \sigma_E = 2$ is considered as an example to present the points. And then Equation (8) can be rewritten as for simple,

$$e_t = \left\{ \frac{\left[\pi g^* Z \frac{(1+\bar{g}^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi \gamma_t}{2} \lambda \right)^2 \right] 2\bar{e}}{3\Theta_t} \right\}^{\frac{1}{2}} \tag{5.9}$$

$$e_t > 0$$

And it is supposed that $F = Z \frac{(1+\bar{g}^*)^{t-1}}{a_{t-1}^0}$, and the trend of F over time[27]

$$\frac{\partial F}{\partial t} = Z \frac{(1+\bar{g}^*)^{t-1}}{a_{t-1}^0} [\ln(1+\bar{g}^*) - g_{t-1}]$$

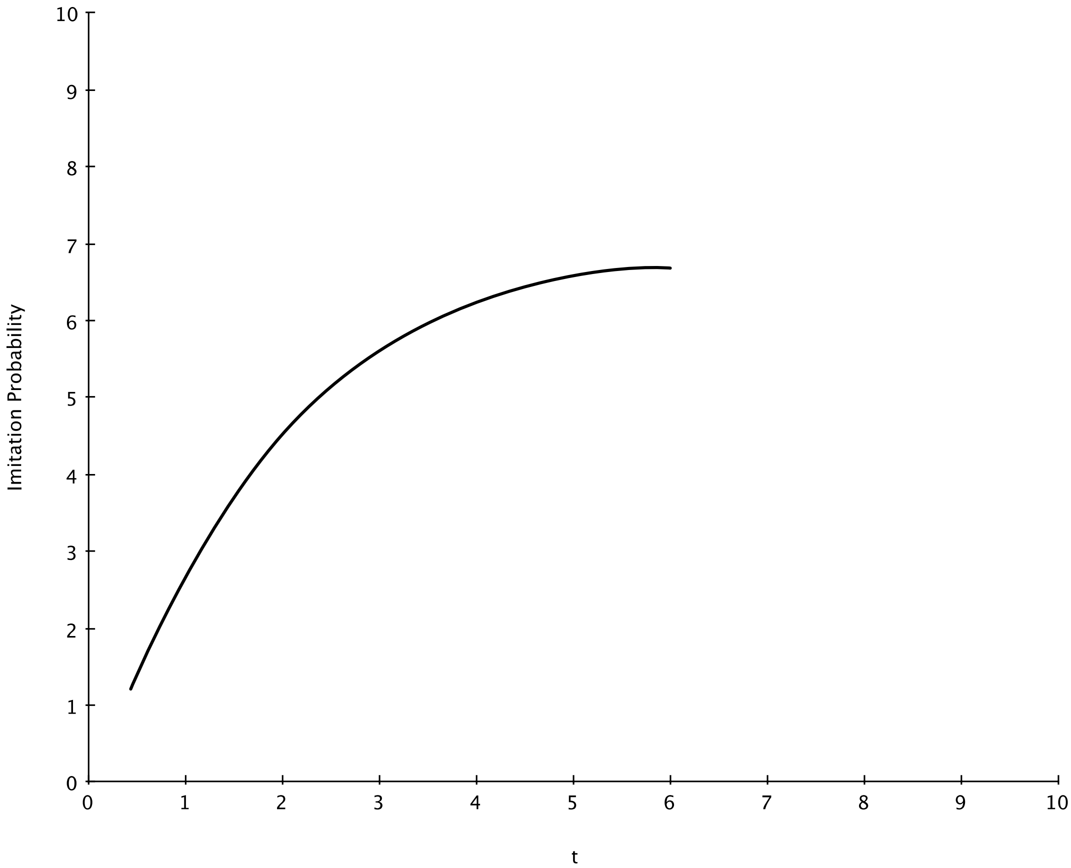
Based on equation (5.9), trend of the probability of each type firms for imitation is presented as follow,

$$\frac{\partial e_t}{\partial t} = \frac{1}{2} \left\{ \frac{\left[\pi g^* Z \frac{(1+\bar{g}^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi \gamma_t}{2} \lambda \right)^2 \right] 2\bar{e}}{3\Theta_t} \right\}^{-\frac{1}{2}} \left(\frac{2\bar{e}}{3\Theta_t} \pi g^* \frac{\partial F}{\partial t} \right) \tag{5.10}$$

[27] See Proof 5.2 in Appendix

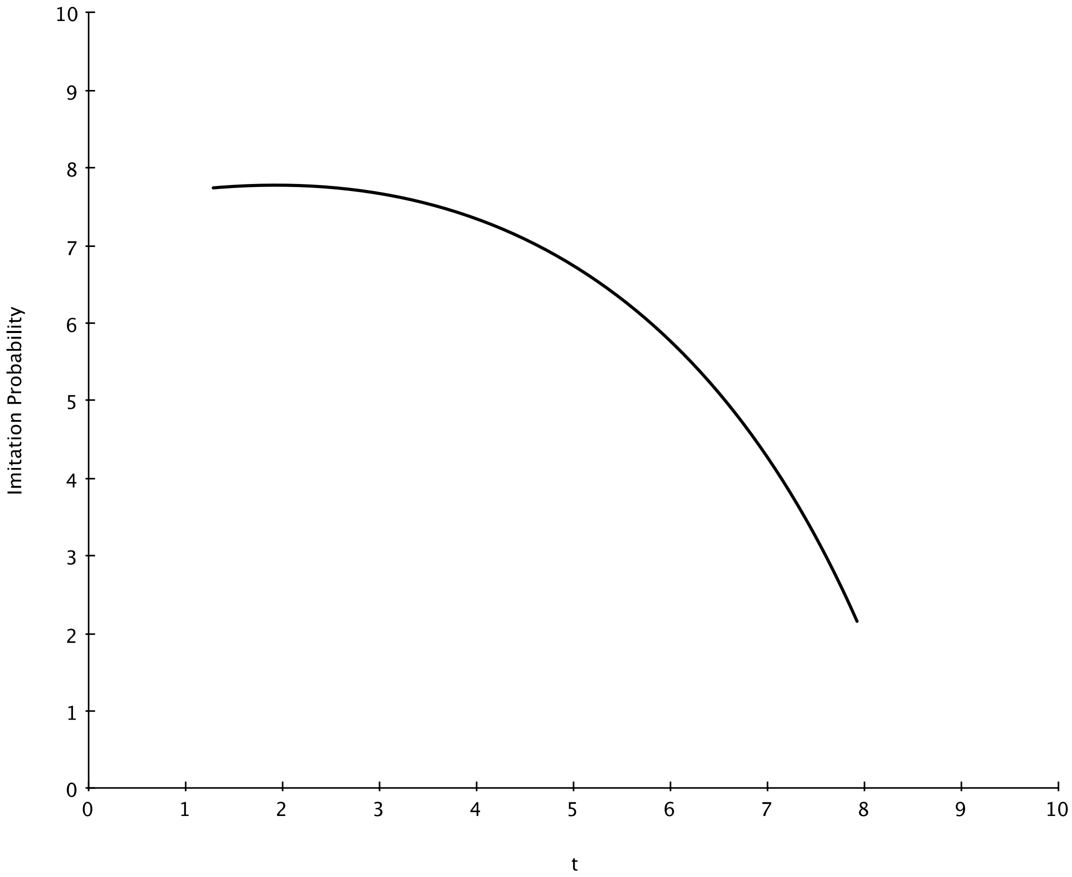
By Equation (5.10), $\frac{\partial F}{\partial t}$ determines trend of imitation probability over time.

If $\frac{\partial F}{\partial t} < 0 \Leftrightarrow P_{t-1} > \ln(1+\bar{g}^*)$, the probability of imitation decreases. And if $\frac{\partial F}{\partial t} > 0 \Leftrightarrow P_{t-1} < \ln(1+\bar{g}^*)$, the probability of imitation increases. Graph 5.2 shows that for each type of firm, if the technology causing growth rate doesn't reach the point $\ln(1+\bar{g}^*)$ they prefer to borrow advanced technology and the imitation probability increases. Technology causing productivity improvement including innovation and imitation is far below the average growth rate of the technology frontier, which indirectly shows that the current domestic technology level is far behind the technology frontier. The optimal choice is to borrow and learn advantaged technology in order to narrow the gap.



Graph 5.12 TREND OF PROBABILITY OF IMITIATION OVER TIME IF $P_{t-1} < \ln(1 + \bar{g}^*)$

In Graph 5.3, if technology causing growth rate is up to $\ln(1 + \bar{g}^*)$, the imitation probability of each type of firm will decrease over time. If the firms extend to a certain scale, $e^{P_{t-1}} - 1$ is over than the average growth rate of the technology frontier, it is not desperate for entrepreneurs now to cover the gap, and they would like to undertake R&D activities in order to be in a leading position in terms of technology.



Graph 5.13 TREND OF PROBABILITY OF IMITIATION OVER TIME IF $P_{t-1} > \ln(1+\bar{g}^{*})$

Proposition 5.2: **If the technology causing growth rates of SOEs, LPEs and SMEs are over $\ln(1+\bar{g}^{*})$, enterprises have less probabilities to choose imitation in the next round; If the technology causing growth rates of each type of firm are lower than $\ln(1+\bar{g}^{*})$, it is more possible for firms to imitate advantaged technology in the next period.**

The growth rate of each type of firm considered with R&D activities and imitation

The technology causing growth rates of SOEs, LPEs and SMEs is presented as,

$$P_{it} = (1 - e_{it})\mu_{it}\gamma_{it} + \frac{e_{it} g^* A^*_{t-1}}{A_{t-1}} = \mu_{it}\gamma_t + \left[g^* Z \frac{(1+\bar{g}^*)^{t-1}}{a^0_{it-1}} - \mu_{it}\gamma_{it}\right] e_{it}$$

In a simple case that $\sigma_I = \sigma_E = 2$, according to Equation (5.5) and Equation (5.8), and let $\varkappa_i = \left(\frac{\pi}{2}\right)(\lambda_i \gamma_{it})^2 = \frac{\pi \Omega^2_{it}}{2}, F = Z\frac{(1+\bar{g}^*)^{t-1}}{a^0_{it-1}}, \Im = \sqrt{\frac{2\pi \bar{e}}{3\Theta_t}}$, the technology causing growth rate with optimal inputs of R&D activities or/and imitation will be rewritten as,

$$P_{it} = \varkappa_i + \Im_i (g^* F_i - \varkappa_i)\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{\frac{1}{2}} \qquad (5.11)$$

In this chapter, the step size of technology improvement γ_{it}, research effectiveness λ_i and the patent protection Θ_t are considered as exogenous variables.

If $\frac{\partial F}{\partial t} < 0 \Leftrightarrow P_{t-1} > \ln(1 + \bar{g}^*)$, the probability of imitation decreases. Under this circumstance, if $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\bar{A}_{t-1}}} > \frac{3g^*}{\pi}$, the technology causing growth rate will increase over time. However, if $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\bar{A}_{t-1}}} < \frac{3g^*}{\pi}$, the technology causing growth rate will decrease.

In fact, $\omega = \frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\bar{A}_{t-1}}}$ is the requirement of innovation research capability to cover up per unit distance to the technology frontier. $\omega^* = \frac{3g^*}{\pi}$ is the lowest requirement. If the technology causing growth rate is up to $\ln(1+\bar{g}^*)$ which means the distance to technology frontier is already narrowed down to a certain level, entrepreneurs are not desperate to cover the gap and they prefer to undertake innovation activities in order to obtain a leading position. However, whether this action will affect a growth rate increase is determined by the innovation research capability of each type of firm. If the innovation research capability could satisfy the lowest requirement $(\omega > \omega^*)$, it is good choice to increase the probability of innovation and invest less in imitation. However, if firms don't have enough research capability, even though the distance to the technology frontier is narrowed down to the certain level, the action of taking more innovation and less imitation will sacrifice growth rates because of overestimated R&D capability.

If $\frac{\partial F}{\partial t} > 0 \Leftrightarrow P_{t-1} < \ln(1+\bar{g}^*)$, and $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} < \frac{3g^*}{\pi}$, the technology causing growth rate will increase over time. However, if $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{3g^*}{\pi}$, the technology causing growth rate will decrease. If the distance to technology frontier is still larger than a certain level $[P_{t-1} < \ln(1+\bar{g}^*)]$, entrepreneurs think it is urgent to learn advantage technology and their research capability can't meet the least requirement for innovation. Therefore, the strategy taking more imitation rather than innovation is better for increasing the technology growth rate. However, if the research capability is enough for innovation activities and entrepreneurs prefer to borrow advantaged technology to narrow down the gap to technology frontier, in fact, the research capability is underestimated and wasted. Moreover, the growth rate will decrease because of ineffective utilisation and innovation research capability.

Proposition 5.3: **The technology-led growth rate of SOEs, LPEs and SMEs increases over time in both two cases: (1) $\boldsymbol{\omega > \omega^*}$ and $\boldsymbol{P_{t-1} > \ln(1 + \bar{g}^*)}$; and (2) $\boldsymbol{\omega < \omega^*}$ and $\boldsymbol{P_{t-1} < \ln(1 + \bar{g}^*)}$. The technology-led growth rate of each type of firm declines over time if $\boldsymbol{\omega < \omega^*}$ and $\boldsymbol{P_{t-1} > \ln(1 + \bar{g}^*)}$; or $\boldsymbol{\omega > \omega^*}$ and $\boldsymbol{P_{t-1} < \ln(1 + \bar{g}^*)}$.**

The relationship between probability of imitation and the growth rate of each type of firm

In the last part, the relationship between the technology causing growth rate and imitation probability is indirectly shown by the trends of the technology causing growth rate. In this part, it will directly study whether the effects of imitation on the growth rate are always positive.

$$\frac{\partial P_{it}}{\partial e_{it}} = g^* \frac{A_{t-1}^*}{\check{A}_{t-1}} - \mu_{it}\gamma_{it} = g^* \frac{A_{t-1}^*}{\check{A}_{t-1}} - \left(\frac{\pi}{2}\right)\Omega_{it}^2 \qquad (5.12)$$

According to Function (5.12), it is clear that, if the research capability needed to cover up per unit distance to the technology frontier is lower than a certain level $\left(\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} < \frac{2g^*}{\pi}\right)$, then an increase of imitation probability will lead to an increase of the technology causing growth rates of SOEs, LPEs and SMEs. However, if $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi}$, an increase of imitation probability will cause the technology causing growth rate of each type of firm to decline. There is the least research capability to cover up per unit distance to the technology frontier $\omega_{Pe}^* = \frac{2g^*}{\pi}$. If the research capability of each type of firm to cover up per unit distance to the technology frontier cannot satisfy this least requirement, which means the research capability for innovation is not strong enough, then imitation and learning advanced technology is a better strategy than innovation for each firm.

Proposition 5.4: **If the research capability needed to cover up per unit distance to the technology frontier is better than the least research capability ($\frac{2g^*}{\pi}$), imitation won't promote the technology causing growth rate of domestic firms.**

5.3.2 With Financial Frictions

In the previous parts, the trends of probability of imitation, growth rate of outputs of SOEs, LPEs and SMEs and their relationships are discussed. However, it is assumed that there are no financial frictions. In fact, enterprises have to deal with problems of limited capital when they try to innovate products and processes of production, especially with SMEs. As Chapter 4 in this chapter, it is also supposed that bank borrowing is the only financing channel for SOEs, LPEs, and SMEs. This chapter follows King and Levine (1993) and only concerns the Ex-Ante Screening model.

In the model, fC_t is the screening cost. θ is the probability that banks can get money back. P is the repayment. Then the expected profit of banks will be $\theta P - fC_t$

It is assumed as a simple circumstance in this chapter that there is perfect competition in banking,

$$P = \frac{f}{\theta} C_t$$

The benefit from productivity improvement,

$$\mathrm{H} = \pi \check{A}_t - C_t - \frac{f}{\theta} C_t$$

Maximising the benefit from productivity improvement, equations that followed are worked out,

$$\pi \gamma_t \lambda^{\sigma_\mathrm{I}} = \left(1 + \frac{f}{\theta}\right) \sigma_I (\mu_t)^{\sigma_I - 1}$$

The probability of R&D activities with optimal inputs of R&D activities is

$$\mu_t = \left[\frac{\pi \gamma_t \lambda^{\sigma_\mathrm{I}}}{\sigma_I \left(1 + \frac{f}{\theta}\right)}\right]^{\frac{1}{\sigma_I - 1}} \tag{5.13}$$

The imitation probability with optimal inputs of imitation is[28]

$$e_t = \left\{ \frac{\left[Z\pi g^* \frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi\gamma_t}{\sigma_I}\lambda\right)^{\frac{\sigma_I}{\sigma_I-1}} \left(\sigma_I - 1 - \frac{f}{\theta}\right) \right] \sigma_E \bar{e}}{\left(1+\frac{f}{\theta}\right)(\sigma_E+1)\Theta_t} \right\}^{\frac{1}{\sigma_E}} \qquad (5.14)$$

In a simple situation $\sigma_I = \sigma_E = 2$, Equation (14) will be changed to,

$$e_t = \sqrt{\frac{2\pi\bar{e}}{3\Theta_t}} \left\{ \frac{\left[g^* F - \frac{1}{2}\varkappa\left(1 - \frac{f}{\theta}\right) \right]}{\left(1+\frac{f}{\theta}\right)} \right\}^{\frac{1}{2}}$$

The relationship between financing cost and imitation probability is determined by[29]

$$\frac{\partial e_t}{\partial\left(\frac{f}{\theta}\right)} = \frac{1}{2}\sqrt{\frac{2\pi\bar{e}}{3\Theta_t}} \left\{ \frac{\left[g^* F - \frac{1}{2}\varkappa\left(1 - \frac{f}{\theta}\right) \right]}{\left(1+\frac{f}{\theta}\right)} \right\}^{-\frac{1}{2}} \left[\frac{\varkappa - g^* F}{\left(1+\frac{f}{\theta}\right)^2} \right] \qquad (5.15)$$

According to Function (5.15), if $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi}$, financing cost $(\frac{f}{\theta})$ is positively related to probability estimation, and if $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} < \frac{2g^*}{\pi}$, impacts of financing cost on probability estimation is negative.

If the research capability to cover up per unit distance to the technology frontier is up to the certain level $(\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi})$, entrepreneurs are deprecated to catch up technology frontier. Under this circumstance, if the financing cost is higher, entrepreneurs have less motivation to undertake R&D activities because of high

[28] See proof 5.4 in Appendix

[29] See proof 5.5 in Appendix

cost of failed innovation activities. And according to Proposition 5.4, if the research capability to cover up per unit distance to technology frontier is enough ($\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi}$), a higher imitation probability will cause the decrease of the technology causing growth rate.

If the research capability to cover up per unit distance to technology frontier is far lower than the certain level ($\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} < \frac{2g^*}{\pi}$), then the first task for entrepreneurs is to increase the research capability rather than narrow down the technology gap. Therefore, undertaking innovation activities become more attractive to firms with higher financing costs. Capital invested in technology improvements is limited because of financial frictions, and they have to increase the amount in the innovation in order to increase the probability of successful innovation activities. However, based on Proposition 5.4, in this situation of technology research capability, imitation is a good strategy for an increase of technology causing growth rates. The less invested in imitation because of higher financing costs will lead to declines of technology causing growth rates.

As already discussed in Chapter 4, SMEs have the highest financing costs and SOEs have the least financing costs ($\frac{f_M}{\theta_M} > \frac{f_L}{\theta_L} > \frac{f_S}{\theta_S}$). Therefore, compared with LPEs and SOEs, if SMEs can not satisfy the required least advantage in

Proposition 5.1 and $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\breve{A}_{t-1}}} > \frac{2g^*}{\pi}$. SMEs have the highest probability to borrow technology rather than undertake R&D activities. And under this situation, according to Proposition 4.4, the growth rate of SMEs will be the smallest.

Proposition 5.5: **Considering the impacts of financing cost, if $\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\breve{A}_{t-1}}} > \frac{2g^*}{\pi}$, SMEs have stronger motivation to imitate advanced technology rather than undertaking R&D activities because of the higher financing costs**

5.4 Quantitative Analysis

In previous part of this chapter, it already discussed preferences of SOEs, LPEs and SMEs to imitation, the trend of preference to imitation in China, and relationship between imitation and growth of firms. And in this part, the theoretical results will be related to data in reality.

In a simple case, it is supposed that $\sigma_I = 1/2, \sigma_E = 1/2$ and $\bar{e} = 1$. The parameter of patent right protection in China is 3.1, which is the average value of standard Ginarte-Park index of patent right in 1995, 2000, and 2005 (Park, 2008). The technology gap is inversely measured by relative labour productivities to US (labour productivities in US is normalized to one). Data on US labour productivities from 1994 to 2014 is obtained from the website of Bureau of

Labour Statistics in US. There is no direct data on China labour productivities, and read GDP per worked hour (USD, PPP) is used to present the data. According to Labour Law in China, there are 250 working days a year and 8 working hours a day. Therefor, total worked hours a year used to calculate labour productivity in China are supposed to be 2000 hours. And similarly, labour productivities of SOEs are presented by the real output[30] per worked hour. It is complex to calculate labour productivities of LPEs and SMEs. The labour productivities of PEs are calculated in first. And it is known that, in last chapter, the research capability of LPEs is 1.65 times SMEs. Then it is reasonable to think labour productivities of LPEs are also 1.65 times SMEs. The exogenous growth rate of technology in technology frontier g^* is presented by average growth rate of US labour productivities. In this chapter, the research capabilities of SOEs, LPEs, and SMEs are the 1.109, 1.451 and 0.879[31].

Factor	**Method**	**Type of Firms**	**Value**
The exogenous growth rate of technology in technology frontier g^*	Average growth rate of US labour productivities from 2001 to 2014.	SOEs	1.55
		LPEs	1.55
		SMEs	1.55
Technology gap F	Inverse relative labour productivities to US from 2001 to 2014.	SOEs	Data
		LPEs	Data
		SMEs	Data

30 Output=main business income＋inventory－inventory in last period
31 Research capability=1/10* new products sale income/expenditure on R&D activities.

Research capability Ω	$Research\ Capability = \frac{New\ products\ sale\ income}{10 * Expenditure\ on\ R\&D\ activities}$	SOEs	1.109
		LPEs	1.451
		SMEs	0.879
Patent Right Protection Θ	Average value of standard Ginarte-Park index of patent right in 1995, 2000, and 2005 (Park, 2008)	SOEs	3.1
		LPEs	3.1
		SMEs	3.1

Table 5.8 VALUES OF PARAMETERS IN THE MODEL

Original Data Source: CSMAR Database, China Statistics Database, Bureau of Labor Statistics in US.

5.4.1 Impacts of ownership of enterprises

In this chapter, it is known that for one certain type firms, if the required least advantage in research capability to cover up per unit of difference in technology gap could be satisfied, compared with another type firms, this type firms will more prefer innovation rather than imitation.

Zero-line in Figure 5.7 presents the required least advantage and the area up zero-line means the required least advantage is satisfied while the area below zero-line means that required least advantage is not satisfied.

It is clearly shown by Figure 5.7, compared with SMEs and LPEs, the required least advantages of SOEs are not satisfied, and based on the model, SOEs should more prefer imitation than LPEs and SMEs.

Compared with SMEs, LPEs' required least advantage is satisfied, therefore, LPEs should have less probability to choose imitation.

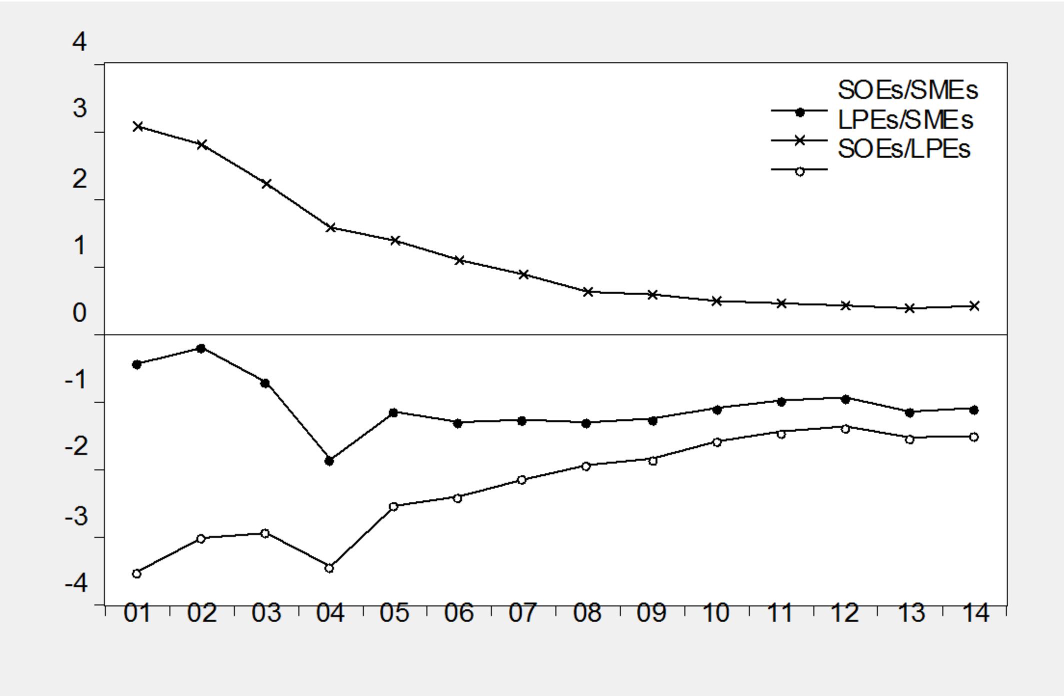


Figure 5.7 REQUIRED LEAST ADVANTAGE IN RESEARCH CAPABILITIES TO COVER UP PER UNIT OF DIFFERENCE IN TECHNOLOGY GAP

Figure 5.8 shows the imitation probabilities of SOEs, LPEs and SMEs. As the theatrical results, SOEs have more imitation probability than LPEs, and SMEs, because SOEs do not satisfy the required least advantage. LPEs more prefer to innovation than SOEs and SMEs, because the required least advantages of LPEs are satisfied.

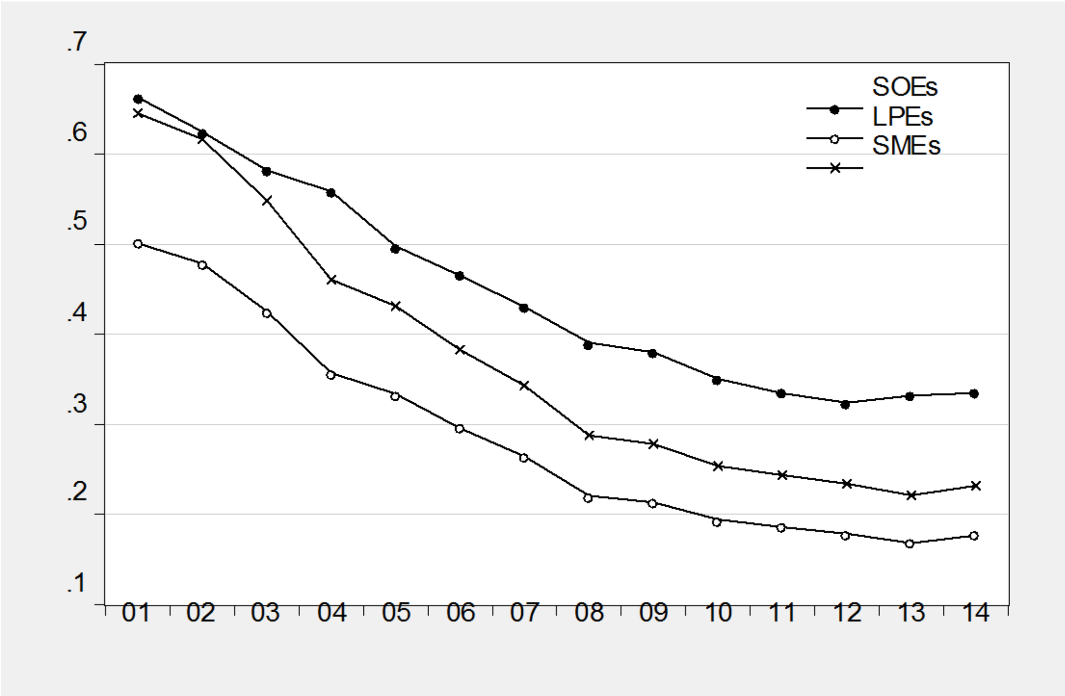


Figure 5.8 IMITATION PROBABILITIES OF SOES, LPES AND SMES

5.4.2 Change of imitation rate

Based on the model in this chapter, when growth rate caused by technology improvement is up to a certain level $[\ln(1+\bar{g}^{*})]$, the probability of imitation decreases over time. $\bar{g}^{*}$ is geometric mean of exogenous growth rate of technology improvements in technology frontier from 2001 to 2014. And the value of $\ln(1+\bar{g}^{*})$ is 0.91. By Figure 5.9, growth rates caused by technology of SOEs are larger than $\ln(1+\bar{g}^{*})$ from 2001 to 2014, except in 2013 and 2014. During this period, the growth rates caused by technology of LPEs and SMEs are also over than $\ln(1+\bar{g}^{*})$, except in 2014. Therefore, imitation probability of SOEs declines from 2001 to 2012 but increase in 2013 and 2014. LPEs and SMEs have decreasing preference to imitation from 2001 to 2014 but more preference in 2014. And Figure 5.8 proves those results.

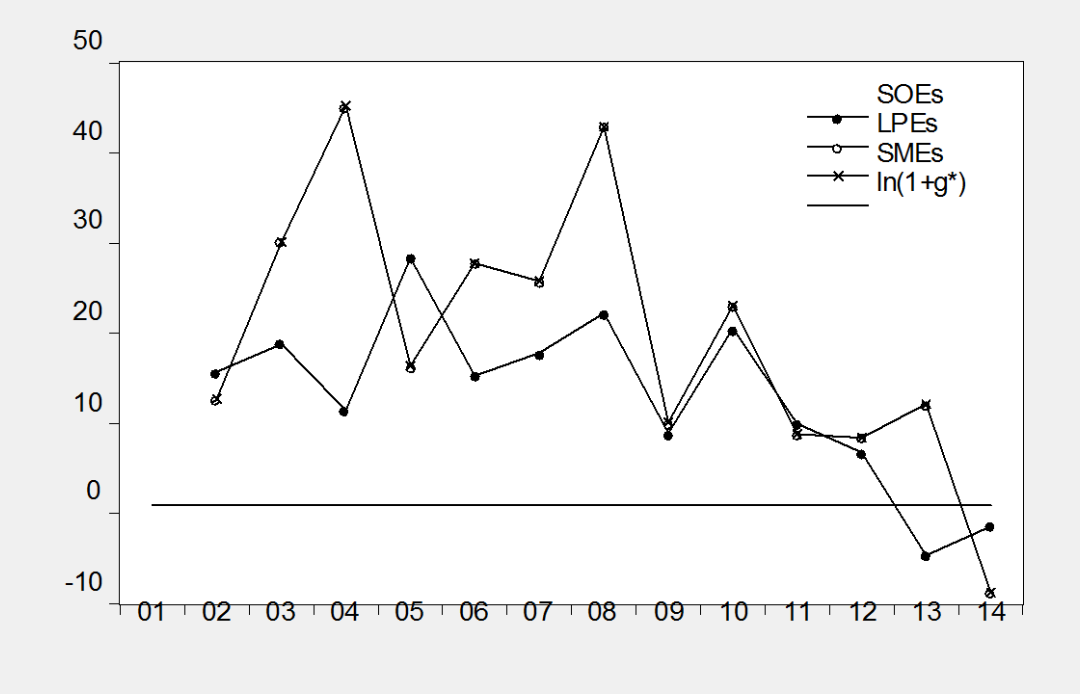


Figure 5.9 p_{t-1} AND $ln(1+\bar{g}^{*})$ OF SOES, LPES AND SMES

5.4.3 Growth rate caused by technology considered with R&D activities and imitation

In this part, related data of domestic firms on variables in the model are presented by data in country level rather than firms level, and sample size expends (1994 to 2014) in order to clearly show the results. Then the research capability is 1.5 calculated by the same method in Table 4.8. Technology gap between China to US is inversely measured relative labor productivity of China to US.

It is clearly shown by Figure 5.10 that in the sample $p_{t-1} > \ln(1+\bar{g}^*)$, and Figure 5.11 shows from 1994 to 2013, ω<ω^* but ω>ω^* in 2014. Based on Proposition 4.3, the technology-led growth rate should decline from 1994 to 2013. And in 2014, the growth rate increases. And Figure 5.12 proves this, in 2014, the technology-led growth rate slightly increase than 2013.

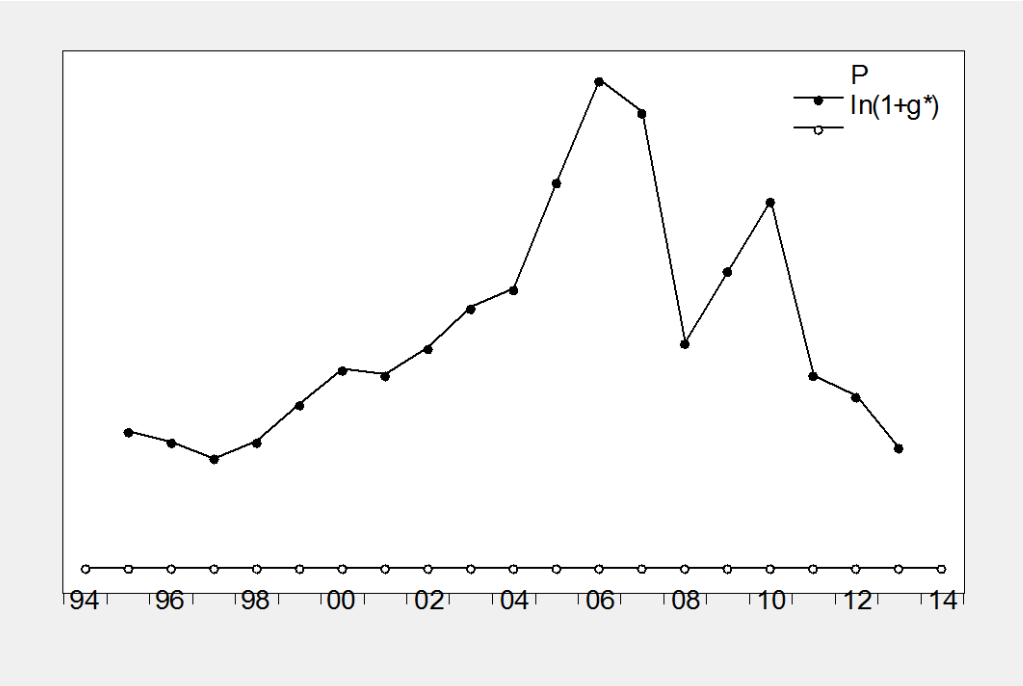


Figure 5.10 p_{t-1} AND $\ln(1+\bar{g}^*)$

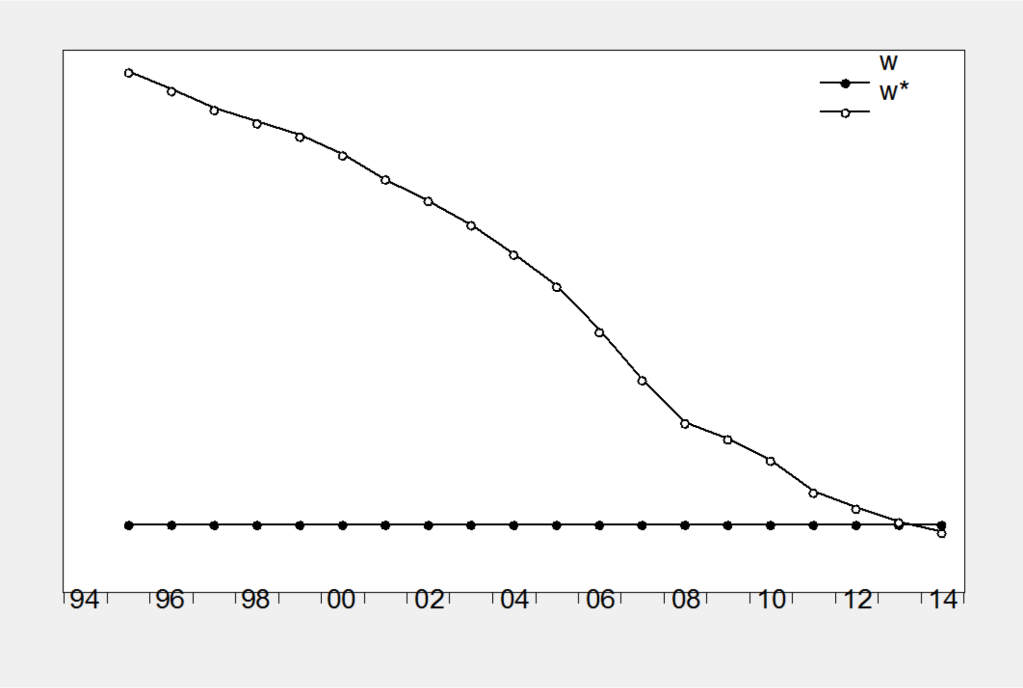


Figure 5.11 ω AND ω^*

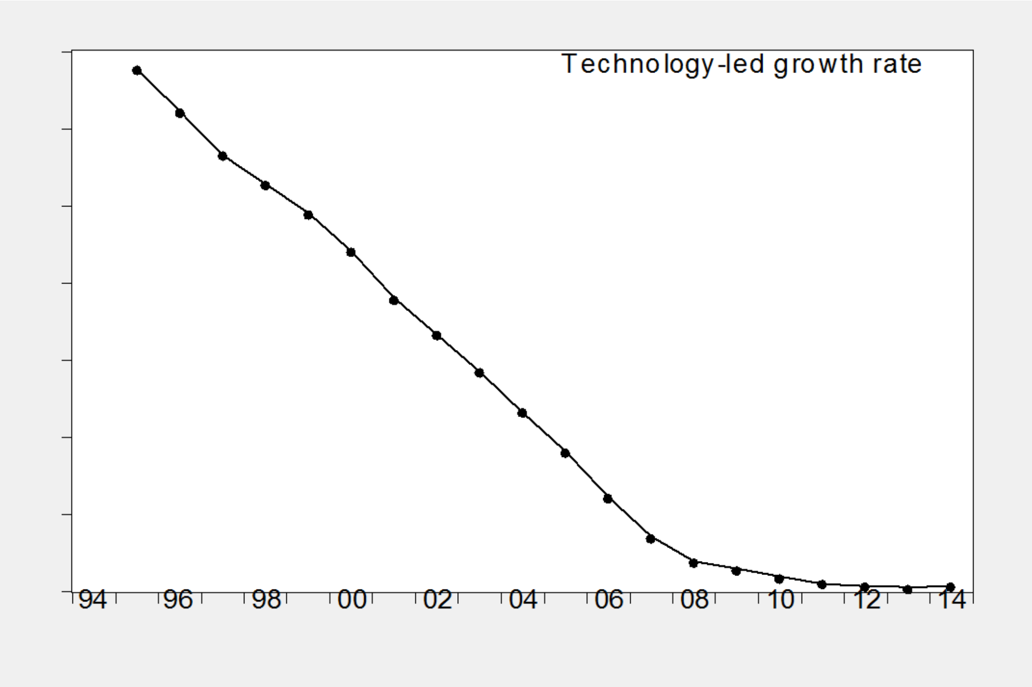


Figure 5.12 TECHNOLOGY-LED GROWTH RATE FROM 1994 TO 2014

5.5 Conclusion

This chapter constructs a model to describe the innovation strategy of SOEs, LPEs and SMEs. At the early stage of development, it may be a good choice for each type of firm to be imitating advanced technology. However, when the growth rate of each type reaches a certain level and if the innovation research capability could satisfy the lowest requirement ($\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{3g^*}{\pi}$), then SOEs and LPEs and SMEs need to carry out R&D activities to keep the growth rate increasing, and the probability of each type of firm, in this situation, decreases.

The relationship between probability of imitation and technology causing growth rate of domestic firms are negative, if research capability needed to cover up per unit distance to technology frontier is better than $\frac{2g^*}{\pi}$.

In addition, the model in this chapter indicates that financing cost is negatively related to the chance of carrying out R&D activities if the research capability to cover up per unit distance to the technology frontier meets the least requirement ($\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi}$). Under these circumstances, because of the highest financing costs that were discussed in Chapter 4, SMEs have more motivation than SOEs and LPEs to choose imitation.

The conclusions suggest some policy implications. If the government tries to enhance indigenous innovation, they need to help enterprises reduce the financing cost, for example by providing subsidy, encouraging banking sectors to decrease the interest rates of bank borrowing for R&D activities and imitation, or providing guarantees for credits - especially for SMEs to reduce their credit risks. The government of China now gradually cancels frictions of establishing banking sectors and encourages private banking sectors to diverse the channel of financing, which can promote the technology improvement.

Regarding patent rights protection, Chu et al. (2014) pointed out that in the earlier developing stage, strong IPR protection will hurt the social welfare, and they suggested that for developing countries, IPR protection should be gradually strengthened with a decrease in distance to the technology frontier. This chapter has similar points. Patent rights protection negatively affects the imitation probability of firms, and when the least research capability to cover up per unit distance to the technology frontier is not satisfied, imitation will promote the technology causing growth rate. Therefore, if the research capability of domestic firms is not up to the given level, the government could weaken the patent rights protection to promote the growth rate.

The limitations of this chapter are that the growth rate of the technology frontier is considered as exogenous and a constant, which is not true in reality, and that the step size of domestic innovation is also considered as an exogenous constant, but in fact it may be endogenous, which changes over time and is related to research funds, the structure of ownership, and the human capital.

Chapter 6 Endogenous innovative steps model

6.1 Introduction

The innovation strategy of firms in China was discussed in Chapter 5 and the step size of domestic innovation in the model is considered to be exogenous.

However, Romer (1990) thinks that new technology production is determined by the research labour and accumulated technology level. The growth rate of technology is affected by research labour, and the effects are positive.

Jones (1995) has similar points. However, in his model, the step size of technology improvements is determined by research labour and the accumulated technology level. The 'fishing out effect' occurs if the impact of the accumulated technology level is negative. This means that the more advanced technology is more difficult to achieve. In a lower technology level, new technology is easier to produce. However, in a higher technology level, it is more difficult to obtain new technology.

Research funds are considered to be another factor that will affect new technology production by Rivera-Batize and Romer (1991) and Jones and Williams (2000). However, the impact of research labour is not included in their model.

Cheung and Lin (2004) think of research funds as capital input in new technology production. Yan et al. (2010) combined these models and concluded new technology production is affected by research labour, research funds and accumulated technology level. Yan et al. (2010) use cross-province panel data from 1998 to 2007 to estimate new knowledge production in China. Except research labour, research funds and accumulated technology level, impacts of FDI, importing production facilities from abroad, accumulated technology level in other provinces are also consider in their estimation model. And their empirical results support Jones (1995) that there is no scale effect in the knowledge production and the power of accumulated technology is lower than 1.

As Yan et al. (2010), in this chapter, step size is determined by research labour, research capital and accumulated technology level. And based on Jones (1995) and empirical results of Yan et al. (2010), this thesis also think in China, step size of technology improvement is negatively affected by the accumulated technology level because of the 'fishing out effect'.

This chapter focus on step size of three type firms in China (SOEs, LPEs and SMEs), and does not consider impacts of FDI. Therefore, different from Yan et al. (2010), 'spillover effects' and 'crowding out effects' of FDI and 'raising the bar effects' and 'spillover effects' between provinces are not included in this chapter. The key difference between this chapter and Jones (1995) is that impacts of research capital are not neglected.

This chapter will analyse the firms' strategy of technology improvements, including undertaking R&D activities and imitating advanced technology from the technology frontier in world. The trend of imitation rate is also discussed in this chapter. In addition, the impact of the trend of imitation on technology causing growth is analysed.

6.2 The model

In the model, the step size of domestic innovation is assumed to be endogenous and related to research funds, the structure of ownership, the research labour input and the accumulated technology level in the last period. If the R&D activities are successful, then the technology improvements caused by this successful domestic innovation produced in period t are:

$$\widetilde{A_t} - A_{t-1} = \Delta\widetilde{A_t} = \delta L_{Rt}^{\beta} R_t^{\epsilon} A_{t-1}^{\chi} \qquad \beta > 0\,, \epsilon > 0$$

$\widetilde{A_t}$ is the current accumulated technology level with successful innovation activities. $\Delta\widetilde{A_t}$ is the new technology production resulting from successful R&D activities in time t. L_{Rt} is research labour input and R_t is R&D funds which are capital input for R&D activities. A_{t-1} is accumulated the technology levels in the last period. According to Jones (1995), it is assumed that $\chi < 1$, which means that as a higher accumulated technology level, new technology is more difficult to achieve. δ presents the efficiency of innovation activities. In general, SOEs could be considered to be less efficient than PEs. In terms of size effect, LPEs are more efficient than SMEs.

On the other hand, the new technology production caused by R&D activities is presented by the step size of domestic innovation and the accumulated technology level.

$$\Delta\widetilde{A_t} = \widetilde{A_t} - A_{t-1} = \gamma_t A_{t-1}$$

γ_t is the domestic innovation step size. Therefore, the step size of innovation can be presented as follows,

$$\gamma_t = \delta L_{Rt}^{\beta} R_t^{\epsilon} A_{t-1}^{\chi-1} \quad (6.1)$$

As in Chapter 5, the capital investment in R&D activities R_t is

$$R_t = \breve{A}_{t-1}\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} \qquad \sigma_I > 1 \quad (6.2)$$

where μ_t is the probability of succeeding in R&D activities.

Technology improvements are caused by R&D activities and imitating advanced technology. The expected productivity in time t is,

$$E(A_t) = A_{t-1} + (1 - e_t)\mu_t\gamma_t A_{t-1} + e_t g^* A_{t-1}^*$$

g^* is the exogenous growth rate of advanced technology on the world technology frontier, and A_{t-1}^* is the accumulated technology level in the last period in the world technology frontier. e_t is the probability of enterprises choosing the strategy of imitating advanced technology from the technology frontier.

The expected input for enhancing technology improvement without financial friction is:

$$E(C_t) = (1 - e_t)R_t + e_t E_t$$

Because of patent right protection, imitating advanced technology is not free and E_t is the cost of imitating advanced technology from the technology frontier.

According to the Schumpeterian model, the optimal production per labour input is:

$$\widehat{y_t^*} = \pi A_t$$

The reward from R&D activities or/and imitation is,

$$\ddot{\Pi} = \pi E(\check{A}_t) - E(C_t)$$

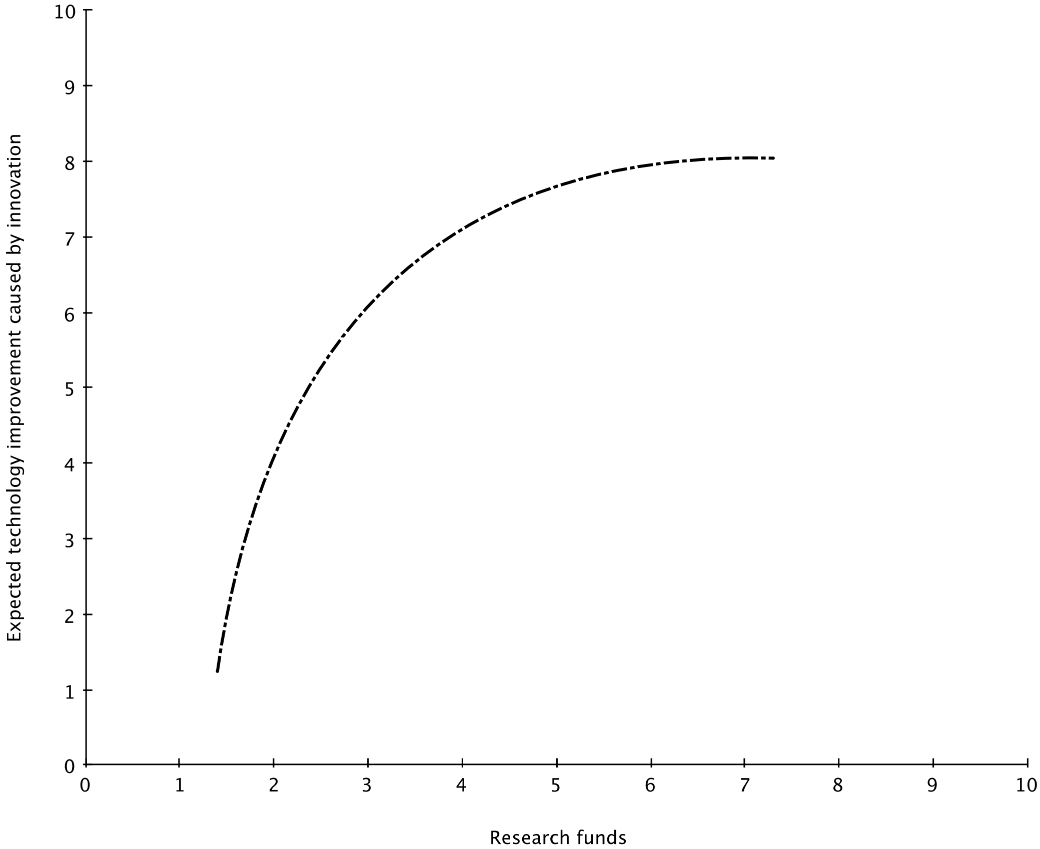
As Chapter 4 shows, to maximize the reward $\ddot{\Pi}$ caused by innovation and imitation, optimal input of R&D activities is:

$$R_t^* = \left[\pi\delta\lambda\left(\epsilon + \frac{1}{\sigma_I}\right)\right]^{\frac{-1}{\epsilon+\frac{1}{\sigma_I}-1}} L_{Rt}^{\frac{-\beta}{\epsilon+\frac{1}{\sigma_I}-1}} A_{t-1}^{\frac{\frac{1}{\sigma_I}-\chi}{\epsilon+\frac{1}{\sigma_I}-1}} \quad (6.3)$$

If firms decide to undertake R&D activities to improve technology, then the expected technology improvement caused by innovation is:

$$E(\Delta \ddot{A}_t) = \mu_t \gamma_t A_{t-1} = \delta \lambda L_{Rt}^{\beta} R_t^{\epsilon+\frac{1}{\sigma_I}} A_{t-1}^{\chi-\frac{1}{\sigma_I}} \qquad \epsilon + \frac{1}{\sigma_I} < 1$$

The total influence of research funds on step size and the probability of successful R&D activities is presented by $\epsilon + \frac{1}{\sigma_I}$. The marginal expected technology improvement caused by innovation will decrease with the growth of the research funds. Based on Equation (6.3), the optimal research funds for innovation are positively related to the research labour input in R&D activities. However, if $\epsilon + \frac{1}{\sigma_I} > 1$, the marginal expected technology improvement caused by innovation will increase with the growth of the research funds. The expected technology improvement caused by innovation is driven by the research funds. In this case, according to Equation (6.3), the optimal research funds for innovation are negatively related to research labour input in R&D activities, which is not realistic. Therefore, considering the reality, the assumption $\epsilon + \frac{1}{\sigma_I} < 1$ is reasonable. For simple, σ_I is supposed to be 2, and in this case ϵ should be larger than 0 but smaller than 0.5 ($0 < \epsilon < 0.5$).



Graph 6.1 THE RELATIONSHIP BETWEEN THE EXPECTED TECHNOLOGY IMPROVEMENT, WHICH IS CAUSED BY INNOVATION, AND RESEARCH FUNDS

Based on equation (6.1) and (6.3), the step size with optimal research funds for R&D activities is:

$$\gamma_t^* = k_1 L_{Rt}^{\frac{-\beta}{2\epsilon-1}} A_{t-1}^{\frac{-(\epsilon+\chi-1)}{2\epsilon-1}} \tag{6.4}$$

where $k_1 = \left[\delta\pi^{2\epsilon}\lambda^{2\epsilon}\left(\epsilon+\frac{1}{2}\right)^{2\epsilon}\right]^{\frac{-1}{2\epsilon-1}}$.

Similarly, the probability of successful innovation with optimal research funds is obtained by Equations (6.2) and (6.3),

$$\mu_t^* = k_2 L_{Rt}^{\frac{-\beta}{2\epsilon-1}} A_{t-1}^{\frac{-(\epsilon+\chi-1)}{2\epsilon-1}} \tag{6.5}$$

where $k_2 = \left[\delta\pi\lambda^{2-2\epsilon}\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}}$.

It is clearly shown by Equations (6.4) and (6.5) that the optimal step size and optimal probability of successful R&D activities are positively affected by research labour input in R&D activities. In reality, the higher the technology level, the more difficult successful R&D activities are and the more difficult it is to achieve a higher step size of technology improvements. Therefore, the optimal step size and optimal probability of successful R&D activities should be negatively affected by accumulated technology level in last period, which means: $\epsilon + \chi < 1$.

6.2.1 Trend of probability of imitating advanced technology over time

It is known that in a simple case when $\sigma_I = \sigma_E = 2$, the optimal possibility of imitating advanced technology while maximising the rewards of imitation and innovation activities is,

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \pi\mu_t^*\gamma_t^* + \frac{1}{\lambda^2}\mu_t^{2*}\right]^{\frac{1}{2}}$$

where $F = \frac{A_{t-1}^*}{A_{t-1}}$. F is the gap between the advanced technology level abroad and the domestic technology level in the last period. According to Equations (6.4) and (6.5), the possibility of imitation can be rewritten as,

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \left(\frac{1}{2} - \epsilon\right)\pi\kappa f\right]^{\frac{1}{2}} \tag{6.6}$$

where $\kappa = k_1 k_2$ and $f = \left(\frac{L_{Rt}^{\beta}}{A_{t-1}^{1-\epsilon-\chi}}\right)^{\frac{2}{1-2\epsilon}}$. It is already known that $\epsilon + \chi < 1$ and $0 < \epsilon < 0.5$. Therefore, f is positively related to research labour input in R&D activities but negatively affected by the accumulated technology level in the last period. f is the function that presents the ratio of research labour input in current period to the accumulated technology level in last period. A higher value of f means higher research labour inputs to the accumulated technology level. Therefore, f could indicate research labour input per unit accumulated technology level in last period. If f decreases, then the research labour inputs per unit accumulated technology level in the last period declines. In addition, κ presents the effectiveness of R&D activities and its impact on the possibility of imitating advanced technology is negative.

Based on Equation (5.6), the trend of the probability of imitation is presented as:

$$\frac{\partial e_t^*}{\partial t} = \frac{1}{2}\sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \left(\frac{1}{2} - \epsilon\right)\pi k_1^2 f\right]^{-\frac{1}{2}}\left[\frac{\pi g^* \partial F}{\partial t} - \left(\frac{1}{2} - \epsilon\right)\pi\kappa\left(\frac{\partial f}{\partial t}\right)\right] \tag{6.7}$$

It is known that $\left(\frac{1}{2} - \epsilon\right) > 0$ and to make equation (6.7) hold, the condition $\frac{f}{F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$ must be satisfied. In fact, $\frac{f}{F}$ presents the research labour input required, with optimal research capital input, to cover the technology gap to the technology frontier. $\frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$ is the upper bond for research labour input with optimal research capital input. If firms or countries could hire enough research labour to cover the technology gap ($\frac{f}{F} > \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$), then they would have to potential to achieve the technology frontier and imitating advanced technology would not be necessary. Therefore, when condition $\frac{f}{F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$ holds, the trend of imitation activities of firms is determined by $\frac{\pi g^* \partial F}{\partial t} - \left(\frac{1}{2} - \epsilon\right)\pi\kappa\left(\frac{\partial f}{\partial t}\right)$.

Proposition 6.1: **If $P_{t-1} < ln(1 + \overline{g^*}) \Leftrightarrow \frac{\partial F}{\partial t} > 0$ and $l_t < \frac{1-\epsilon-\chi}{\beta} ln(1 + \bar{P}) \Leftrightarrow \frac{\partial f}{\partial t} < 0$[32], the trend of imitation increases over time.**

l_t is the growth rate of the research labour input and $\bar{P}$ is the average growth rate (geometric mean) of the domestic technology causing growth rate. If the domestic technology causing growth rate is lower than $ln(1 + \overline{g^*})$, then the technology gap of domestic firms to the technology frontier expands. At the same time, if the research labour growth rate cannot catch up to the average domestic technology causing growth rate [$l_t < \frac{1-\epsilon-\chi}{\beta} ln(1 + \bar{P})$], then the research labour input per unit of domestic accumulated technology level in last period will decrease. Under these circumstances, firms will be in a difficult position wherein there is not enough research labour to deal with the increasing technology gap.

32 See Proof 6.2 in Appendix.

Therefore, imitation seems to be a better choice for firms than innovation. The possibility of imitation will increase over time.

Proposition 5.2: **If $\boldsymbol{P_{t-1} > ln(1+\overline{g^*}) \Leftrightarrow \frac{\partial F}{\partial t} < 0}$ and $\boldsymbol{l_t > \frac{1-\epsilon-\chi}{\beta} ln(1+\bar{P}) \Leftrightarrow \frac{\partial f}{\partial t} > 0}$[33], the trend of imitation decreases over time.**

In this situation, firms are in a better position in that the technology gap is decreasing while there are enough research labour inputs. R&D activities are now a better choice than imitation for firms

Proposition 5.3: **If $\boldsymbol{P_{t-1} < ln(1+\overline{g^*}) \Leftrightarrow \frac{\partial F}{\partial t} > 0, l_t > \frac{1-\epsilon-\chi}{\beta} ln(1+\bar{P}) \Leftrightarrow \frac{\partial f}{\partial t} > 0}$ and $\boldsymbol{\frac{\partial f}{\partial F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}}$, the trend of imitation activities of firms increases over time.**

In this case, the gap to the technology frontier is being widened if the technology causing growth rate (P_{t-1}) is lower than $\ln(1+\overline{g^*})$, and the research labour per unit accumulated technology level is increasing if the growth rate of R&D labour is up to $\frac{1-\epsilon-\chi}{\beta} ln(1+\bar{P})$. $\frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$ is the least growth required of research labour per unit accumulated technology level to cover the per unit increase in the

33 See Proof 6.2 in Appendix.

technology gap. If the least growth $\frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$is satisfied, the trend of imitation activities will decrease over time, and firms will prefer to innovate new technology to improve technology rather than imitate advanced technology abroad. Otherwise, imitation activities are more attractive for firms than innovation.

Proposition 5.4: **If $P_{t-1} > ln(1+\overline{g^*}) \Leftrightarrow \frac{\partial F}{\partial t} < 0, l_t < \frac{1-\epsilon-\chi}{\beta} ln(1+\overline{P}) \Leftrightarrow \frac{\partial f}{\partial t} < 0$ and $\frac{\partial f}{\partial F} > \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$, the trend of imitation activities of firms increases over time.**

The greatest decrease in research labour per unit accumulated technology level for per unit decrease in technology gap is $\frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$if the research labour per unit accumulated technology level and the gap to the technology frontier are both declining. When $\frac{\partial f}{\partial F}$ exceeds the most decrease $\frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$, the loss of research labour is higher than the decline in the technology gap and there is not enough research labour. Under this circumstance, imitating advanced technology is preferable to undertaking R&D activates.

6.2.2 The influences of probability of imitation on technology causing growth rate

As in Chapter 4, the expected technology causing growth rate of firms is presented as,

$$P_{it} = (1 - e_t)\mu_t\gamma_t + \frac{e_{it}g^*A^*_{t-1}}{A_{t-1}} = \mu_t\gamma_t + [g^*F - \mu_t\gamma_t]e_{it}$$

The impact of the probability of imitating advanced technology on expected technology causing growth rate is:

$$\frac{\partial P_t}{\partial e_t} = g^*F - \mu_{it}\gamma_t = g^*F - \kappa f$$

Proposition 5.5: **If $\frac{f}{F} < \frac{g^*}{\kappa}$, technology causing growth rate is positively affected by the possibility of imitating advanced technology. If $\frac{g^*}{\kappa} < \frac{f}{F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$, influences of possibility of imitation are negative.**

$\frac{f}{F}$ indicates the research labour input required to cover the gap to the technology frontier. If $\frac{f}{F} < \frac{g^*}{\kappa}$ which means there is not enough R&D labour to cover the technology gap, increasing the preference of firms to imitate advanced technology will lead to a higher growth rate caused by technology improvements. However, there is enough human capital undertaking R&D activities [$\frac{g^*}{\kappa} < \frac{f}{F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$], that increasing reference to imitation will cause a lower technology causing growth rate. Therefore, in this case, firms should gradually change their technology improvement pattern and undertake more R&D activities and less imitation activities, otherwise it is waste of research labour.

6.3 Conclusion

This Chapter is an extension of Chapter 5 wherein step size of innovation is considered to be endogenous and is determined by research labour input and research capital.

Considering step size of innovation to be endogenous, the probability of imitating advanced technology from the technology frontier to improve technology is positively affected by the distance to the technology frontier but negatively influenced by the effectiveness of R&D activities and research labour for the per unit accumulated technology level, while in Chapter 5, because of the exogenous innovative step size, the impact of distance to the technology frontier is positive but the influence of the technology research capability is negative.

The trend of the possibility of choosing to imitate advanced technology is determined by whether the technology gap could be narrowed down to a certain level $[\ln(1+\overline{g^*})]$ in Chapter 5. However, if innovative step size is assumed to be endogenous, then there are more complex situations to be discussed in this

Chapter. Generally, it is determined by the technology gap and research labour input.

In addition, whether the technology causing growth rate will increase is determined by the probability of imitating advanced technology and the research labour required to close the technology gap. If the research labour input to cover per unit technology gap is lower than $\frac{g^*}{\kappa}$, then the technology causing growth rate is positively affected by the probability of imitating advanced technology. However, if the condition $\frac{g^*}{\kappa} < \frac{f}{F} < \frac{g^*}{\left(\frac{1}{2}-\epsilon\right)\kappa}$ holds, increasing preference to imitation will lead to a decrease in the technology causing growth rate.

Overall, the impact of research labour input is stressed in the endogenous innovative step size model. The findings of this chapter will be helpful for the government to set policies which encourage firms to take R&D activities and narrow the gap to the technology frontier.

Chapter 7 Final Conclusions

Based on the Schumpeterian model, this thesis determines the average growth rates of SOEs and PEs in two parts: increase rates of scale effect and technology causing growth rates. The average growth rates of SOEs and PEs are compared with consideration of financial friction. In addition, preferences of innovation strategy and trends of preference for imitating advanced technology of SOEs and PEs are analysed.

In the analysis of the average growth rates of SOEs, LPEs and SMEs, in the En Ante Screening model, and Ex Post Monitoring and Moral Hazard model, the order of the average growth rates of each type of firm is determined by whether their advantages in technology causing growth rates exceed their disadvantages in scale. If a certain type of firm has a dominant position in technology causing growth rates, then, to control their average growth rate, their rate of expenditure must be lower than the other two types of firms.

In terms of technology causing growth rates, SMEs grow the slowest in the En Ante Screening model. The order of technology causing growth rates of LPEs and SOEs is determined by the advantages of SOEs in financing, if the cost is significant then the LPEs have the advantage in terms of research capabilities.

In addition, in the Ex Post Monitoring and Moral Hazard model, technology growth rates are positively affected by research capabilities, default costs and self-funding research investment but negatively influenced by accumulated technology improvements and management effectiveness. If a certain type of firm is superior in some determinants of technology causing growth rates then it could prevail over their weakness in other determinants resulting in a higher average technology-led growth rate for this firm type.

The proportion of SOEs, LPEs and SMEs in total production in the market are determined by their growth rates. The proportion of firms with the highest growth rate increases over time, however, the proportion of firms with the lowest growth rate decreases. The weight of firms with medium growth rate increases over time if the difference between the highest growth rate and the medium growth rate is lower than the difference between the medium growth rate and the lowest growth rate.

With the exogenous step size of technology improvements, based on the Schumpeterian model, a new model was constructed to describe the innovation strategy, which will increase the total factor productivities. To the improve technology level in the next period, firms will choose between either learning advanced technology from the technology frontier or undertaking R&D activities.

In this model, research capability and distance to the technology frontier determine the choice of innovation strategy for SOEs, LPEs, and SMEs. At the early stage of development, imitating advanced technology from the technology frontier is a better choice than undertaking R&D activities for each firm type. For one certain type firms, if the required least advantage in technology research capability to cover per unit of differences in technology gap could be satisfied, this type firm will have less possibility to choose imitation.

However, if the growth rates of each type of firm meets a certain level and its innovation research capability can satisfy the lowest requirement $(\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{3g^*}{\pi})$, the probability of choosing imitation will decrease in order to improve technology causing growth rates.

If the research capability required to compensate for the per unit distance to the technology frontier exceeds $\frac{2g^*}{\pi}$, then the probability that imitation will harm the technology-led growth rates of domestic firms will increase.

In addition, the impacts of financing costs are discussed in this model. They are negatively related to the probability of carrying out R&D activities if the research capability to compensate for the per unit distance to the technology frontier can satisfy the least requirement $(\frac{\Omega_{it}^2}{\frac{A_{t-1}^*}{\bar{A}_{t-1}}} > \frac{2g^*}{\pi})$. Therefore, it can be concluded that

SMEs prefer imitation and their technology-led growth rate is the lowest because of the highest financial costs.

If the step size of technology improvements is endogenous, which is determined by the accumulated technology level, research funds and research labour, the innovation strategy will affected by the distance to the technology frontier, the effectiveness of R&D activities and research labour per unit of the accumulated technology level. There are more complex situations regarding trends of probability of imitating advanced technology. Generally, it is determined by the technology gap and research labour. In addition, the probability of imitating advanced technology and research labour required to compensate for the technology gap will determine whether the technology-led growth rate will increase.

The models discussed in this thesis could offer some suggestions for the government's policy making. Based on the theories in this thesis, there are two ways to develop a certain type of firm. One is increasing the increase rate of the total number of this type of firm. The other is improving the total factor productivity that is affected by technology improvement. Policies about reducing the financing cost and encouraging research investment could be issued. Lower financing costs would also enhance domestic innovation.

In order to promote total factor productivities, the government could weaken the patent rights protection if the domestic research capability is worse than the least required research capability to compensate for the per unit distance to the technology frontier as, in this situation, patent rights protection negatively affects the imitation capability of firms and imitation will promote the technology causing growth rate. In addition, the models in Chapter 5 and 6 may be helpful for the government to make policies which encourage SOEs, LPEs and SMEs to undertake R&D activities and narrow the gap with the technology frontier.

Financial frictions play important role in this thesis, which accounts for the different financing cost of SOEs, LPEs and SMEs for research activities. In this thesis, I use two methods to model financial frictions Ex Ante Screening model (King and Levine, 1993) and Ex Post Monitoring and Moral Hazard Model (Aghion, Banerjee and Piketty, 1999).

According to Calomiris and Ramirez (1996), there are four types of financial frictions: information cost, control cost, monitoring cost and market segmentation. The two methods used in this thesis indicate information cost and monitoring costs. Control cost and market segmentation are not included in the model.

Another key limitation of these two methods, only consider one financing channel: borrowing from banks. Other financing channels such as stock market (Levine and Zervos, 1998a, 1998b) are not included. In addition, law system in a country could also affect financial frictions (Levine, 1998, 1999, 2000; Levine et al., 2000).

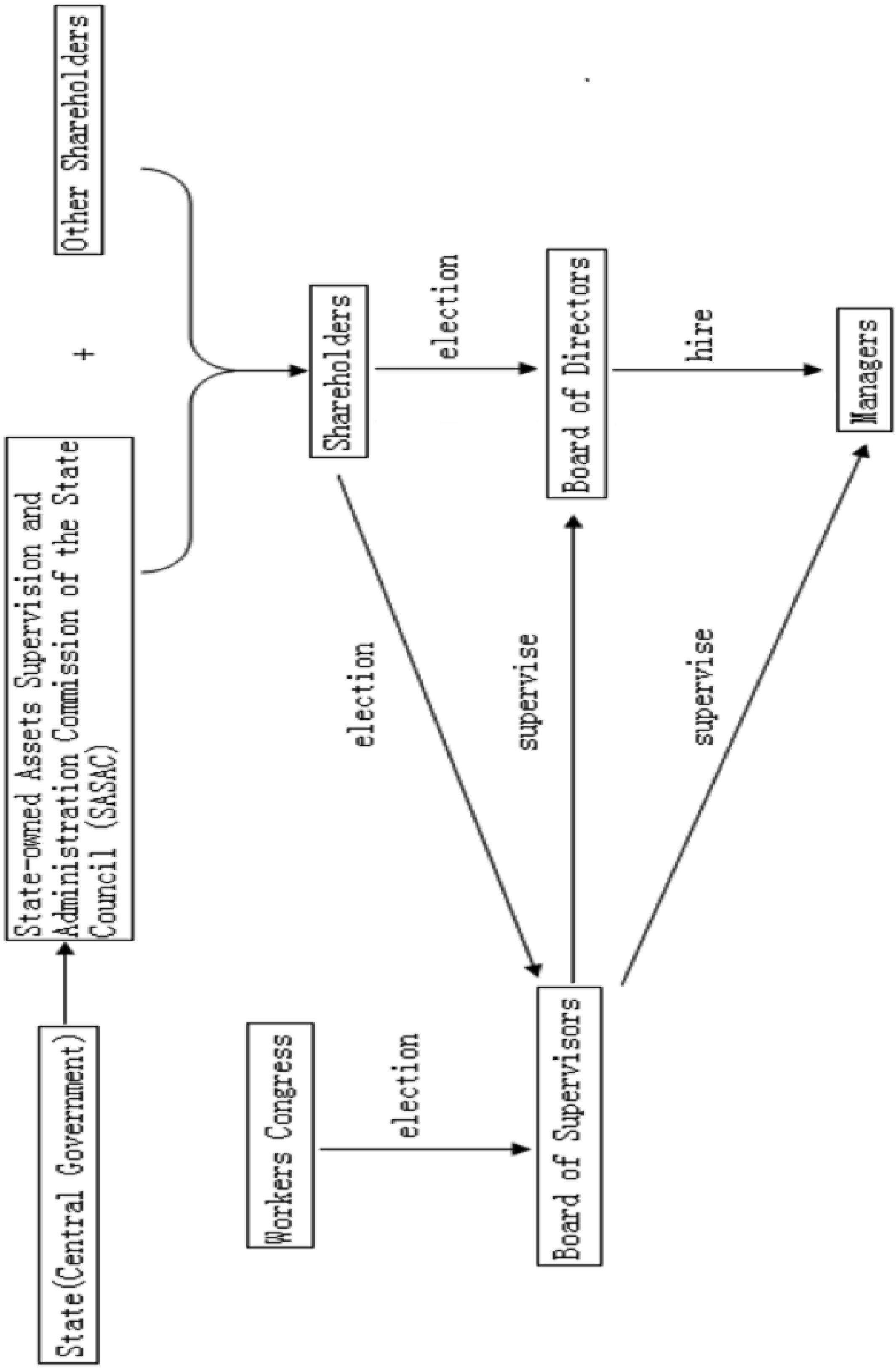
However, base on reality in China, even though SOEs more heavily rely on bank loans for financing while PEs rely more significantly on retained earnings, family and friends (Dollar and Wei, 2007; Riedel et al., 2007), borrowing loans from banks is a main financing channel. And stock market still play an insignificant role to PEs despite that stock market in China grows rapidly (Gregory and Tenev, 2001). Therefore, it is reasonable to focus on financial intermediate sector – banks to model financial frictions.

The method, Ex Post Monitoring and Moral Hazard Model, used in this thesis is similar as the method used by Aghion, et al. (2005), where credit multiplier presents the level of financial development. However, Acemoglu et al. (2006) use retained earnings as financing channel of firms. In Schumpeterian theory, methods used to model financing friction should clearly show financing cost of R&D activities. The two method used in this model could accomplish this task.

This thesis analysed the growth of SOEs and PEs and their innovation strategy in theory. The most important limitation of this thesis is that the impacts of FDI are not considered. In fact, in developing countries, FDI could significantly improve technology in the early stages of development. The analysis of the growth of SOEs and PEs does not consider the linkage effects between them.

Appendix

Appendix 4.1 Structure of SOEs in China



Proof 4.1 Proof of proposition 1

According to Function (4.7), the ratio of growth rates of SOEs to LPEs is,

$$\frac{T_S}{T_L} = \frac{\Omega_S\left(\frac{\pi\sigma}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}}{\Omega_L\left(\frac{\pi\sigma}{1+\frac{f_L}{\theta_L}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}} = \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}\left(\frac{\Omega_S}{\Omega_L}\right)$$

And followings are known

$$\frac{f_L}{\theta_L} > \frac{f_S}{\theta_S}$$

$$\frac{\Omega_L}{\Omega_S} > 1$$

$$\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}} > 1$$

And $0 < \sigma < 1$, therefore $\left(\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}}\right)^{\frac{\sigma}{1-\sigma}} > 1$.

If $\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} < \left(\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}}\right)^{\frac{\sigma}{1-\sigma}}$, it can be worked out

$$\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} < \left(\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}}\right)^{\frac{\sigma}{1-\sigma}}$$

$$\left(\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}}\right)^{\frac{\sigma}{1-\sigma}}\left(\frac{\Omega_S}{\Omega_L}\right) > 1$$

Therefore it can be conducted $\frac{T_S}{T_L} > 1$

If $\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} > \left(\frac{1+\frac{f_L}{\theta_L}}{1+\frac{f_S}{\theta_S}}\right)^{\frac{\sigma}{1-\sigma}}$, it can be worked out

$$\frac{\boldsymbol{\Omega_L}}{\boldsymbol{\Omega_S}} > \left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}}$$

$$\left(\frac{1+\frac{f_L}{\theta_L}+\varepsilon}{1+\frac{f_S}{\theta_S}+\varepsilon}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{\Omega_S}{\Omega_L}\right) < 1$$

Therefore it can be conducted $\frac{T_S}{T_L} < 1$

If $\frac{T_S}{T_L} > \frac{n_L}{n_S}$, it can be worked out

$$\left(\frac{T_S}{T_L}\right)\left(\frac{n_S}{n_L}\right) > 1$$

$$\frac{T_S n_S - 1}{T_L n_L - 1} >$$

Therefore $g_S > g_L$

If $\frac{T_S}{T_M} > \frac{n_M}{n_S}$, it can be worked out

$$\left(\frac{T_S}{T_M}\right)\left(\frac{n_S}{n_M}\right) > 1$$

$$\frac{T_S n_S - 1}{T_M n_M - 1} >$$

Therefore $g_S > g_M$

If $\frac{T_L}{T_M} > \frac{n_M}{n_L}$ it can be worked out

$$\left(\frac{T_L}{T_M}\right)\left(\frac{n_L}{n_M}\right) > 1$$

$$\frac{T_S n_S - 1}{T_M n_M - 1} >$$

Therefore $g_L > g_M$

Proof 4.2 Proof of proposition 2

According to Function (4.10), the followings are worked out

$$\frac{\mathbb{C}_S}{\mathbb{C}_L}=\frac{\Omega_S\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\,)}\right]^\sigma+1}{\Omega_L\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{S}(1+\varsigma_M\,)}\right]^\sigma+1}$$

$$\frac{\mathbb{C}_S}{\mathbb{C}_M}=\frac{\Omega_S\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\,)}\right]^\sigma+1}{\Omega_M\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{S}(1+\varsigma_M\,)}\right]^\sigma+1}$$

$$\frac{\mathbb{C}_L}{\mathbb{C}_M}=\frac{\Omega_L\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\,)}\right]^\sigma+1}{\Omega_M\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{S}(1+\varsigma_M\,)}\right]^\sigma+1}$$

If $\left(\frac{\Lambda_\mathrm{S}}{\Lambda_\mathrm{L}}\right)^\sigma>\frac{\Omega_L}{\Omega_\mathrm{S}}\left(\frac{\nu_L}{\nu_S}\right)^\sigma\left(\frac{1+\varsigma_S}{1+\varsigma_L}\right)^\sigma\left(\frac{\Phi_S}{\Phi_L}\right)^\sigma$,

$$\frac{\Omega_S}{\Omega_\mathrm{L}}\left(\frac{\nu_S}{\nu_L}\right)^\sigma\left(\frac{\Lambda_\mathrm{S}}{\Lambda_\mathrm{L}}\right)^\sigma\left(\frac{1+\varsigma_L}{1+\varsigma_S}\right)^\sigma\left(\frac{\Phi_L}{\Phi_S}\right)^\sigma>1$$

$$\frac{\Omega_S\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\,)}\right]^\sigma+1}{\Omega_L\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{S}(1+\varsigma_M\,)}\right]^\sigma+1}>1$$

$$\frac{\mathbb{C}_S}{\mathbb{C}_L}>1$$

$$\mathbb{C}_S>\mathbb{C}_L$$

SOEs perform better than LPEs in terms of average technology causing growth rate.

If $\frac{\Omega_S}{\Omega_\mathrm{M}}\left(\frac{\Lambda_\mathrm{S}}{\Lambda_\mathrm{M}}\right)^\sigma\left(\frac{\Phi_M}{\Phi_S}\right)^\sigma>\left(\frac{\nu_M}{\nu_S}\right)^\sigma\left(\frac{1+\varsigma_S}{1+\varsigma_M}\right)^\sigma$,

$$\frac{\Omega_S\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\,)}\right]^\sigma+1}{\Omega_M\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{M}(1+\varsigma_M\,)}\right]^\sigma+1}>1$$

$$\frac{\mathbb{C}_S}{\mathbb{C}_M}>1$$

$$\mathbb{C}_S > \mathbb{C}_M$$

The average technology causing growth rate of SOEs will be higher than SMEs.

If $\frac{\Omega_L}{\Omega_\mathrm{M}}\left(\frac{\Lambda_\mathrm{L}}{\Lambda_\mathrm{M}}\right)^\sigma\left(\frac{1+\varsigma_M}{1+\varsigma_L}\right)^\sigma\left(\frac{\Phi_M}{\Phi_L}\right)^\sigma > \left(\frac{\nu_M}{\nu_L}\right)^\sigma$,

$$\frac{\Omega_L}{\Omega_\mathrm{M}}\left(\frac{\nu_L}{\nu_M}\right)^\sigma\left(\frac{\Lambda_\mathrm{L}}{\Lambda_\mathrm{M}}\right)^\sigma\left(\frac{1+\varsigma_M}{1+\varsigma_L}\right)^\sigma\left(\frac{\Phi_M}{\Phi_L}\right)^\sigma > 1$$

$$\frac{\Omega_L\left[\frac{\nu_S\Lambda_\mathrm{S}}{\Phi_\mathrm{S}(1+\varsigma_S\ )}\right]^\sigma + 1}{\Omega_M\left[\frac{\nu_M\Lambda_\mathrm{M}}{\Phi_\mathrm{S}(1+\varsigma_M\ )}\right]^\sigma + 1} > 1$$

$$\frac{\mathbb{C}_L}{\mathbb{C}_M} > 1$$

$$\mathbb{C}_L > \mathbb{C}_M$$

The average technology causing growth rate of LPEs is larger than SMEs.

Proof 4.3 Proof of proposition 3

According to Function (4.11), weights of each type firms can be worked out respectively,

$$w_1 = \frac{y_{1t}}{Y_t} = \frac{y_{1t}}{y_{1t} + y_{2t} + y_{3t}} = \frac{1}{1 + \left(\frac{1+g_2}{1+g_1}\right)^t \left(\frac{\varpi_0^2}{\varpi_0^1}\right) + \left(\frac{1+g_3}{1+g_1}\right)^t \left(\frac{\varpi_0^3}{\varpi_0^1}\right)}$$

$$w_2 = \frac{y_{2t}}{Y_t} = \frac{y_{2t}}{y_{1t} + y_{2t} + y_{3t}} = \frac{1}{1 + \left(\frac{1+g_1}{1+g_2}\right)^t \left(\frac{\varpi_0^1}{\varpi_0^2}\right) + \left(\frac{1+g_3}{1+g_2}\right)^t \left(\frac{\varpi_0^3}{\varpi_0^2}\right)}$$

$$w_3 = \frac{y_{3t}}{Y_t} = \frac{y_{3t}}{y_{1t} + y_{2t} + y_{3t}} = \frac{1}{1 + \left(\frac{1+g_1}{1+g_3}\right)^t \left(\frac{\varpi_0^1}{\varpi_0^3}\right) + \left(\frac{1+g_2}{1+g_3}\right)^t \left(\frac{\varpi_0^2}{\varpi_0^3}\right)}$$

Let ϱ presents the ratio of two types firms' growth rate and W indicates the ratio of two types firms' ϖ. Weights of each type firms can transformed into

$$w_{1t} = \frac{1}{1 + (\varrho_1^2)^t W_1^2 + (\varrho_S^M)^t W_1^3}$$

$$w_{2t} = \frac{1}{1 + (\varrho_2^1)^t W_2^1 + (\varrho_2^3)^t W_2^3}$$

$$w_{3t} = \frac{1}{1 + (\varrho_3^1)^t W_3^1 + (\varrho_3^2)^t W_3^2}$$

The derivative of weight of each type firms to t is,

$$\frac{dw_{1t}}{dt} = \frac{(-1)[W_1^2(\varrho_1^2)^t \ln \varrho_1^2 + (\varrho_1^3)^t W_1^3 \ln \varrho_1^3]}{[\,1 + (\varrho_1^2)^t W_1^2 + (\varrho_1^3)^t W_1^3]^2}$$

$$\frac{dw_{2t}}{dt} = \frac{(-1)[W_2^1(\varrho_2^1)^t \ln \varrho_2^1 + (\varrho_2^3)^t W_2^3 \ln \varrho_2^3]}{[\,1 + (\varrho_2^1)^t W_2^1 + (\varrho_2^3)^t W_2^3]^2}$$

$$\frac{dw_{3t}}{dt} = \frac{(-1)[W_3^1(\varrho_3^1)^t \ln \varrho_3^1 + (\varrho_3^2)^t W_3^2 \ln \varrho_3^2]}{[\,1 + (\varrho_3^1)^t W_3^1 + (\varrho_3^2)^t W_3^2]^2}$$

Weight of a certain type firms with highest average growth rate

$$\ln \varrho_1^2 < 0$$

$$\ln \varrho_1^3 < 0$$

Therefore, I get the followings,

$$W_1^2 (\varrho_1^2)^t \ln \varrho_1^2 < 0$$

$$(\varrho_1^3)^t W_1^3 \ln \varrho_1^3 < 0$$

$$W_1^2 (\varrho_1^2)^t \ln \varrho_1^2 + (\varrho_1^3)^t W_1^3 \ln \varrho_1^3 < 0$$

$$(-1)[W_1^2 (\varrho_1^2)^t \ln \varrho_1^2 + (\varrho_1^3)^t W_1^3 \ln \varrho_1^3] > 0$$

$$\frac{dw_{1t}}{dt} = \frac{(-1)[W_1^2 (\varrho_1^2)^t \ln \varrho_1^2 + (\varrho_1^3)^t W_1^3 \ln \varrho_1^3]}{[\,1 + (\varrho_1^2)^t W_1^2 + (\varrho_1^3)^t W_1^3]^2} > 0$$

The proportion of a certain type firms with highest average growth rate increases over time.

Weight of a certain type firms with middle range growth rate

If $g_3 < g_2 < g_1$, I get $\varrho_2^1 > 1$ and $0 < \varrho_2^3 < 1$

It then can be calculated that $\ln \varrho_2^1 > 0$ and $\ln \varrho_2^3 < 0$

I get the followings,

$$W_2^1 (\varrho_2^1)^t \ln \varrho_2^1 > 0$$

$$(\varrho_2^3)^t W_2^3 \ln \varrho_2^3 < 0$$

It is difficult to directly tell whether value of $\frac{dw_{2t}}{dt}$ is negative or positive.

When the value of $W_2^1(\varrho_2^1)^t \ln \varrho_2^1 + (\varrho_2^3)^t W_2^3 \ln \varrho_2^3$ is positive, the value of $\frac{dw_{2t}}{dt}$ is negative.

$$W_2^1(\varrho_2^1)^t \ln \varrho_2^1 + (\varrho_2^3)^t W_2^3 \ln \varrho_2^3 > 0$$

$$W_2^1(\varrho_2^1)^t \ln \varrho_2^1 > -(\varrho_2^3)^t W_2^3 \ln \varrho_2^3$$

$$W_2^1(\varrho_2^1)^t \ln \varrho_2^1 > (\varrho_2^3)^t {W_2^3}^t \ln\left(\frac{1}{\varrho_2^3}\right)$$

Based on the followings,

$$\varrho_2^3 < 1$$

$$\frac{1}{\varrho_2^3} > 1$$

$$\ln\frac{1}{\varrho_2^3} > 0$$

$$(\varrho_2^3)^t {W_2^3}^t \ln\left(\frac{1}{\varrho_2^3}\right) > 0$$

$$W_3^1 \frac{(\varrho_2^1)^t \ln \varrho_2^1}{(\varrho_2^3)^t \ln\left(\frac{1}{\varrho_2^3}\right)} > 1$$

$$W_3^1 \left(\frac{\varrho_2^1}{\varrho_2^1}\right)^t \left[\frac{\ln \varrho_2^1}{\ln\left(\frac{1}{\varrho_2^3}\right)}\right] > 1$$

$$\frac{\ln \varrho_2^1}{\ln\left(\frac{1}{\varrho_2^3}\right)} > \left(\frac{\varrho_2^1}{\varrho_2^3}\right)^{-t} W_1^3$$

$$\frac{\ln \varrho_2^1}{\ln\left(\frac{1}{\varrho_2^3}\right)} > \left(\frac{\varrho_2^3}{\varrho_2^1}\right)^{t} W_1^3$$

$$\frac{\ln\left(\frac{1+g_1}{1+g_2}\right)}{\ln\left(\frac{1}{\frac{1+g_3}{1+g_2}}\right)} > \left[\frac{\left(\frac{1+g_3}{1+g_2}\right)}{\left(\frac{1+g_1}{1+g_2}\right)}\right]^t W_1^3$$

$$\frac{\ln\left(\frac{1+g_1}{1+g_2}\right)}{\ln\left(\frac{1+g_2}{1+g_3}\right)} > \left(\frac{1+g_3}{1+g_1}\right)^t W_1^3$$

$$\ln\left(\frac{1+g_1}{1+g_2}\right) > \ln\left(\frac{1+g_2}{1+g_3}\right)\left(\frac{1+g_3}{1+g_1}\right)^t W_1^3$$

$$\frac{1+g_1}{1+g_2} > e^{\left[\ln\left(\frac{1+g_2}{1+g_3}\right)\left(\frac{1+g_3}{1+1}\right)^t W_1^3\right]}$$

$$\frac{1+g_1}{1+g_2} > \left[e^{\ln\left(\frac{1+g_2}{1+g_3}\right)}\right]^{\left(\frac{1+g_3}{1+g_1}\right)^t W_1^3}$$

$$\frac{1+g_1}{1+g_2} > \left(\frac{1+g_2}{1+g_3}\right)^{\left(\frac{1+g_3}{1+g_1}\right)^t W_1^3}$$

As the followings,

$$\frac{1+g_3}{1+g_1} < 1$$

$$\left(\frac{1+g_3}{1+g_1}\right)^t < 1$$

$$W_1^3 = \frac{1+\varsigma_3}{1+\varsigma_1} < 1$$

$$\frac{1+g_2}{1+g_3} > 1$$

The upper bond of $\left(\frac{1+g_2}{1+g_3}\right)^{\left(\frac{1+g_3}{1+g_1}\right)^t W_1^3}$ is $\frac{1+g_2}{1+g_3}$, so I can know that when inequality $\frac{1+g_L}{1+g_S} > \frac{1+g_S}{1+g_M}$ *holds*, the value of $[W_2^1(\varrho_2^1)^t \ln \varrho_2^1 + (\varrho_2^3)^t W_2^3 \ln \varrho_2^3]$ is always positive

If $\frac{g_1}{g_2} > \frac{g_2}{g_3}$, the inequality $\frac{1+g_L}{1+g_S} > \frac{1+g_S}{1+g_M}$ *holds* holds. And the weight of that kind of firms with middle range of growth rate decreases over time

The process of proof is,

$$\frac{g_1}{g_2} > \frac{g_2}{g_3}$$

$$g_1 * g_3 > (g_2)^2$$

$$\frac{g_1 - g_2 + g_2}{g_2} > \frac{g_2 - g_3 + g_3}{g_3}$$

$$\frac{g_1 - g_2}{g_2} + 1 > \frac{g_2 - g_3}{g_3} + 1$$

$$\frac{g_1 - g_2}{g_2} > \frac{g_2 - g_3}{g_3}$$

$$g_1 - g_2 > (g_2 - g_3)\left(\frac{g_2}{g_3}\right)$$

As $g_2 > g_3$, then $g_2 - g_3 > 0$ and $\frac{g_2}{g_3} > 1$. Therefore, I can get the following inequality,

$$(g_2 - g_3)\left(\frac{g_2}{g_3}\right) > g_2 - g_3$$

$$g_1 - g_2 > g_2 - g_3$$

$$g_1 + g_3 > 2g_2$$

$$g_1 * g_3 + g_1 + g_3 > 2g_2 + (g_2)^2$$

$$1 + g_1 * g_3 + g_1 + g_3 > 1 + 2g_2 + (g_2)^2$$

$$(1 + g_1)(1 + g_3) > (1 + g_2)^2$$

$$\frac{1 + g_1}{1 + g_2} > \frac{1 + 2}{1 + g_3}$$

The difference between growths of firms with first and second highest growth rate and the difference between growths of firms with second highest and lowest growth rate determine the proportion of that kind of firms with second highest growth rate over time.

Weight of firms with lowest growth rate

$$\ln \varrho_3^1 > 0$$

$$\ln \varrho_3^2 > 0$$

I get the inequalities,

$$W_3^1 (\varrho_3^1)^t \ln \varrho_3^1 > 0$$

$$(\varrho_3^2)^t W_3^2 \ln \varrho_3^2 > 0$$

$$W_3^1 (\varrho_3^1)^t \ln \varrho_3^1 + (\varrho_3^2)^t W_3^2 \ln \varrho_3^2 > 0$$

$$(-1)[W_3^1 (\varrho_3^1)^t \ln \varrho_3^1 + (\varrho_3^2)^t W_3^2 \ln \varrho_3^2] < 0$$

$$\frac{dw_{3t}}{dt} = \frac{(-1)[W_3^1 (\varrho_3^1)^t \ln \varrho_3^1 + (\varrho_3^2)^t W_3^2 \ln \varrho_3^2]}{[\,1 + (\varrho_3^1)^t W_3^1 + (\varrho_3^2)^t W_3^2]^2} < 0$$

Weight of firms with lowest growth rate decreases over time

Appendix 5.1 The number of state-owned enterprises and private enterprises from 2003 to 2012

The number of enterprises	State-owned enterprises	Private enterprises
2012	8214	189289
2011	8048	180612
2010	10205	273259
2009	10559	256031
2008	11080	245850
2007	11403	177080
2006	15898	149736
2005	18138	123820
2004	24866	119357
2003	24558	67607

Data Source: China Statistics Database

Appendix 5.2 The number of large-medium sized enterprises from 2003 to 2012

Year	**The number of large-medium sized enterprises**
2012	63314
2011	61347
2010	46648
2009	41290
2008	40392
2007	36506
2006	32930
2005	29774
2004	27692
2003	23631

Data Source: China Statistics Database

Appendix 5.3 The value of outputs by R&D activities in large-medium sized enterprises in terms of state-owned and private enterprises

The value of outputs caused by R&D in large-medium sized enterprises (10 thousands yuan)	**State-owned enterprises**	**Private enterprises**
2008	224162481	45144590.5
2009	252978363.8	58637200.6
2010	290667158	85120865.7

Data Source: China Statistics Database

Proof 5.2

$$\frac{\partial F}{\partial t} = Z\left\{\frac{[(1+\bar{g}^{*})^{t-1}\ln(1+\bar{g}^{*})]}{a_{t-1}^{0}} - \frac{(1+\bar{g}^{*})^{t-1}}{(a_{t-1}^{0})^{2}}\frac{\partial a_{t-1}^{0}}{\partial t}\right\}$$

$$= \frac{Z(1+\bar{g}^{*})^{t-1}}{a_{t-1}^{0}}\left[\ln(1+\bar{g}^{*}) - \frac{\frac{\partial a_{t-1}^{0}}{\partial t}}{a_{t-1}^{0}}\right]$$

$$= Z\frac{(1+\bar{g}^{*})^{t-1}}{a_{t-1}^{0}}\left[\ln(1+\bar{g}^{*}) - \frac{\frac{\partial \check{A}_{t-1}}{\partial t}\frac{1}{A_{0}}}{\frac{\check{A}_{t-1}}{A_{0}}}\right]$$

$$= Z\frac{(1+\bar{g}^{*})^{t-1}}{a_{t-1}^{0}}\left[\ln(1+\bar{g}^{*}) - \frac{\frac{\partial \check{A}_{t-1}}{\partial t}}{\check{A}_{t-1}}\right]$$

$$= Z\frac{(1+\bar{g}^{*})^{t-1}}{a_{t-1}^{0}}[\ln(1+\bar{g}^{*}) - P_{t-1}]$$

Poof 5.3 Proof of Proposition 3

According to Function (4.11), the trend of growth rate of each type firms is the first order of g_{it} to t,

$$\frac{\partial P_{it}}{\partial t} = \mathfrak{I}\left[\left(g^* \frac{\partial F_i}{\partial t}\right)\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{\frac{1}{2}} + \frac{1}{2}\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{-\frac{1}{2}}\left(g^* \frac{\partial F_i}{\partial t}\right)(g^* F_i - \varkappa_i)\right]$$

$$= \frac{1}{2}\mathfrak{I}\left(g^* \frac{\partial F_i}{\partial t}\right)\left[2\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{\frac{1}{2}} + \left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{-\frac{1}{2}}(g^* F_i - \varkappa_i)\right]$$

$$= \frac{1}{2}\mathfrak{I}\frac{\left(g^* \frac{\partial F_i}{\partial t}\right)\left[2\left(g^* F_i - \frac{1}{2}\varkappa_i\right) + (g^* F_i - \varkappa_i)\right]}{\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{\frac{1}{2}}}$$

$$= \frac{1}{2}\mathfrak{I}\left(g^* \frac{\partial F_i}{\partial t}\right)\left[\frac{3g^* F_i - 2\varkappa_i}{\left(g^* F_i - \frac{1}{2}\varkappa_i\right)^{\frac{1}{2}}}\right]$$

And

$$3g^* F - 2\varkappa_i = \frac{3g^* A^*_{t-1}}{\breve{A}_{t-1}} - \pi(\lambda_i \gamma_{it})^2 = \frac{3g^* A^*_{t-1}}{\breve{A}_{t-1}} - \pi\Omega^2_{it}$$

$$\pi g^* F_i - \left(\frac{\pi \gamma_{it} \lambda_i}{2}\right)^2 > 0$$

$$g^* F_i - \frac{1}{2}\left(\frac{\pi}{2}\right)(\lambda_i \gamma_{it})^2 > 0$$

$$g^* F_i - \frac{1}{2}\varkappa_i > 0$$

If $\frac{\partial F}{\partial t} < 0 \Leftrightarrow g_{t-1} > \ln(1 + g^*)$, $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\breve{A}_{t-1}}} > \frac{3g^*}{\pi}$

$$3g^* \frac{A^*_{t-1}}{\breve{A}_{t-1}} < \pi\Omega^2_{it}$$

$$\frac{3g^*A^*_{t-1}}{\breve{A}_{t-1}} - \pi\Omega^2_{it} < 0$$

$$3g^*F - 2\varkappa_i < 0$$

$$\frac{\partial P_{it}}{\partial t} > 0$$

The growth rate of SOEs, LPEs and SMEs increases over time.

If $\frac{\partial F}{\partial t} < 0 \Leftrightarrow g_{t-1} > \ln(1+g^*)$, $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\breve{A}_{t-1}}} < \frac{3g^*}{\pi}$

$$3g^*\frac{A^*_{t-1}}{\breve{A}_{t-1}} > \pi\Omega^2_{it}$$

$$\frac{3g^*A^*_{t-1}}{\breve{A}_{t-1}} - \pi\Omega^2_{it} > 0$$

$$3g^*F - 2\varkappa_i > 0$$

$$\frac{\partial P_{it}}{\partial t} < 0$$

The growth rate of SOEs, LPEs and SMEs decreases over time.

If $\frac{\partial F}{\partial t} > 0 \Leftrightarrow g_{t-1} > \ln(1+g^*)$, $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\breve{A}_{t-1}}} < \frac{3g^*}{\pi}$

$$3g^*\frac{A^*_{t-1}}{\breve{A}_{t-1}} > \pi\Omega^2_{it}$$

$$\frac{3g^*A^*_{t-1}}{\breve{A}_{t-1}} - \pi\Omega^2_{it} > 0$$

$$3g^*F - 2\varkappa_i > 0$$

$$\frac{\partial P_{it}}{\partial t} > 0$$

The growth rate of SOEs, LPEs and SMEs increases over time.

If $\frac{\partial F}{\partial t} > 0 \Leftrightarrow g_{t-1} > \ln(1+g^*)$, $\frac{\Omega^2_{it}}{\frac{A^*_{t-1}}{\breve{A}_{t-1}}} > \frac{3g^*}{\pi}$

$$3g^*\frac{A_{t-1}^*}{\breve{A}_{t-1}} < \pi\Omega_{it}^2$$

$$\frac{3g^*A_{t-1}^*}{\breve{A}_{t-1}} - \pi\Omega_{it}^2 < 0$$

$$3g^*F - 2\varkappa_i < 0$$

$$\frac{\partial P_{it}}{\partial t} < 0$$

The growth rate of SOEs, LPEs and SMEs decreases over time.

Proof 5.4

$$\frac{\partial H}{\partial e_t} = \pi\left(-\mu_t\gamma_t\check{A}_{t-1} + g^* A_{t-1}^*\right) + \check{A}_{t-1}\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} - (\sigma_E + 1)\frac{\check{A}_{t-1}(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t = 0$$

$$\pi\left(-\mu_t\gamma_t\check{A}_{t-1} + g^* A_{t-1}^*\right) + \left(1 + \frac{f}{\theta}\right)\check{A}_{t-1}\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I}$$

$$= \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{\check{A}_{t-1}(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$\pi\left[-\mu_t\gamma_t + Zg^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0}\right] + \left(1 + \frac{f}{\theta}\right)\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} = \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \pi\mu_t\gamma_t + \left(1 + \frac{f}{\theta}\right)\left(\frac{\mu_t}{\lambda}\right)^{\sigma_I} = \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \mu_t\left[\pi\gamma_t - \left(1 + \frac{f}{\theta}\right)\frac{(\mu_t)^{\sigma_I - 1}}{\lambda^{\sigma_I}}\right] = \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi\gamma_t\lambda^{\sigma_I}}{\sigma_I}\right)^{\frac{1}{\sigma_I - 1}}\left[\pi\gamma_t - \left(1 + \frac{f}{\theta}\right)\frac{\frac{\pi\gamma_t\lambda^{\sigma_I}}{\sigma_I}}{\lambda^{\sigma_I}}\right]$$

$$= \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \frac{\left(\frac{\pi\gamma_t\lambda^{\sigma_I}}{\sigma_I}\right)^{\frac{1}{\sigma_I - 1}}\pi\gamma_t\left(\sigma_I - 1 - \frac{f}{\theta}\right)}{\sigma_I} = \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi\gamma_t}{\sigma_I}\right)^{\frac{1}{\sigma_I - 1}+1}\lambda^{\frac{\sigma_I}{\sigma_I - 1}}\left(\sigma_I - 1 - \frac{f}{\theta}\right) = \left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\frac{(e_t)^{\sigma_E}}{\sigma_E\bar{e}}\Theta_t$$

$$(e_t)^{\sigma_E} = \frac{\left[Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi\gamma_t}{\sigma_I}\lambda\right)^{\frac{\sigma_I}{\sigma_I - 1}}\left(\sigma_I - 1 - \frac{f}{\theta}\right)\right]\sigma_E\bar{e}}{\left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\Theta_t}$$

$$e_t = \left\{\frac{\left[Z\pi g^*\frac{(1+g^*)^{t-1}}{a_{t-1}^0} - \left(\frac{\pi\gamma_t}{\sigma_I}\lambda\right)^{\frac{\sigma_I}{\sigma_I - 1}}\left(\sigma_I - 1 - \frac{f}{\theta}\right)\right]\sigma_E\bar{e}}{\left(1 + \frac{f}{\theta}\right)(\sigma_E + 1)\Theta_t}\right\}^{\frac{1}{\sigma_E}}$$

Proof 5.5

$$\frac{\partial e_t}{\partial\left(\frac{f}{\theta}\right)}=\frac{1}{2}\sqrt{\frac{2\pi\bar{e}}{3\Theta_t}}\left\{\frac{\left[g^*F-\frac{1}{2}\varkappa\left(1-\frac{f}{\theta}\right)\right]}{\left(1+\frac{f}{\theta}\right)}\right\}^{-\frac{1}{2}}\left\{-\frac{\frac{1}{2}\varkappa(-1)}{1+\frac{f}{\theta}}+\frac{(-1)\left[g^*F-\frac{1}{2}\varkappa\left(1-\frac{f}{\theta}\right)\right]}{\left(1+\frac{f}{\theta}\right)^2}\right\}$$

$$=\frac{1}{2}\sqrt{\frac{2\pi\bar{e}}{3\Theta_t}}\left\{\frac{\left[g^*F-\frac{1}{2}\varkappa\left(1-\frac{f}{\theta}\right)\right]}{\left(1+\frac{f}{\theta}\right)}\right\}^{-\frac{1}{2}}\left\{\frac{\frac{1}{2}\varkappa\left(1+\frac{f}{\theta}\right)}{\left(1+\frac{f}{\theta}\right)^2}+\frac{(-1)\left[g^*F-\frac{1}{2}\varkappa\left(1-\frac{f}{\theta}\right)\right]}{\left(1+\frac{f}{\theta}\right)^2}\right\}$$

$$=\frac{1}{2}\sqrt{\frac{2\pi\bar{e}}{3\Theta_t}}\left\{\frac{\left[g^*F-\frac{1}{2}\varkappa\left(1-\frac{f}{\theta}\right)\right]}{\left(1+\frac{f}{\theta}\right)}\right\}^{-\frac{1}{2}}\left[\frac{\varkappa-g^*F}{\left(1+\frac{f}{\theta}\right)^2}\right]$$

Proof 6.1 The proof of Equation (6.6)

The probability of imitating advanced technology from technology frontier is

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \pi \mu_t^* \gamma_t^* + \frac{1}{\lambda^2}\mu_t^{2^*}\right]^{\frac{1}{2}}$$

And it is known that

$$\gamma_t^* = k_1 L_{Rt}^{\frac{-\beta}{2\epsilon-1}} A_{t-1}^{\frac{-(\epsilon+\chi-1)}{2\epsilon-1}}$$

$$\mu_t^* = k_2 L_{Rt}^{\frac{-\beta}{2\epsilon-1}} A_{t-1}^{\frac{-(\epsilon+\chi-1)}{2\epsilon-1}}$$

The probability of imitating advanced technology then could be rewritten as

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \pi k_1 k_2 \left(\frac{L_{Rt}^{\beta}}{A_{t-1}^{1-\epsilon-\chi}}\right)^{\frac{2}{1-2\epsilon}} + \frac{1}{\lambda^2} k_2 \left(\frac{L_{Rt}^{\beta}}{A_{t-1}^{1-\epsilon-\chi}}\right)^{\frac{2}{1-2\epsilon}}\right]^{\frac{1}{2}}$$

And it is supposed that $f = \left(\frac{L_{Rt}^{\beta}}{A_{t-1}^{1-\epsilon-\chi}}\right)^{\frac{2}{1-2\epsilon}}$

Therefore, The probability of imitation could be presented as

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F - \pi k_1 k_2 f + \frac{1}{\lambda^2} k_2 f\right]^{\frac{1}{2}} = \sqrt{\frac{2\bar{e}}{3\Theta_t}}\left[\pi g^* F + k_2 \left(\frac{k_2}{\lambda^2} - \pi k_1\right) f\right]^{\frac{1}{2}}$$

Additionally, it is known that $k_2 = \left[\delta\pi\lambda^{2-2\epsilon}\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}}$, then the following equation can be worked out,

$$\frac{k_2}{\lambda^2} = \left[\delta\pi\lambda^{2-2\epsilon}\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}} \lambda^{-2} = \left[\delta\pi\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}} \lambda^{-2+\left(\frac{2\epsilon-2}{2\epsilon-1}\right)}$$

$$= \left[\delta\pi\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}} \lambda^{-\frac{2\epsilon}{2\epsilon-1}} = \left[\delta\pi\lambda^{2\epsilon}\left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}}$$

And it is also know, then the following equation can be worked out,

$$\pi k_1 = \left[\delta \pi^{2\epsilon} \lambda^{2\epsilon} \left(\epsilon + \frac{1}{2}\right)^{2\epsilon}\right]^{\frac{-1}{2\epsilon-1}} = \left[\delta \lambda^{2\epsilon} \left(\epsilon + \frac{1}{2}\right)^{2\epsilon}\right]^{\frac{-1}{2\epsilon-1}} \pi^{\frac{-1}{2\epsilon-1}+1}$$

$$= \left[\delta \pi \lambda^{2\epsilon} \left(\epsilon + \frac{1}{2}\right)^{2\epsilon}\right]^{\frac{-1}{2\epsilon-1}}$$

Then the ratio of $\frac{k_2}{\lambda^2}$ to πk_1 is,

$$\frac{\frac{k_2}{\lambda^2}}{\pi k_1} = \frac{\left[\delta \pi \lambda^{2\epsilon} \left(\epsilon + \frac{1}{2}\right)\right]^{\frac{-1}{2\epsilon-1}}}{\left[\delta \pi \lambda^{2\epsilon} \left(\epsilon + \frac{1}{2}\right)^{2\epsilon}\right]^{\frac{-1}{2\epsilon-1}}} = \left[\left(\epsilon + \frac{1}{2}\right)^{1-2\epsilon}\right]^{\frac{-1}{2\epsilon-1}} = \epsilon + \frac{1}{2}$$

$$\frac{k_2}{\lambda^2} = (\epsilon + \frac{1}{2})\, \pi k_1$$

$$k_2 \left(\frac{k_2}{\lambda^2} - \pi k_1\right) = k_2 \left[\left(\epsilon + \frac{1}{2}\right) \pi k_1 - \pi k_1\right] = k_2 \left(\epsilon - \frac{1}{2}\right) \pi k_1$$

And it is supposed that $\kappa = k_1 k_2$,

$$k_2 \left(\frac{k_2}{\lambda^2} - \pi k_1\right) = \left(\epsilon - \frac{1}{2}\right) \pi \kappa$$

And because $\epsilon < \frac{1}{2}$, the inequality next can be obtained,

$$\epsilon - \frac{1}{2} < 0$$

Overall, The probability of imitating advanced technology from technology frontier is

$$e_t^* = \sqrt{\frac{2\bar{e}}{3\Theta_t}} \left[\pi g^* F - \left(\frac{1}{2} - \epsilon\right) \pi \kappa f\right]^{\frac{1}{2}}$$

Proof 6.2

In this chapter, the geometric mean of domestic technology causing growth rate in each period is introduced to calculated accumulated technology level in last period,

$$A_{t-1} = (1 + \bar{P})A_{t-2}$$

$$A_{t-2} = (1 + \bar{P})A_{t-3}$$

$$\vdots$$

$$A_1 = (1 + \bar{P})A_0$$

Therefore, $A_{t-1} = (1 + \bar{P})^{t-1}A_0$. A_0 is initial domestic technology level. And it is known that,

$$\frac{\partial f}{\partial t} = \frac{2}{1-2\epsilon}\left[\frac{L_{Rt}^{\beta}}{A_{t-1}^{1-\epsilon-\chi}}\right]^{\frac{2}{1-2\epsilon}}\left[\beta\frac{\frac{\partial L_{Rt}}{\partial_t}}{L_{Rt}} - (1-\epsilon-\chi)\ln(1+\bar{P})\right]$$

The growth rate of research labor input l_t is,

$$l_t = \frac{\frac{\partial L_{Rt}}{\partial_t}}{L_{Rt}}$$

Because $\epsilon < \frac{1}{2}$ and $\chi < 0$, then it can be known that $1 - \epsilon - \chi > 0$ and $\frac{2}{1-2\epsilon} > 0$.

If $l_t < \frac{1-\epsilon-\chi}{\beta} ln(1 + \bar{P})$, then

$$1 - \epsilon - \chi > 0$$

$$\beta > 0$$

$$\beta \frac{\frac{\partial L_{Rt}}{\partial_t}}{L_{Rt}} - (1 - \epsilon - \chi)\ln(1 + \bar{P}) < 0$$

$$\frac{2}{1 - 2\epsilon} > 0$$

Therefore, it can be deducted that $\frac{\partial f}{\partial t} < 0$.

If $l_t > \frac{1-\epsilon-\chi}{\beta} ln(1 + \bar{P})$, then

$$1 - \epsilon - \chi > 0$$

$$\beta > 0$$

$$\beta \frac{\frac{\partial L_{Rt}}{\partial_t}}{L_{Rt}} - (1 - \epsilon - \chi)\ln(1 + \bar{P}) > 0$$

$$\frac{2}{1 - 2\epsilon} > 0$$

Therefore, it can be deducted that $\frac{\partial f}{\partial t} > 0$.

Bibliography

Acemoglu, D. (2002). 'Directed technical change'. *Review of Economic Studies*, 69, pp.781–810

Acemoglu, D. (2005) 'Constitutions, politics, and economics: a review essay on Persson and Tabellini's the economic effects of constitutions', *Journal of Economic Literature,* XLIII pp. 1025-1048

Acemoglu, D. (2006) 'A simple model of inefficient institutions', *Scand. J. of Economics*, 108(4), pp.515-546

Acemoglu,D., Johnson, S. and Robinson, J. A. (2002) 'Reversal of Fortune: Geography and Development in the Making of the Modern World Income Distribution', *Quarterly Journal of Economics,* 117(4), pp. 1231-1294.

Acemoglu,D, Johnson, S. and Robinson, J. A. (2004) 'Institutions as the Fundamental Cause of Long-Run Growth', *NBER Working Paper,* No. 10481.

Acemoglu, D., Johnson, S., Robinson, J. and Thaicharoen, Y. (2002a) 'Institutional causes, macroeconomic symptoms: volatility, crises and growth', *NBER Working Paper,* No. 9124

Acemoglu,D. and Robinson, J. A. (2002) 'Economic Backwardness in Political Perspective', *NBER Working Paper,* No.8831.

Acemoglu, D. and Robinson, J. A. (2006) 'De facto political power and institutional persistence', *American Economic Review*, 96 (2), pp. 325-330

Acemoglu, D., Zilibotti, F. and Aghion, P. (2003) 'Vertical integration and distance to frontier', *Journal of the European Economic Association, 1 (2/3), Papers and Proceedings of the Seventeenth Annual Congress of the European Economic Association,* pp. 630-638

Acemoglu, D., Zilibotti, F. and Aghion, P. (2006) 'Distance to frontier, selection, and economic growth', *Journal of the European Economic Association,* 4(1), pp.37-74

Aghion, P., Banerjee, A. and Piketty, T. (1999) 'Dualism and macroeconomic volatility', *The Quarterly Journal of Economics*, 114(4), pp. 1359-1397

Aghion, P., Howitt, P. and Mayer-Foulkes, D. (2005) 'The effect of financial development of convergence: theory and evidence', *The Quarterly Journal of Economics,* 120(1), pp.173-222

Allen, F., Qian M. and Qian, J. (2005) 'Law, finance, and economic growth in China' *Journal of Financial Economics,* 77, pp.57-116

Amsden, A. (1989) Asia's Next Giant: South Korea and Late Industrialization. Oxford University Press, New York.

Arrow, K. (1998) 'What has economics to say about racial discrimination', *Journal of Economic Perspectives,* 12 (2), pp.91–100

Atkinson, A. B. and Stiglitz, J. E. (1969). 'A new view of technological change', *Economic Journal*, 79, pp.573–578

Bai, C., Li, D.D., Tao, Z. and Wang, Y. (2000) 'A multitask theory of state enterprise reform', *Journal of Comparative Economics*, 28, pp. 716–738

Bai, C., Lu, J. and Tao, Z. (2006) 'A multitask theory of state enterprise reform: empirical evidence from China', *American Economic Review,* 96, pp. 353–35

Banerjee, A., Gertler, P. J. and Ghatak, M. (2002) 'Empowerment and efficiency: tenancy reform in West Bengal', *Journal of Political Economy,* 110 (2), pp.239-278

Barro, R. J. (1986) 'Reputation in a model of monetary policy with incomplete information', *Journal of Monetary Economics*, 17(1), pp.3-20

Barro, R. J. (1991) 'Economic growth in a cross section of countries', *NBER Working Papers,* No. 3120

Barro, R. J. (1996) 'Democracy and growth', *Journal of economic growth*, 1(1), pp.1-27

Barro, R. and Sala-i-Martin, X. (1995). Economic growth. New York: McGraw Hill, pp. 186–194

Barry, B. and Collins, S. M. (2008) 'Accounting for Growth: Comparing China and India', *Journal of Economic Perspectives,* 22(1), pp. 45–66.

Basu, S., & Weil, D. N. (1998) 'Appropriate technology and growth', *Quarterly Journal of Economics,* 113, pp.1025–1054

Benhabib, J., Perla, J. and Tonetti, C. (2014) 'Catch-up and fall-back through innovation and imitation', *Journal of Economic Growth,* 19(1), pp.1-35

Berger, A., Hasan, I., and Zhou, M. (2009) 'Bank ownership and efficiency in China: What will happen in the world's largest nation?' *Journal of Banking & Finance,* 33, pp.113-130

Besley, T. (1995) 'Property rights and investment incentives: theory and evidence from Ghana', *Journal of Political Economy,* 103(5), pp.903-937

Brandt, L. and Li, H.B. (2003) 'Bank discrimination in transition economies: Ideology, information or incentives?' *Journal of Comparative Economics,* 31, pp.387-413

Brandt, L. and Zhu, X. (2000) 'Redistribution in a decentralized economy: growth and inflation in China under reform', *Journal of Political Economy,* 108(2), pp.422-439

Brandt, L. and Zhu, X. (2001) 'Soft budget constraint and inflation cycles: a positive model of the macro-dynamics in China during transition', *Journal of Development Economics,* 64 (2), pp. 437-457

Brandt, L. and Zhu, X. (2009) 'Accounting for China's Growth', *Institute for the Study of Labor Discussion Paper 4764.*

Buera, F. J., and Shin, Y. (2009) 'Productivity Growth and Capita Flows: The Dynamics of Reforms', *NBER Working Paper,* No. 15268

Cagetti, M. and De Nardi, M. (2006) 'Entrepreneurship, Frictions, and Wealth', *Journal of Political Economy,* 114(5), pp. 835–870.

Cai, J., Tylecote, A. (2008) 'Corporate governance and technological dynamism of Chinese firms in mobile telecommunications: a quantitative study', *Research Policy*, 37, pp.1790–

1811

Calomiris, C. and Ramirez, C. (1996) 'Financing the American Corporation: The Changing Menu of Financial Rela-tionships', *NBER Historical Working Papers 0079*, National Bureau of Economic Research, Inc.

Chang, E. C. and Wong, S. M. L. (2004) 'Political Control and Performance in China's Listed Firms', *Journal of Comparative Economics,* 32(4), pp. 617–636.

Chang, S.J., Chung, C., Mahmood, I.P. (2006) 'When and how does business group affiliation promote firm innovation? A tale of two emerging economies', *Organization Science,* 17, pp.637–656

Chen, B., and Feng, Y. (1996) 'Some political determinates of economic growth', *European Journal of Political Economy*, 12, pp.609-627

Cheung, K. and Lin, P. (2004) 'Spillover Effects of FDI on Innovation in China: Evidence from the Provincial Data', *China Economic Review*, 15(1), pp.25-44

Chu, A. C., Cozzi, G. and Galli, S. (2014) 'Stage-dependent intellectual property rights', *Journal of Development Economics,* 106, pp.239-249

Cull, R. and Xu, L.X. (2003) 'Who gets credit? The behaviour of bureaucrats and state banks in allocating credit to Chinese state-owned enterprises', *Journal of Development Economics,* 71, pp. 533-559

Darity, W. and Mason, P. (1998) 'Evidence on discrimination in employment: codes of color, codes of gender', *Journal of Economic Perspectives*, 12 (2), pp.63–90

Dawson, J. W. (1998) 'Institutions, investment, and growth: new cross-country and panel data evidence', *Economic Inquiry,* 36, pp. 603-619

Dinopoulos, E. and Segerstrom, P. (2010) 'Intellectual property rights, multinational firms and economic growth', *Journal of Development Economics,* 92, pp. 13-27

Doamekpor, K.F. (1998) 'Contributions of state-owned enterprises to the growth of total output', *International Economic Journal,* 12, pp. 65–77

Dollar, D. and Wei, S-J. (2007) 'Das (Wasted) Kapital: Firm Ownership and Investment Efficiency in China', *NBER Working Paper,* No. 13103*.*

Domar, E. (1946) 'Capital expansion, rate of growth, and employment', *Econometrica,* 14, pp. 137-147

Dwayne, B., Brandt, L., Giles, J. and Wang, S. (2008) ‘Income In- equality during China’s Economic Transition’, in Brandt, L. and Rawski, T.G. (ed.) *China’s Great Economic Transformation*. New York: Cambridge University Press, pp. 729-775

Easterly, W., Islam, R, and Stiglitz, J. (2000) ‘Shaken and stirred: explaining growth volatility’, *Annual Bank Conference on Development Economics*, World Bank.

Eicher, T. and Garcia-Penalosa, C. (2008) ‘Endogenous strength of intellectual property rights: implications for economic development and growth’, *European Economic Review,* 2008, 52(2), pp.237-258

Fafchamps, M. (2000) ‘Ethnicity and credit in African manufacturing’, *Journal of Development Economics,* 61 (1), pp.205–235

Feng, Y. (1997) ‘Democracy, political stability and economic growth’, *British Journal of Political Science*, 27, pp.391-418

Ferri, G. (2009) ‘Are New Tigers supplanting Old Mammoths in China’s banking system? Evidence from a sample of city commercial banks’, *Journal of Banking & Finance,* 33, pp.131-140

Firth, M., Lin, C., Liu, P. and Wong, S.M.L. (2009) ‘Inside the black box: Bank credit allocation in China’s private sector’, *Journal of Banking &Finance,* 33, pp.1144-1155.

Fu, X. (2004) ‘Limited linkages from growth engines and regional disparities in China’, *Journal of Comparative Economics,* 32(1), pp.148–164

Fu, X. (2008) ‘Foreign direct investment, absorptive capacity and regional innovation capabilities: Evidence from China’, *Oxford Development Studies*, 36(1), pp.89–110

Fu, X. and Heffernan, S. (2009) ‘The effects of reform on China’s bank structure and performance’, *Journal of Banking & Finance,* 33, pp.39-52

Genevieve, B-D. and Wei, S-J. (2005) ‘Pitfalls of a State-Dominated Finan- cial System: The Case of China’, *National Bureau of Economic Research Working Paper 11214.*

Giavazzi, F. and Tabellini, G. (2005) ‘Economic and political liberalizations’, *Journal of Monetary Economics,* 52, pp.1297-1330

Glaeser, E.L., Porta, R.L., Lopez-De-Silanes, F. and Shleifer, A. (2004) ‘Do Institutions cause growth?’, *Journal of Economic Growth*, 9, pp. 271-303.

Glass, A. and Saggi, K. (2002) ‘Intellectual property rights and foreign direct investment’, *Journal of International Economics,* 56, pp.387-410

Glass, A. and Wu, X. (2007) 'Intellectual property rights and quality improvement', *Journal of Development Economics,* 82, pp. 393-415

Gregory, N. and Tenev, S. (2001) 'The Financing of Private Enterprise in China', *Finance and Development,* 38(1), pp. 14-17.

Grossman, G. and Helpman, E. (1994) 'Technology and Trade', *NBER Working Papers,* No.4926

Guan, J.C., Yam, R.C.M., Tang, E.P.Y. and Lau, A.K.W. (2009) 'Innovation strategy and performance during economic transition: evidences in Beijing', *China. Research Policy,* 38, pp.802–812

Gwartney, J. D., Holcombe, R. G. and Lawson, R. A., (2006) 'Institutions and the impact of investment on growth', *KYKLOS*, 59 (2), pp.255-273

Gylfason, T., Herbertsson, T.T. and Zoega, G. (2001) 'Ownership and growth', *The World Bank Economic Review,* 15, pp. 431–449

Haggard, S. (1994) 'Business, politics and policy in Northeast and Southeast Asia', in

Maclntyre, A. (ed.), *Business and Government in Industrializing Asia*, Cornell University Press, NY, Ithaca

Harrod, R.F. (1939) ‘An essay in dynamic theory’, *The Economic Journal,* pp.14-33

Helpman, E. (1993) ‘Innovation, imitation and intellectual property rights’, *Econometrica,* 61(6), pp.1247-1280

Hirschman, A. O. (1958) *The Strategy of Economic Development*, New Haven: Yale University Press.

Holz, C. A. (2011) ‘The unbalanced growth hypothesis and the role of the state: The case of China's state-owned enterprises’, *Journal of Development Economics*, 96 (2), pp. 220-238

Holz, C. A. (2002) ‘Long live China’s sate-owned enterprises: deflating the myth of poor financial performance’, *Journal of Asian Economics,* 4, pp. 493-529

Holz, C. A. (2003) ‘China’s industrial state-owned enterprises: between profitability and bankruptcy’, *World Scientific,* Singapore.

Howitt, P. and Mayer-Foulkes, D. (2005) ‘ R&D, implementation, and stagnation: a

Schumpeterian theory of convergence clubs', *Journal of Money, Credit and Banking,* 37(1), pp.147-177

Howitt, P. (2000) 'Endogenous growth and cross-country differences', *American Economic Review,* 90(4), pp. 829-846

Hu, A.G.Z., Jefferson, G.H. and Qian, J. (2005) 'R&D and technology transfer: firm-level evidence from Chinese industry', *The Review of Economics and Statistics,* 87 (4), pp. 780-786

Hu, M.C., Mathews, J.A., (2008) 'China's national innovative capacity', *Research Policy,* 37, pp.1465–1479

Jalilian, H. and Weiss, J. (1997) 'Bureaucrats, business and economic growth', *Journal of International Development,* 9, pp. 877–885.

Jefferson, G.H. (1998) ' China's state enterprises: public goods, externalities and Coase', *American Economic Review,* 88, pp. 428–432.

Jefferson, G. H. and Su, J. (2006) ' Privatization and Restructuring in China: evidence from shareholding ownership, 1995-2001', *Journal of Comparative Economics*, 34(1), pp. 146-166

Jefferson, G.H., Rawski, T.G., Wang, L. and Zheng, Y. (2000) 'Ownership, productivity change, and financial performance in Chinese industry', *Journal of Comparative Economics,* 28, pp. 786–813

Jefferson, G.H., Rawski, T.G. and Zheng, Y. (1994) 'Productivity change in Chinese industry: a comment', *China Economic Review,* 5, pp. 235–241

Jia, C. (2009) 'The effect of ownership on the prudential behavior of banks – The case of China', *Journal of Banking & Finance,* 33, pp.77–87

Johnson, C. (1982) MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975. Stanford University Press, Stanford

Jones, B. F. and Olken, B. A. (2005) 'Do leaders matter? National leadership and growth since World War II', *Quarterly Journal of Economics,* 120 (3), pp. 835-864

Jones, C. (1995) 'R&D based Models of Economic Growth ', *Journal of Political Economy,* 103(4), pp. 759-784

Jones, C. and Williams, J. (2000) 'Too Much of a Good Thing? The Economics of Investment in R&D', *Journal of Economic Growth*, 5(1), pp.65-85

King, G. R. and Levine, R. (1993) ‘Finance, entrepreneurship and growth theory and evidence’, *Journal of Monetary Economics*, 32(3), pp. 513-542

Knack, S. and Keefer, P. (1995), ‘Institutions and economic performance: cross-country tests using alternative institutional measures’, *Economics and Politics,* 7(3), pp. 207-227

Kneller, R., Morgan, C. W. and Kanchanahatakij, S. (2008) ‘Trade liberalization and economic growth’, *The World Economy,* 31(6), pp. 701-719

Kose, M. A., Prasad, E. S. and Terrones, M. E. (2003) ‘Financial integration and macroeconomic volatility’, *IMF Staff Papers,* 50, pp. 119–142

Kraay, A. (2000) ‘Household Saving in China’, *World Bank Economic Review,* 14(3), pp. 545– 570.

Krieckhaus, J. (2004) ‘The regime debate revisted: a sensitivity analysis of democracy’s economic effect’, *British Journal of Political Science,* 34, pp.635-655

Krugman, P. (2008) *The Return of Depression Economics*, England: Allen Lane.

Kuijs, L. (2005) ‘Investment and Saving in China’, *World Bank Policy Research Working*

Paper 3633

Lai, E. (1998) 'International intellectual property rights protection and the rate of product innovation', *Journal of Development Economics,* 55, pp.133-153

Lall, S. (2001) *Competitiveness, technology and skills*, Cheltenham: Edward Elgar.

Lall, S. (2005) 'Rethinking industrial strategy: The role of the state in the face of globalization' in K. P. Gallagher (ed.), *Putting development first. The importance of policy space in the WTO and IFIs* (pp. 33–68), London and New York: ZED Books.

Lall, S. (2003) 'Foreign direct investment, technology development and competitiveness: Issues and evidence' in S. Lall, & S. Urata (eds.), *Competitiveness, FDI and technological activity in East Asia*, published in association with the World Bank. Cheltenham, UK: Edward Elgar.

Lardy, N. R. (1998) *China's Unfinished Economic Revolution*, Washington D. C: Brookings Institution Press

Lee, P.M. and O'Neill, H.M. (2003) 'Ownership structures and R&D investments of U.S. and Japanese firms: agency and stewardship perspectives', *Academy of Management Journal 46,* pp.212–225.

Levine, R. and Zervos, S. (1998a) 'Stock markets, banks, and economic growth', *American Economic Review*, 32, pp.513-542

Levine, R. and Zervos, S. (1998b) 'Capital control liberalization and stock market development', *World Development,* 26, pp.1169-1184

Levine, R. (1998) 'The legal environment, banks, and long-run economic growth', *Journal of Money, Credit, and Banking,* 30, pp. 596-613

Levine, R. (1999) 'Law, finance, and economic growth', *Journal of Financial Intermediation,* 8, pp.36-67

Levine, R. (2002) 'Bank-based or market-based financial system: which is better?' *Journal of financial intermediation,* 11, pp.398-428

Levine, R., Loayza, N. and Beck, T. (2000) 'Financial intermediation and growth: causality and causes', *Journal of Monetary Economics*, 46, pp.31-77

Lin, J. Y. (1989) 'An Economic Theory of Institutional Change: Induced and Imposed Change', *Cato Journal,* 9, pp.1-33

Lin, J. Y. (1992) 'Rural reforms and agricultural growth in China', *American Economic*

Review, 82(1), pp. 34-51

Lin, J. Y. (2012) Demystifying the Chinese Economy. Cambridge: Cambridge University Press

Lin, J. Y., Cai, F. and Li, Z. (1994) 'China's economic reforms: pointers for other economies in transition?', *Policy Research Working Paper*

Lin, J. Y., Cai, F. and Li, Z. (1998) 'Competition, policy burdens, and state-owned enterprise reform', *American Economic Review,* 89 (2), pp.426-431

Lin, J. Y., Cai, F. and Li, Z. (2003) *The China Miracle: Development Strategy and Economic Reform,* Hong Kong: The Chinese University Press.

Lin, J. Y. and Jeffrey B.N. (1994) 'Institutions and Economic Development', *Handbook of Development Economics*, Volume 3A,Chaper 38, pp.2301-2370

Lin, X. and Zhang, Y. (2009) 'Bank ownership reform and bank performance in China', *Journal of Banking & Finance,* 33, pp.20–29

Liu, H. (2010) *1980s and Chinese Economists,* Guilin: Guangxi Normal University Press.

Liu, X., and White, S.S. (2001) ‘Comparing innovation systems: a framework and application to China’s transitional context’, *Research Policy,* 30, pp.1091–1114.

Lo, D. (1999) ‘Reappraising the performance of China’s state-owned enterprises’, *Cambridge Journal of Economics,* 23, pp. 693–718.

Malthus, T. R. (1817) An essay on the principle of population; or, A view of its past and present effects on human happiness; with an inquiry into our prospects respecting the future removal or mitigation of the evils which it occasions, London: J. Murray.

Marx, K. *Capital .* Translated by Samuel Moore and Edward Aveling. Reprint, Shanghai: Shanghai World Press, 2010

Mondal, D. and Gupta, M.R. (2008) ‘Innovation, imitation and multinationalisation in a North-South model: a theoretical note’, *Journal of Economics,* 94(1), pp.31-62

Motohashi, K. and Yun, X. (2007) ‘ China’s innovation system reform and growing industry and science linkages’, *Research Policy,* 36, pp.1251–1260.

Mukoyama, T. (2003) ‘Innovation, imitation and growth with cumulative technology’, *Journal of Monetary Economics*, 50, pp.361-35

Naughton, B. (1995) *Growing out of the plan: Chinese economic reform, 1978-1993,* New York: Cambridge University Press.

Nolan, P. and Ash, R. F. (1995) 'China's economy on the eve of reform', *The China Quarterly,* 144, pp.980-998

North, D.C. (1990) *Institutions, institutional change and economic performance,* Cambridge University Press

North, D. C. and Robert P. T. (1973) *The Rise of the Western World: A New Economic History,* Cambridge University Press.

Olson, M., (1982) The *Rise and Decline of Nations,* New Haven: Yale University Press.

Parello, C. (2008) 'A north-south model of intellectual property rights protection and skill accumulation', *Journal of Development Economics,* 85, pp.253-281

Park, W. (2008) 'International paten protection: 1960-2005', *Research Policy,* 37, pp.761-766

Paxton, P. (2002) 'Social capital and democracy: an interdependent relationship', *American sociological review,* 67(2), pp.254-277.

Plane, P. (1997) 'Privatization and economic growth: an empirical investigation from a sample of developing market economies', *Applied Economics*, 29, pp. 161-178

Plane, P. (1992) 'Productive efficiency of public enterprises: a macroeconomic analysis based on cross-section estimation of a neoclassical production function', *Applied Economics,* 24, pp.833–844.

Przeworski, A., Limongi, F. (1993) 'Political regimes and economic growth', *Journal of Economic Perspectives,* 7, pp.51–70

Przeworski, A., & Limongi, F. (1997) 'Modernization: Theories and facts', *World Politics,* 49 (2), pp.155-183

Quadrini, V. (1999) 'The Importance of Entrepreneurship for Wealth Concentration and Mobility', *Review of Income and Wealth,* 45(1), pp.1–19

Ram, R. (1986) 'Government size and economic growth: a new framework and some evidence from cross-section and time-series data', *American Economic Review,* 76, pp.191–203

Rawski, T. (1994) 'Progress without privatization: the reform of China's State Industries', in Milor, V. (ed.) *The Political Economy of Privatization and Public Enterprises in Post-Communist and Reforming-Communist States,* Boulder CO: Lynne Rienner, pp. 27-52

Ricardo, D. (1817) *Principles of Political Economy,* London: J. Murray.

Riedel, J, Jin, J. and Gao, J. (2007) *How China Grows: Investment, Finance and Reform.* Princeton, NJ: Princeton University Press.

Rivera-Batiz, L., and Romer, P. (1991) 'Economic Integration and Endogenous Growth', *Quarterly Journal of Economics,* 1991, 106 (2), 531-555

Rodrik, D. (1999) 'Democracies pay higher wages', *Quarterly Journal of Economics,* 114 (3), pp. 707-738

Rodrik, D. and Wacziarg, R. (2005) 'Do democratic Transitions produce bad economic outcomes?, *American Economic Review,* 95 (2), pp. 50-55

Romer, P.M. (1986) 'Increasing returns and long-run growth', *Journal of Political Economy,* 94, pp.1002-1037

Romer,P.M. (1990) 'Endogenous technological change', *Journal of Political Economy*, 98(5), pp.71-102

Romer, P.M. (1994) 'The origins of endogenous growth', *Journal of Economic Perspectives,* 8(1), pp.3–22

Sachs, J and Warner, A. (1995) 'Economic reform and the process of global integration', *Brookings Papers on Economic Activity,* 1, pp.1–118

Sachs, J. and Woo, W. (1997) 'Understanding China's economic performance', *NBER Working Paper,* No.5935

Sachs, J., Zinnes, C. and Eilat, Y. (2000) 'The gains from privatization in transition economies: is "Change of Ownership" enough?, *CAER II Discussion Paper 63*.

Saleh, J. (2004) 'Property rights institutions and investment', *Policy Research Working Paper 3311*

Schwab, S. (1986) 'Is statistical discrimination efficient?', *American Economic Review*, 76 (1), pp. 228–234.

Scully, G.W. (1988) 'The institutional framework and economic development', *Journal of Political Economy,* 96, pp.52-62

Shapiro, C. and Willing, R. (1990) 'Economic rationales for the scope of privatization', in Suleimand, E. N. and Waterbury, J. (eds.) *The Political Economy of Public Sector Reform and Privatization,* London: Westview Press, pp. 55-87

Shleifer, A. and Vishny, R. (1996) 'A theory of privatization', *Economic Journal*, 106, pp.309-319

Smith, A. (1776) *The Wealth of Nations.* Reprint, London: Hi Marketing, 2000

Solow, R.M. (1956) 'A contribution to the theory of economic growth', *The Quarterly Journal of Economics,* 70(1), pp.65-94

Song, Z., Storesletten, K. and Zilibotti, F. (2010) 'The 'Real' Causes of China's Trade Surplus', *VoxEU.org,* http://www.voxeu.org/index.php?q=node/4985.

Song, Z., Storesletten, K. and Zilibotti, F. (2011) 'Growing like China', *American Economic Review,* 101 (1), pp. 196-233(38)

Sun, Q., Tong, J. and Tong, W. H.S. (2002) 'How does government ownership affect firm performance? Evidence from China's privatization experience', *Journal of Business Finance and Accounting,* 29, pp.1–27

Tavares, J. and Wacziarg, R., (2001) 'How democracy affects growth', *European Economic Review*, 45, pp. 1341–1378

Vandenbussche, J., Aghion, P. and Meghir, Costas (2006) 'Growth, distance to frontier and composition of human capital', *Journal of Economic Growth,* 11(2), pp.97-127

Ventura, J. (1997) 'Growth and Interdependence', *Quarterly Journal of Economics,* 112(1), pp. 57–84.

Vickers, J. and Yarrow, G. (1990) *Privatization: an Economic Analysis,* Cambridge: MIT Press.

Wacziarg, R. and Welch, K. H. (2008) 'Trade globalization and growth: new evidence', *World Bank Economic Review,* 22 (2), pp. 187–231.

Weingast, B. (1993) 'The political Foundations of Democracy and the Rule of Law', *IRIS Working Paper 54*

Williamson, J.G. (1991) *Inequality, poverty, and history: The Kuznets memorial lectures of the economic growth center*, *Yale University.* New York: Basil Blackwell.

Woo, W., Hai, W., Jin, Y. and Fan, G. (1994) 'How successful has Chinese enterprise reform been? Pitfalls in opposite biases and focus', *Journal of Comparative Economics,* 18, pp. 410–437

Wu, L. and Yue, H. (2009) 'Corporate tax, capital structure, and the accessibility of bank loans: Evidence from China', *Journal of Banking & Finance,* 33, pp.30-38

Yan, C. and Gong, L. (2009) 'The Schumpeterian growth theory: a survey', *China Economic Quarterly,* 8(3), pp. 1163-1196

Yan, C., Zhou, M. and Gong, L. (2010) ' Knowledge Production, Innovation and the Return to R&D Investment', *China Economic Quarterly,* 9(3), 1051-1070

Yang, B. (2011) 'Political democratization, economic liberalization, and growth volatility', *Journal of Comparative Economics,* 39, pp. 245-259

Yinger, J. (1998) 'Evidence on discrimination in consumer markets', *Journal of Economic Perspectives,* 12 (2), pp. 63–90

Young, A. (1995) 'The tyranny of numbers: confronting the statistical realities of the East Asian growth experience', *The Quarterly Journal of Economics,* pp.641-679

Yusuf, S., Nabeshima, K. and Perkins, D. H. (2006) *Under New Ownership: Privatizing*

China's State-owned Enterprises, Washington D.C and Palo Alto: The World Bank and Stanford University Press.