PhD Research Proposal

An Economic Analysis of the Patent Institution in China

Major Contents of the PhD Research

I. Introduction

Patent institution is generally acknowledged as an effective way to stimulate innovation, facilitate technology dissemination, promote trade, and enhance competitiveness. However, by granting exclusive property rights, patent institution stimulates innovation but may also cause monopoly, which in turn results in the loss of social welfare and may impede the use and development of the patented technologies by others. Therefore, the overall role of the patent system in promoting economic development, especially for developing countries characterized by a generally low technology level, is rather ambiguous and empirical (Boldrin and Levine, 2002; Drahos, 1995, 1999).

Moreover, due to the disparity in technology capabilities and economic strength among nations, it is questionable to apply the same patentability standard to all nations as the current international treaties intend. For example, *the Agreement on Trade Related Aspects of Intellectual Property Rights* (TRIPS) under the World Trade Organization (WTO) has imposed a set of minimum requirements for protection of intellectual property rights including patents, while *the Substantive Patent Law Treaty* (SPLT) under the World Intellectual Property Organization (WIPO), which is still under negotiation, tries to harmonize and unify the patent examination criteria and procedures among its future member countries.

China promulgated its first patent law on 12 March, 1984, not long after it started the economic reform and the opening-up policy in late 1978. Patent filings in China have increased tremendously since 1st April 1985 when the Chinese Patent Law formally came into force, and especially since China's accession to WTO in 2000, with an average annual growth rate over 20%. In 2011, China received 526,412 applications for (invention) patents[1], for the first time overtaking the United States to become the largest recipient of patent applications in the world. In 2012, the patent applications filed in China continued its increase to about 653,000, up 24.0% over the previous year. In recent years, China has also increased its international patent application dramatically, reaching 18,605 and ranking the fourth behind the USA (51,207), Japan (43,660), and Germany (18,855), up 13.6% over the previous year. As the world has entered a knowledge-based era, patent institution is expected to be playing a more and more important role in technological and economic development of China.

Although there is quite a large amount of patent-related economic literature in the world, especially in developed countries, there has been inadequate economic research dealing with the patent institution in China for most patent-related research in China has been done from the legal perspective. This study tries to fill in some of gap in the literature by giving an economic analysis of the patent institution in China. Specifically, this study aims to empirically explore the relationship between patents and innovation inputs (R&D), trade (FDI), and economic or productivity growth by identifying the major determinants of patenting in China and to find how the patent institution in China has influenced technology transfer from advanced economies and promoted economic growth in China from the perspective of economics.

Why is the economic research on patent institution in China important? First, the ultimate purpose of patent institution is to promote economic development through

[1] There are three types of patents in China, namely invention patents, utility model patents, and industrial design patents. Only invention patents are required for substantive examination, equivalent to the definition of patents in most other countries. In this paper, a patent refers to an invention patent, unless it is specified as a utility model or an industrial design.

technological progress. However, there are insufficient studies on how the patent institution promotes economic development especially in China. If without adequate empirical verification done by economic research, the allegation on the positive roles of patent institution in economic development looks rather pale because patent institution might have both positive and negative impacts on a nation's economic development.

Second, an important role of the patent system is to disseminate new technologies and facilitate technology transfer. As Hayami and Godo (2005, p. 349) assert, "Effective borrowing of technologies developed in advanced economies is the key for late starters of industrialization to catch up with early starters". By setting international minimum standards on intellectual property protection through the Agreement on the Trade Related Aspects of Intellectual Property Rights, the WTO has a profound impact on the revision of patent institution in China. Therefore, it is interesting and important to learn how the Chinese patent institution has contributed to the foreign technology transfer to China, especially after its revisions to be in line with the international standards set under the WTO.

Last but not least, patents have long been used as an indicator of innovative activity and technological change in both micro- and macro-economic studies (Griliches, 1990). Eaton and Kortum (1997) argue that the relative constancy of US domestic patenting prior to the late 1980s is consistent with the behaviour of other indicators of technological change, in particular, constant productivity growth and increasing research efforts. It is interesting to check whether China has the same consistency during its rapid economic growth in the last thirty years.

Therefore, there is a strong demand for empirical data, verification of economic theories related to patents, and detailed information on possible impacts that the patent institution might have on economic development in China. The economic reform and development in China have been accompanied by the evolution of the Chinese patent institution, providing a worthy empirical study to check the economic impacts of the patent institution in China.

The remainder of this proposal is structured as follows: Section II provides an overview of relevant economic literature on patents, while Section III discusses some key issues this study tries to explore, following which some preliminary hypotheses and methodologies are raised. In the final section, data source and schedule for data collection are presented.

II. Literature Review

This chapter reviews the economic literature on patents with a view to summarizing findings that will be useful later in analysing the economic impacts of the patent institution in China. In the first part, I focus on theoretic economic studies related to patents by beginning with a brief review of the economic theories behind patent institution and then putting forward the arguments for and against it. Next, I discuss the literature related to optimal patent design to find out the gap between theoretical and real-world design of patent institution. In the second part, I focus on empirical studies related to patents. First, the determinants of the patenting activities are explored including the relationship between innovation inputs and patents and the nexus between patent institution and trade to see how patents have influenced cross-border technology transfer. Next, the relationship between patent institution and economic growth is investigated. Finally, I summarize the current findings in the literature and point out which areas the future research efforts should be devoted to.

1. Theoretical Economic Studies related to Patents

1.1 Economic Theories of Patents

The core economics of patents, also applicable to some other intellectual property rights, is that it is an institution facing the inherent trade-off between encouraging innovation and suffering the consequences of potential monopoly. Like knowledge or information, an invention, can be non-rival and non-excludable in its nature of consumption. The non-rival feature of knowledge implies that the amount of knowledge available to any user does not decrease when others use it, while the non-excludable character of knowledge means that once it is made public, we cannot exclude others from using it unless it is protected by a legal exclusive right. Although an invention sometimes can be excludable by keeping it as a secret, such as the secret recipe of Coca Cola, there is a potential risk that such secrets may be easily discovered through reverse engineering or by other means.

A patent is a right granted by a government to an inventor(s) or its assignee(s) to exclusively make, use and sell the patented invention for a certain period of time in exchange for the public disclosure of the invention. Thus, acquiring a patent for a particular creation of information is an example of making a non-rival and non-excludable good excludable. By granting the exclusive right on a patented invention, the patentee(s) can charge a higher price or enjoy a lower marginal cost while excluding others from doing so.

Since newly invented knowledge has the characteristics of non-excludability and non-rivalry, it is observed that the provision of such goods will be below the socially desired level due to the free-rider problem unless there are some incentives granted by the government. Entrepreneurs that expect profit from research and development (R&D) may not be willing to take risks and invest in such activities since any rewards from doing so may dissipate due to imitation. Under such a context, it is traditionally argued that, perfect competition in the market of knowledge-based products does not allow innovators to recover their innovation costs such as R&D investment (Arrow, 1962). It is called innovation market failure summarized in Martin and Scott (2000) and Colombo and Delmastro (2002), which mainly refers to the phenomenon of underinvestment in innovation from the social standpoint. The patent system is a social institution intended to alleviate the negative impact caused by the innovation market failure by granting patent owners exclusive rights to make, use, and sell their inventions for a certain period of time.

Nonetheless, some scholars argue that there is no general market failure for innovations as in most industries, the cost of invention is low; or just being first in market confers a durable competitive advantage (Moir 2008; Psoner 2012). In addition, the exclusive rights given by the patent law may cause monopoly, which is another sort of market failure. Economic theories indicate that monopoly harms social welfare at least from the static point of view. Although not all patents can cause monopoly, the market power associated with patents may impose social costs, and the potential for abusing the market power inherent in patent grants is considered anticompetitive, even as it encourages invention and commercialization. Accordingly, societies limit the power of patent grants not only in duration and scope, but also in disclosure requirements.

Because of the trade-off nature of patent institution, arguments for and against patents are not new, but still continue. In the early age of establishing patent system, those who were in favour of the patent system believed that it could stimulate inventions and creations at a relatively small social cost (Smith 1776; Bentham 1839), whereas some thought that the patent system was unnecessary because inventions were based on the inspiration of inventors and had little to do with incentives, and even when some inventions were induced by profit incentives, the profits obtained through selling first in the market were large enough to compensate their invention costs (Pigou 1920; Taussig 1915).

The philosophy of patents was developed in response to the use of monopoly power to spur innovation. Adam Smith (1776, pp. 277-278), while generally critical of monopoly power as detrimental to the operation of the 'invisible hand', nonetheless justified the need for limited monopolies to promote innovation and commerce requiring substantial up-front investments and risk. Jeremy Bentham (1839, p. 71) went beyond this justification for patents, providing a clear explication of the differential fixed costs borne by innovators and imitators: [T]hat which one man has invented all the world can imitate. Without the assistance of the laws, the inventor would almost always be driven out of the market by his rival, who finding himself, without any expense, in possession of a discovery which has cost the inventor much time and expense, would be able to deprive him of all his deserved advantages, by selling at a lower price.

This debate may be intensified and complicated under the current context of economic globalization. *The Agreement on Trade-Related Aspects of Intellectual Property Rights* (*TRIPS*) was reached, during the Uruguay Round (1986-1994) of negotiations on the reform of the world trading system, with a view to reducing tensions due to cross-country differences in the treatment of intellectual property rights (IPRs). The *TRIPS* Agreement essentially imposes "minimum" standards on the protection of intellectual property rights to all member economies. For example, the term of patent protection is at least twenty years counted from the filing date and the patentable subject matter covers almost all fields of technology including such areas as pharmaceuticals, agriculture, chemicals, food, and micro organisms where most developing countries used to provide no or little patent protection. Although the countries on the United Nation's list of least developed countries may implement *TRIPS* in respect of pharmaceutical products until January 1st, 2016, extended by the *Doha Declaration*, the standard on IP protection required by *TRIPS* is still rather high for most developing countries.

Under such a context, some argue strongly that intellectual property rights including patents are necessary to stimulate economic growth which, in turn, contributes to poverty reduction. By stimulating invention and development of new technologies, patents will increase agricultural or industrial production, promote domestic and foreign investment in technology research and development, facilitate technology transfer and improve the availability of medicines necessary to combat disease. Others argue equally vehemently the opposite that patents do little to stimulate invention in developing countries, because the necessary human and technical capacity may often be absent. Patents are ineffective at stimulating research to benefit poor people because they will not be able to afford to buy the newly developed products for their high prices. Patents limit the option of technological learning through imitation and allow foreign firms to drive out domestic competition by obtaining patent protection and to service the market through imports, rather than domestic manufacture. Moreover, they increase the costs of essential medicines and agricultural inputs, affecting poor people and farmers particularly badly (UK Commission of IPR, 2002).

Thus, the debate over patents is a heated international issue as the relationship between patent institution and economic development is extremely complex, and the evidence is mixed and insufficient. Generally speaking, the world has been moving towards a stronger and stronger patent system for developed countries as they believe pro-patent strategies are in their interest, while developing countries have little bargaining power on intellectual property issues.

1.2 Optimal Patent Design

To tackle with the trade-off between providing incentives and causing potential monopoly inherent in the patent institution, many economists try to fit patent system with a measurable design of optimal patent length (life) and breadth (scope). Moreover, there seems to be a gap between the theoretical optimal patent design and the real-world patent policy making, which might have been particularly caused by a lack of communication between economic researchers and the patent community, whose members are mainly consisted of engineers and legal professionals, but might also be due to the inability of economists to make their messages operational.

It is commonly recognized that Nordhaus (1969) initiates an analysis of the optimal patent life by modelling the trade-off inherent in the patent institution – an institution that creates static losses by granting innovators temporary monopoly power in order to realize social gains by inducing greater innovative effort. Scherer (1972) gives a geometric reinterpretation of Nordhaus' optimal patent model to make it more straightforward for understanding. In their models, the resolution of this trade-off leads to the economic justification for a finite length of protection. According to their argument, it is better to restrict patent life in order to reduce the associated deadweight loss because usually the longer is the patent protection term, the stronger is the incentive for innovation, but also the monopoly power.

According to Nordhaus (1969) and Scherer (1972), theoretically, differentiated patent protection terms are better than a unified statutory patent life for all types of technologies. However, in reality it is impractical for any government to differentiate which inventions should be given longer or shorter patent life due to asymmetry of information and inherent uncertainty of invention. Moreover, such models are based on some strong assumptions, such as perfectly inelastic supply of inventors, no uncertainty and etc., which are also recognized by Nordhaus (1972) himself in his reply to Scherer's geometric reinterpretation of the optimal patent life model.

Unfortunately, technological change is not an easy process to model, since any realistic model of this process must recognize the uncertainty involved by considering the fact that the processes of invention and diffusion are learning processes, that decisions are made either independently or sequentially, and that externalities play a key role. Moreover, each invention is different with each other in terms of technical improvement and economic contribution. Thus, model builders have inadequate empirical guidelines in many areas, and there is, sometimes, a temptation to build models on the basis of convenient assumptions regardless of whether they are realistic. Nonetheless, Nordhaus' and Scherer's research is a useful step toward better and more complete models, and their efforts unquestionably contribute to the development of economic research in the area of patents.

Following Nordhaus (1969) and Scherer (1972), some economists, such as Gilbert and Shapiro (1990), Klemperer (1990), and Gallini (1992), assume that there is a trade-off between patent length and patent breadth in providing rewards to innovators. They argue that both patent length and breadth determine the extent of patent protection and affect the expected revenues from patenting an invention, but they work in different ways, with different effects on the economic behaviour of patent holder(s) and his competitors. In principle, both longer protection and larger breadth stimulate R&D but increase the deadweight loss. Optimal patent design is obtained by minimizing the discounted value of the deadweight loss created by the patent under the constraint that the discounted profit provides enough incentives to invest. It appears that the optimal design depends heavily on both the retained definition of breadth and the way patent breadth affects deadweight loss.

In reality, there is no trade-off issue between patent length and breadth as governments usually fix a finite patent duration to avoid excessive monopoly power for it is technically and practically difficult to allow different statutory patent length across technologies. Since the design of patent length is relatively clear-cut, while that of patent breadth is rather complex, more research is concentrated on the optimal design of patent breadth in different situations. However, there is a presumption that, under the constraint of the finite and uniform statutory patent life, broad patents may do more bad than good to innovation, as broad patents may distort incentives and allocation of research funds, which may or may not hold in the reality.

Denicolò (1996) re-examines the issue of optimal patent breadth in extending the earlier literature to the case where many firms race for patents on same or similar technologies. Generally speaking, reducing the breadth of a patent leads to more competition in the product market after the innovation. Denicolò (1996) shows that more competition is not always socially desirable since it may involve social costs, like duplication of entry costs, inefficient production, and so on. For example, it is not optimal to award patents of minimum breadth if the additional competition brought about by narrowing the patent is on balance socially costly. Loosely speaking, the less efficient is competition in the product market, the more likely it is that broad and short patents are socially optimal.

The above analysis of optimal patent design only considers patented inventions in isolation, without taking into consideration of the externalities or spillovers that early innovators might confer on later innovators. However, the cumulative nature of research poses problems for optimal patent design since today's innovations are more or less based on early innovations. The aim of optimal patent design in a sequential innovation setting is to increase the rate of innovation. The challenge of optimal patent design is to reward not only early innovators for the technological foundation they provide to later innovators, but also later innovators adequately for their improvements and new products as well. To deal with this challenge, many economists address the issue of sequential innovations, where later innovations build upon the early ones (Scotchmer and Green, 1990; Merges and Nelson, 1990, 1994; Scotchmer, 1991, 1996; Green and Scotchmer, 1995; Chang, 1995; Matutes, Regibeau, and Rockett, 1996; Van Dijk, 1996, O'Donoghue, Scotchmer and Thisse, 1998; O'Donoghue, 1998; Denicolò, 2000; and Denicolò and Zanchettin, 2002).

Scotchmer and Green (1990) point out that the stringency of the novelty requirement in patent law affects the pace of innovation because it affects the amount of technical information that is disclosed among firms. They observe that disclosure of technologies is socially valuable because further research builds on prior arts. Disclosure of technical advances reduces the cost of seeking progress for other researchers. Firms may be reluctant to disclose interim technologies in a multistage race because they cannot profit from the cost reductions provided to competitors. Indeed, these externalities hurt them directly because disclosure of their technical advances may lead them to lose their technical advantage in market competition.

As a consequence, the apparent social value of making the novelty requirement weak – to encourage disclosure of many small increments to technical knowledge – is undermined. However, novelty means new to the world in the case of invention patents, which is rather a requirement to prove the authenticity of an inventor in case that such an invention has been made public somewhere already. By lowering the novelty requirement, for example, from new to the world to new to a nation, it may increase the rate of disclosure of some new technologies in that nation, but it may be unfair since some people may simply copy inventions in other countries in order to obtain patents in their home country.

In reality, the current patent systems in most nations generally adopt the absolute novelty rule, which is new to the world. Thus, the novelty requirement is not a key factor influencing the rate of disclosure of innovations, but the non-obviousness requirement is. Therefore, it is more appropriate to say that patentability requirements including novelty, non-obviousness or an inventive step, and industrial applicability affect the pace of innovation and disclosure of technologies. For example, in general, a weak requirement for non-obviousness may induce more patent applications and thus more disclosure of technologies. However, weak requirements for patentability may also result in more patents with little value for their lower standards on technical improvements.

In addition, Scotchmer and Green (1990) also compare the first-to-invent rule adopted by the United States before 2005, which was changed to the first-to-file rule in 2005, and the first-to-file rule adopted by most other countries. In general, first-to-file engenders more disclosure than first-to-invent, but it also creates excessive incentives for firms to stay in a patent race that may lead to overinvestment of R&D. To summarize, in general, a weaker patentability requirement and first-to-file system may increase the rate of disclosure of new inventions through filing patents and hence speed up the rate of innovation.

As observed by Scotchmer (1991), in markets with cumulative research, patent protection cannot offer both the first and second innovators the full surplus from the second innovation. As a result, some distortion of incentives is unavoidable under a patent system: for at least one firm, the private reward for its innovation will fall short of the social value of that innovation. However, it seems there is no reason why the second innovator must earn the "*entire social surplus*" since there is an incentive for the second innovator to innovate if there is a profit.

Scotchmer (1991) also finds that "*the first innovator's incentive to patent the initial technology depends on: (i) the profitability of marketing the first technology prior to the development of second-generation products; (ii) the extent of disclosure that patenting entails; (iii) the ease with which the technology could be reverse-engineered if marketed but not patented; and (iv) the breadth of patent protection.*" The incentive to file initial patents is especially weak when patent protection is narrow since a second-generation product is then more likely to damage the first innovator's profit.

Scotchmer (1991) investigates the use of cooperative agreements and patent licenses among firms to protect incentives for cumulative research, in particular focusing on how the breadth of patent protection and cooperation among research firms work together in protecting incentives to innovate. The key role of patent protection on how incentives to innovate are protected is that it sets bargaining positions for the prior agreements and licenses that will form, and therefore determines the division of profit in these contracts. According to her analysis, there are no simple conclusions on the optimal patent breadth. It is not necessarily optimal to protect the first innovation so broadly that every derivative or second-generation product infringes, nor so narrowly that a new product never infringes.

While keeping debating whether strong patents are conducive for increasing the rate of innovation, some economists start to emphasize the importance of providing adequate incentives for the first-generation inventions, especially those characterized as basic technologies which can be used in many areas, such as Texas Instrument's microchip, Gould's laser technology, Genentech's technique for inducing bacteria to produce human proteins, and etc. However, this is very controversial. There are mainly two opposite camps on how to balance the incentives for first-generation inventors of initial technologies and second-generation innovators of applied research and development. Green and Scotchmer (1995), Chang (1995), Matutes, Regibeau, and Rockett (1996), and Scotchmer (1996) argue that first-generation inventors of initial technologies should be given strong forward protection so as to overcome the inter-temporal externality that arises when second-generation improvements can be obtained by outsiders. However, broad forward protection may stifle second-generation improvement, affect the accessibility of patented knowledge embedded in the initial inventions, and thus slow down the rate of innovation, as emphasized by Merges and Nelson (1990, 1994) and Heller and Eisenberg (1998).

Green and Scotchmer (1995) show that in markets with sequential innovations, inventors of derivative improvements might undermine the profit of initial innovators through competition. Profit erosion can be mitigated by broadening the first innovator's patent protection scope and/or by permitting cooperative agreements between initial innovators and later innovators. They investigate the policy that is most effective to ensure that the first innovator earns a large share of profit from the second-generation products it facilitates. "*In general, not all the profit can be transferred to the first innovator, and therefore patents should last longer when a sequence of innovations is undertaken by different firms rather being concentrated in one firm.*" However, in reality it is difficult for patent law to provide different statutory patent length across inventions mainly due the asymmetry of information for governments do not have enough information to make such decisions.

By focusing on patent scope instead of patent life, Chang (1995) points out that the decisions made by patent offices and courts on patent scope have important effects on the pace of technological progress and suggests that "*courts should set infringement standards so as to extend the broadest protection not only to a basic invention with a very large stand-alone value relative to all possible subsequent improvements, but also to the patent with very little stand-alone value relative to the improvements that it may inspire.*" However, in reality and in principle, courts should judge the infringement according to the fact and the law whether the accused products or processes infringe the claims of the patent with a precondition that the patent is still valid. Thus, courts seldom compare the values of the original invention and the improvements, nor they will adopt the rule suggested by Chang (1995). Chang (1995) further argues that an inventor would be reluctant to patent a "*stepping-stone*" innovation in the absence of broad protection since others can improve upon the imperfect technology disclosed by the patent and invent around it. "*Thus, broad patent protection would serve the disclosure objectives of the patent system, encourage licensing, and thereby mitigate the winner-take-all aspect of patent races that can induce excessive levels of R&D investment. At the same time, rapid dissemination of new technology increases the probability of quick and successful perfection of the technology. Thus, broad patent protection for inventions with little stand-alone value could promote more efficient R&D investments without reducing the pace of innovation.*" However, he neglects the possibility that broad patent protection may deter the further improvement made by other firms if they have to get licenses from the patent holder, which may exceed the expected profit from improvements. Therefore, there is no straightforward answer whether broad patent protection will achieve such objectives as proposed by Chang (1995).

Matutes, Regibeau and Rockett (1996) concentrate on the patent protection of basic innovations, which can be used in wide areas. They argue that "*in the absence of patent protection, an innovator who has made a significant breakthrough in technologies may delay its disclosure and would be tempted to get a head start in developing the applications of the new discovery before commercializing any product.*" Such a delay in disclosing the basic innovation and hence introducing the first application is socially undesirable both because it postpones the diffusion of the knowledge of the basic innovation and because it withholds desirable products from the market. Their main finding is patent breadth rather than length should be used to induce early disclosure of fundamental innovations while still preserving firm's incentive to do R&D and suggest that broad patent protection should be applied on basic innovations. Although they notice that protecting ideas has traditionally been outside of patent scope because it overly restricts the flow of information necessary to the progress of science, they do not give enough consideration from this perspective. In practice, such basic innovations as a new simplex algorithm or new scientific discoveries are not patentable, but others like the location and purifying of human genes and Genentech's technique for inducing bacteria to produce human proteins are in great controversy for their patentability. One general conclusion we can draw is that different countries with different technological and economic strength may treat differently the tradeoff between promoting the diffusion of knowledge and rewarding innovators. For example, Japan has traditionally had a narrower patent scope than the United States since Japan has a comparative advantage on applied research and development (See Whitener (1990) and Sakakibara and Branstetter (2001)).

Scotchmer (1996) argues that "*patents on second-generation products are not necessary to encourage their development and the patent holder of the basic technology collects a larger share of the profit if applications and other second-generation products are not patentable.*" By denying the patentability of the second-generation products that infringe prior patent, second-generation inventors have less bargaining power in the licensing negotiation with the first patent holder, thus the first patent holder ends up with more profit.

However, the question is how the patent law can treat differently towards the first- and second-generation technologies. The general patentability requirement must be consistent towards all technologies, that is novelty, an inventive step (or non-obviousness) and industrial applicability as required by almost all patent laws in the world. It seems to me that Scotchmer (1996) overemphasizes the importance of providing the incentives to encourage initial inventions. Moreover, she neglects the potential excessive deadweight loss of social welfare caused by strong monopoly power associated with patents on basic technologies. In fact, as I mentioned, most basic research is not patentable such as scientific discoveries or new mathematical formulas, for granting patents on such basic scientific knowledge may cause huge social welfare loss since other people cannot use it for free and may impede the development of technology. One way to solve this dilemma is to let governments fund basic research, while another possibility is to internalize the externality by doing basic research and application under one roof.

On the other side, Merges and Nelson (1990) argue that broad patent scope may increase incentives to invent for some pioneers, but any lessening of the patentee's potential reward by narrowing patent scope may not severely undercut the incentive to invent based on an empirical-historical examination of the course of technical advance in several industries. However, broad patents diminish incentives for others to stay in the invention competition, compared again with a patent whose claims are trimmed more closely to the inventor's actual results. In many industries the efficiency gains from the pioneer's ability to coordinate are likely to be outweighed by the loss of competition for improvements to the basic invention. Merges and Nelson (1990) draw their basic conclusion: "*Without extensively reducing the pioneer's incentives, the law should attempt at the margin to favour a competitive environment for improvements, rather than an environment dominated by the pioneer firm.*"

Merges and Nelson (1994) reemphasize their view that broad and prospect claiming pioneer patents may cut down on the diversity and creativity of the development when their holder try to uphold them in a cumulative research setting. Other parties are often more active or creative than the pioneer patent holder, but are obstructed by the pioneer's broad patent for bargaining about the terms of individual licenses proves to be difficult and fractious. Nor is there reason to believe that more narrowly drawn patents would have damped the incentives of the pioneers and other early comers to the field. Even under a cumulative technology framework, superior design, production, and marketing rather than strong patent protection are the principal source of profit (See Levin, Klevovick, Nelson, and Winter 1987), and an inventor has a natural lead time advantage in incorporating his or her own invention into the product or process. Thus, Merges and Nelson (1994) suggest that patent authorities should provide more consistently strict interpretation on patent scope, especially for basic technologies.

Heller and Eisenberg (1998) show a famous "tragedy of anti-commons" phenomenon in biomedical research. Contrary to the "tragedy of commons" introduced by Garrett Hardin to explain why people overuse shared resources, a proliferation of patents on individual fragments held by different owners in biomedical research suggests a different tragedy, an "anti-commons" in which people underuse scarce resources because too many owners can block each other. Follow-on inventors may be confronted with obstacles raised by previous inventors, in terms of exclusive rights over knowledge or resources they might need to access. More patents may lead paradoxically to fewer useful products for improving human health.

In the real world, patent length is almost statutorily the same, usually 20 years from the filing date for invention patents, across countries and industries as regulated by TRIPS, whereas the terms for patent breadth and height are not commonly recognized by the patent community. For patent breadth, which refers to patent scope in the sense of patent law, in principle, it is determined by claims made in an application and accorded by patent examiners to a patentee, defining the boundaries between what is protected and what is not, and also by the courts' interpretation of these claims where a litigation occurs. In reality, an applicant usually wants to claim as much as he/she can, and then a patent office must decide what claims are allowable. While decisions regarding what to allow are constrained by a number of legal principles, and by the invention itself, in many cases a patent office has considerable room for discretion. Within that discretionary zone, the office must decide which claims should be admitted and which ones pruned back or rejected. After a patent has been issued, a patentee will often allege to a court that her invention has been infringed by competitors. In arguing the case, she will try to demonstrate that the accused infringer's product falls within the boundaries of her invention, as defined in her patent claims, or that any differences between the infringer's device and her invention are insignificant. The challenger, meanwhile, will argue first that the patent is invalid, and second that her invention or product does not infringe the patent – that it is different from the invention claimed by the patentee. Again, the legal principles and objective evidence often leave considerable room for discretion.

Whether an invention can be granted with a patent is closely related to the patentability requirements. In general, according to TRIPS, with some very limited exceptions, "*patents shall be available for any inventions, whether products or processes, in all fields of technology, provided that they are new, involve an inventive step and are capable of industrial application*" (TRIPS, 1994). However, under this general requirement, a national patent law can be flexible in recognizing what inventions can satisfy its standards for novelty, non-obviousness (an inventive step), and industrial applicability. For example, some inventions related to software or business methods are recognized as patents by the United States Patent and Trademark Office, but they may be turned down by the Chinese Patent Office for Chinese patent examiners may interpret such inventions lacking of an inventive step according the Chinese Patent Law. Thus, we can see that patent breadth, or patent scope, is closely related to patentability requirements.

Apparently, patentability requirements are an important and operational instrument for optimal patent design at a national level, but there is a tendency to harmonize the substantive patent laws in the world, which will further limit the discretionary power in patent examination in each nation. To summarize, the analysis of economic literature on optimal patent design suggests that optimal patent policies are more complicated than recognized in the prior literature. Although the gap between the economic research on optimal patent design and the real-world patent policy making is narrowing, some economic arguments are often cast in terms that are not especially helpful for policy makers, based on variables that do not constitute real policy levers. Moreover, empirical economic studies on optimal patent design are still inadequate.

2. Empirical Economic Studies related to Patents

To provide more empirical evidence on the role of patents in economic development, some economists try to empirically test the relationship between patents and R&D, FDI and economic or productivity growth. Economic theories indicate that patents are important incentives to induce private investment in producing new knowledge or knowledge-based products, and patents affect international trade by granting exclusive patent rights on cross-border technologies, and hence patents should have certain impact on a nation's economic growth. Therefore, it is interesting to explore the relationship between patents and innovation inputs (R&D), trade statistics (such as exports and imports and/or FDI), and economic growth indicators (such as TFP). Many economists have made their efforts to provide some empirical evidence on explaining their relationship.

2.1 Patenting Determinants

2.1.1 Innovation and Patents

Pakes and Griliches (1980), Bound et al. (1982), Hausman, Hall, and Griliches (1984), Hall, Griliches, and Hausman (1986) focus on the relationship between patenting and R&D activity at the firm level. They find an interesting phenomenon, which is a persistent significant contemporaneous relationship between the R&D expenditures of firms and the number of patents applied for by them.

Pakes and Griliches (1980) analyze 121 U.S. companies' annual patent data for 8 years (1968-1975) as a function of their current and lagged R&D expenditures. A log-log functional form is used and the "zero value" problem is "solved" by (a) choosing companies so as to minimize this problem (only 8 per cent of the observations were zero in any one year) and (b) setting zeroes equal to one and adding a dummy variable to allow the equation to choose implicitly another value between zero and one. Pakes and Griliches (1980) find that a high fit (R square is almost 0.9) in the full cross-sectional sample and a lower (R square is only 0.3) though still statistically significant fit in the "within" time series dimension of the data. The estimated elasticity is around 1.0 in the cross-sectional dimension, dropping to about 0.5 in the within, shorter-run time dimension. Pakes and Griliches (1980), using the standard fixed effects model, also find evidence of a lag truncation effect in the distributed lag of patents on R&D, that is, when they controlled for permanent differences across firms in the propensity to patent, the estimated coefficient on the last lag of R&D was significantly higher than the coefficients of more recent R&D.

There are some salient aspects of patent and R&D data: (1) the number of patents filed by firms are nonnegative integers and usually have non-negligible probabilities of zero; (2) the data are repeated observations for the same firms over years, thus there are possible separate persistent individual (fixed or random) effects in short panel data. To deal with those problems, Hausman, Hall, and Griliches (1984) continue the work of Pakes and Griliches (1980) by adopting some new functional forms, namely the Possion model and the negative binomial model, and respectively with fixed effects and random effects. In addition, Hausman, Hall and Griliches (1984) also introduce new firm specific variables (log book value and scientific industry dummy) and the log R-time interaction into their various models. They find that the coefficient of current R&D is very close to the sum of the coefficients of lagged R&D and the lagged effects become quite small and difficult to identify when firm specific effects are added, thus they have also tried the above models only including contemporaneous R&D. The estimated contemporaneous elasticity of patenting with respect to R&D ranges from 0.4 to 0.9, the difference of which can be decomposed roughly as follows: size and sector effects about 0.3; lagged R&D effects during the first five years about 0.07; effects of pre-sample R&D about 0.08. In other words, while the "pure" current R&D coefficient is around 0.38, the overall sum is at least 0.53 for the total effect of R&D on subsequent patenting.

Hall, Griliches and Hausman (1986) continue the work in this area by extending the number of firms and years to some extent, but still constrained as a short time series, to see whether there is a significant lagged effect in addition to the strong contemporaneous effect of R&D on patenting found in the earlier research. They take two approaches, a nonlinear least squares specification with additive errors and a Possion or negative binomial model, in obtaining their estimates. Hall, Griliches and Hausman (1986) reaffirm that there does seem to be a rather strong contemporaneous relationship between R&D expenditures and patenting, which does not disappear when they control for the firm size, its permanent patenting policy, or even the effects of its R&D history. The contemporaneous elasticity appears to be about 0.3, which the contribution of the observed R&D history to the current year's patent applications is quite small, about from 0.05 to 0.08 depending on specific models. The contribution of the unobserved or pre-sample R&D appears to be large, about 0.25, and is a possible explanation of the existence of the observed differences across the firms in the propensity to patent. Hall, Griliches and Hausman (1986) also find that the characterization of the pattern of R&D investment within a firm is essentially a random walk with an error variance which is small relative to the total variance of R&D expenditures between firms. In other words, R&D budgets over this short horizon (eight years) are roughly constant or growing slightly and therefore it is difficult to estimate complicated lag structures in the presence of such high multicollinearity. They conclude that there is a strong simultaneity in the year-to-year movements of patents and R&D, indicating that successful research leads both to a patent application and to a commitment of funds for development.

In exploring the relationship between firms' patent applications and their contemporaneous R&D expenditures, Bound et al. (1982) show that the negative binomial model, which is a Poisson-type model with a disturbance, is a preferable choice of econometric specification. Specifically, they find that a much larger output of patents per R&D dollar for the small firms, with a decreasing propensity to patent with size of R&D programs. However, they also note with care that this conclusion is highly tentative both because of its sensitivity to specification and choice of sample and because of the possible bias since they only focus on R&D and patent applications in a single year. Bound et al. (1982) also notice that research and development is done across all manufacturing industries with much higher intensity in such technologically progressive industries as chemicals, drugs, computing equipment, communication equipment, and professional and scientific instruments. They find an elasticity of R&D with respect to sales of close to unity, but they also found significant non-linearity in the relationship, implying that both very small and very large firms are more R&D intensive than average size firms. They also find evidence of complimentarily between capital intensity and R&D intensity, which is increased when they correct for the selectivity of R&D.

The above analysis of the relationship between patenting and R&D assumes that patents are an indicator of the output of R&D rather than the input of R&D. Theoretically speaking, patents should be a fraction of the output of past R&D, usually with 1 or 2 years' lags or even longer, and the fraction may vary considerably over industries and possibly also over time, meanwhile patents may also be an input of R&D

since patent protection may induce firms to invest in R&D. Thus, it is difficult to explain why there is a strong contemporaneous relationship between patent applications and R&D expenditures. One possible explanation is that both patent applications and R&D expenditures are non-stationary time series with a unit root. Hall, Griliches and Hausman (1986) show that R&D expenditures within a firm are highly correlated over time, thus it is difficult to discern the independent contribution of patents to the R&D program in the presence of this noise. Maskus and McDaniel (1999) find a unit root in most patent applications and grant series aggregated at a national level, but they focus on the relationship between patents and TFP growth without measuring R&D expenditures. Suppose patent applications and R&D expenditures at firm level are non-stationary time series with a unit root, the previous estimated results would be seriously biased. In this sense, future research should focus more on time-series characteristics of these two variables.

There are few empirical papers dealing with the incentive role of patents to induce more R&D expenditures. Sakakibara and Branstetter (2001) explore the question whether an expansion of patent scope induces more innovative effort by firms based on the evidence from the 1988 Japanese patent law reform. It is recognized that the 1988 Japanese patent law reform expanded patent protection scope by allowing multiple independent claims under one patent application to replace the single independent claim system adopted before. Sakakibara and Branstetter (2001) find no evidence of an increase in either R&D spending or innovative output that could plausibly be attributed to the patent reform. However, there are some flaws in the paper. First, it is not a good proxy to use year dummies to measure the effect of the change in patent scope on R&D spending since such identification may come from common shifts in a time trend as recognized by the authors themselves. Second, the assumption of constant firm-level research productivity may not be valid since the research productivity may change over time with the development of a firm. Third, the endogeneity problem is mitigated by adopting the fixed-effect model but not fully solved.

Based on the previous research on the relationship between R&D and patenting activities, a few research papers try to identify the determinants on patenting to explain the fast increase of patent applications in many countries such as Kortum and Lerner (1998) and Rafiquzzaman and Whewell (1998).

Kortum and Lerner (1998) consider a function explaining the determinants of patenting. They assume that the level of patenting by the source country *i* in the destination country *n* depends upon three factors: (1) $R_{it,}$ the rate at which the source country generates patentable inventions in year t; (2) X_{ni}, the probability that an invention developed in the source country is applicable in the destination country; and (3) f_{nt}, the propensity to patent, which means the fraction of inventions applicable in the destination country that source country entities choose to patent in the destination country in year *t*. Therefore, the number of patent applications from country *i* for protection in country *n* in year t, or $P_{nit,}$ is:

$$P_{nit} = R_{it} X_{ni} f_{nt},. \qquad (1)$$

Kortum and Lerner (1998) investigate the cause of an unprecedented surge of US patenting from 1985 to 1997 based on three possible hypotheses: first, friendly court hypothesis, that is due to the establishment of the Court of Appeals of the Federal Circuit by Congress in 1982; second, fertile technology hypothesis, that is caused by a widening set of technological opportunities, increased R&D productivity, and changes in the management of R&D facilities; third, regulatory capture hypothesis, that is because patent regulations and policies are reinforced by domestic firms that benefit from the patent protection. Kortum and Lerner (1998) attribute the jump in patenting to the changes in management of research. However, the conclusion may be too absolute for the hypotheses are not mutually exclusive as pointed out by Klenow (1998).

Nonetheless, Kortum and Lerner's study provides an innovative way to analyze patenting patterns into and out of the United States. Following them, the Canadian experience is analyzed by Rafiquzzaman and Whewell (1998), who perform an analysis similar to Kortum and Lerner to identify the determinants on patenting activities in some developed countries from 1978 to 1992. Rafiquzzaman and Whewell find that the research intensity measured by the proportion of workers who are doing research out of the total work force, human capital measured by the average years of schooling of the labor force, market size of the destination country, distance between the source and destination countries, and etc. are statistically significant, indicating that these explanatory variables have some impact on patenting. However, they find that imports are not an important vehicle for technology diffusion and that patenting cost in the destination country does not matter.

Hall and Ziedonis (2001) examine the patenting behaviour of firms in the U.S. semiconductor industry characterized by rapid technological change and cumulative innovation. They find that the propensity of semiconductor firms to patent has risen dramatically since the mid-1980s, however, the survey evidence suggest that semiconductor firms do not rely heavily on patents to appropriate returns to R&D. They explore this apparent paradox by conducting interviews with industry representatives and analysing the patenting behaviour of 95 U.S. semiconductor firms during 1979-1995. The results suggest that the 1980s strengthening of U.S. patent rights has led to the socially wasteful accumulation of defensive patent portfolios.

Hall (2004) looks more closely at the sources of patent growth in the United States since 1984. She finds that: first, the surge of patenting is largely due to U.S. firms, but with some contribution from Asia and Europe; second, the structural shift to a higher growth rate in overall patenting is largely accounted for by firms in the electrical and computing technology sectors, although patenting growth has taken place in all industries. Hall (2004) also finds that in industries based on electrical and mechanical technologies the market value of entrants' patents is positively related to the publicly traded firm value in the post-1984 period (after the patenting surge), but not before, when patents were relatively unimportant in these industries. In addition, the value of patents in complex product industries (where each product relies on many patents held by a number of other firms) is much higher for entrants than incumbents in the post-1984 period. For discrete product industries (where each product relies on only a few patents, and where the importance of patents for appropriablility has traditionally been higher), there is no difference between incumbents and entrants.

Hu and Jefferson (2006) examine what is behind China's recent patent explosion from 1995 to 2001 by focusing on all types of patents filed by large and medium-sized enterprises (LMEs). They adopt a Poisson-based model to explore the reasons of patenting surge in China by including R&D, FDI, labour, industry characteristics, ownership type, and year dummies into their models. They find that the patents-R&D elasticity estimate is significantly positive but relatively small by OECD standard, suggesting R&D intensification in China is one of the primary driving forces of the China's patenting boom but the productivity of R&D in generating patents is lower than their OECD counterparts. They also find that the impact of industry FDI on patenting is large, slightly less important than R&D in explaining the patent explosion. In addition, the pro-patent amendments to China's patent law in 2000, China's entry to the WTO, and the deepening of enterprise reform all partially explain the patent boom from 1995 to 2001 in China.

In general, both economic theories and empirical studies have shown that the patent system is important to stimulate R&D, while more R&D input will usually lead to more patents. Next, how about the effects of the patent system on trade, especially on attracting foreign direct investment and promoting technology spillover? Some economists have been working in this field to explore the relationship between the patent system and trade.

2.1.2 Patents, Trade and Technology Transfer

Generally speaking, patent rights affect international trade flows. If a nation strengthens its patent law, it could experience higher or lower imports for foreign firms may face increasing net demand for their products due to strengthened patent protection, but they may also choose to reduce their sales in this nation’s market because of their greater market power in an imitation-safe environment. Maskus and Penubarti (1995) use an augmented version of the Helpman-Krugman model of monopolistic competition to estimate the effects of patent protection on international trade flows. In their model, deviations of bilateral sectoral imports from anticipated levels are related to income, trade barriers, and patent laws. Patent regulations in the importing country are corrected for endogeneity through the use of instrumental variables. The results of the final equations indicate that increasing patent protection has a positive impact on bilateral manufacturing imports into both small and large developing economies. These results are confirmed by Primo Braga and Fink (1997), whose results for a similar model show that the same positive link between patent protection and trade flows.

Fink and Primo Braga (1999) further provide new evidence regarding the effects of patent protection on international trade. They use a gravity model of bilateral trade flows and estimate the effects of increased patent protection on a cross section of 89 by 88 countries. Their study improves on previous studies in two aspects. First, they estimate the gravity model for two different kinds of aggregates: total non-fuel trade and high-technology trade. Moreover, they address the problem of zero trade flows between countries by adopting a bivariate probit model. Second, to measure the strength of IPR regimes, they use a fine-tuned index on national patent systems developed by Park and Ginarte (1997). Fink and Primo Braga (1999) confirm a positive link between IPR protection and trade flows for the aggregate of non-fuel trade, but do not find a significant positive relationship between patent protection and high-technology trade flows.

Maskus (1997) discusses the role of IPRs in attracting technology flows through FDI and licensing. Multinational enterprises make multifaceted decisions regarding the means by which they can serve foreign markets. Firms may choose simply to export their products to a particular country or region. Alternatively, they may decide to undertake FDI, which requires selecting where to invest, what kind of facilities to invest in, whether to purchase existing operations or construct new plants, which production techniques to pursue, and how large an equity position to take with potential local partners. Firms may prefer a joint venture with some defined share of input costs, technology provision, and profits or losses. Finally, multinational enterprises may opt to license a technology, product, or service, thus leading to complicated issues of bargaining over license fees and royalty payments. These decisions are not made independently, and the outcome depends on a host of complex factors regarding local markets and regulations. IPRs clearly play an important role in those processes, though their importance varies by industry and market structure.

Maskus (1997) summarizes the predicted relationship between IPRs, FDI and technology transfer. First, foreign direct investment (FDI) and technology transfer are relatively insensitive to international differences in IPRs in sectors that have old products and standardized, labour-intensive technologies because FDI is influenced more by factor costs, market sizes, trade costs, and other location advantages than by IP policies in this setting. Second, other things being equal, FDI that represents complex but easily copied technologies is likely to increase as IPRs are strengthened because patents, copyrights, and trademarks increase the value of knowledge-based assets, which may be efficiently exploited through internalized organization. Third, to the extent that stronger IPRs reduce licensing costs, FDI could be displaced over time by efficient licensing. Finally, whatever the mode, the likelihood that the most advanced technologies will be transferred rises with the strength of IPRs.

Patents have some special features distinct with other IPRs in attracting technology transfer. Patents directly facilitate additional information transfer by disclosing the details of inventions in application materials while other IPRs do not provide such detailed technical information. This information then is available for use by local firms to develop follow-on products that do not violate the scope of the original patent. On the one hand, as more countries provide and enforce patents, there should be additional global innovation and patenting, with a positive effect on follow-on innovation. On the other hand, patents could slow down technology diffusion by limiting the use of key technologies through restrictive licensing arrangements. This view of patents has long been held in numerous developing nations and still command widespread respect in some quarters.

In fact, theoretical treatments of the effects of IPRs on technology diffusion in growth models bear mixed messages. In some models, technology is transferred through imitation by firms in developing countries. When the global IPR system is strengthened by the adoption of minimum standards, imitation becomes more difficult as foreign patents are enforced. The rate of imitation declines, and contrary to what might be expected, this decline shows down the global rate of innovation also: if innovative firms expect slower loss of their technological advantages, they can earn higher profits per innovation, reducing the need to engage in R&D (Glass and Saggi 2002; Helpman 1993). However, this result is sensitive to model assumptions and may not hold up to alternative specifications. Indeed, Lai (1998) found that product innovation and technology diffusion are strengthened under tighter IPRs if production is transferred through FDI, rather than through imitation. This result points clearly to the need for developing economies to remove impediments to inward FDI as they strengthen their intellectual property systems. The discussion so has focused on a narrow interpretation of how IPRs interact with incentives for FDI and technology transfer. However, strong IPRs play a much larger role in signalling to potential investors that a particular country recognizes and protects the rights of foreign firms to make strategic business decisions with few government impediments. Because IP protection has taken on increasing importance to multinational enterprises, the adoption of stronger IPR regimes has become a primary device that governments in emerging economies use to indicate a shift toward a more business-friendly environment. The objective is to attract more FDI through this signal, whatever the particular incentives that may be generated in various sectors by stronger IPRs. To date, there is little evidence supporting the responsiveness of investment to this signal, but in emerging economies there is a widespread and growing belief in its importance.

A few studies have included the strength of IPRs in different countries as a potential determinant of FDI and licensing. The theoretical discussion earlier showed that this is essentially an empirical question. Three early studies (Ferrantino 1993; Mansfield 1993; Maskus and Konan 1994) cannot find any relationship between crude measures of intellectual property protection and the international distribution of FDI by U.S. multinational enterprises. These articles suffer from limited specification of models and poor measurements of IPRs. Lee and Mansfield (1996) use survey results to develop an index of weakness of IPRs in destination countries, as perceived by U.S. firms. They find that weakness of IPRs has a significant negative impact on the location of U.S. FDI. Furthermore, in a sample of chemical firms, the proportion of FDI devoted to final production or R&D facilities was negatively and significantly associated with weakness of protection.

Another area in which additional empirical research would be particularly valuable is in tracing the effect of patent reform in developing countries on the relative production levels in FDI-source and FDI-recipient nations. The theoretical work noted above by Glass and Saggi (1995) and Helpman (1993) argued that stronger patent rights in developing countries would restrict imitation there and reinforce profitability of production in industrial countries. As a result, the effect of stronger patents would be to reduce production in the south relative to the north, slowing down the so-called product cycle of international production transfer. However, the article by Lai (1998) finds that if technology were transferred through FDI, stronger patents would accelerate the shift in production from innovative countries to developing countries. Gould and Gruben (1996) perform cross-country growth regressions using data on patent protection, openness of trade regimes, and country-specific characteristics. They find that patent strength is an important determinant of economic growth across countries and that this effect is stronger in relatively open economies. In their preferred specification, estimates suggested that growth induced by IP protection was approximately 0.66 percent higher per year in open economies than it is in closed economies. This finding bears the important implication that, as countries liberalize their trade regimes, simultaneous strengthening of IPRs provides a more affirmative path to economic growth.

Few empirical studies have examined the determinants of patenting in China and its relationship with foreign direct investment. Cheung and Lin (2004) analyse the spillover effects of FDI on innovation in China. They use provincial data from 1995 to 2000 and find positive effects of FDI on the number of domestic patent applications in China. In their model, they also find that R&D input is the most important element in determining patenting and also FDI. They find that a 1% increase in S&T personnel can lead to a 0.56% increase in the number of applications for all patents, and a 1% increase in FDI can lead to a 0.14% increase in the number of applications for all patents. They also check the effects of these explanatory variables for the three types of patents in China respectively, namely invention, utility model and design patents. They find that the spillover effect of FDI is the strongest for minor innovation such as design patents, highlighting a "demonstration effect" of FDI.

2.2 Patents and Economic Growth

A few studies have investigated the impact of IP protection on cross-country economic growth. Gould and Gruben (1996) estimate a growth model on a cross-section of up to 95 countries with data averaged over the period 1960-1988, including an index measuring IP protection strength created by Rapp and Rozek (1990) in their regression. They find IP protection has a significant positive impact on economic growth. Gould and Gruben (1996) examine whether IP protection affects growth in open versus closed economies differently, by interacting their measure of IP protection with three measures of a country's trade orientation. Their results suggest that IP protection can have a slightly larger impact on growth in open economies. Therefore, trade liberalization in combination with stronger intellectual property protection enhances growth because it improves the competitive nature of markets and increases access to foreign technologies.

Thompson and Rushing (1996) estimate cross-section growth regressions including up 112 countries for the period 1970-1985, again using the Rapp and Rozek measure. They employ a switching regression model to examine whether increased IP protection is more beneficial once a country has reached a particular level of development, as measured by initial GDP per capita. Their results indicate a break point at an initial level of $3,400 (1980 U.S. dollars). For countries below this no relationship between IP protection and growth is found, but above it a positive and significant relationship is found. Thompson and Rushing (1999) extend this using a simultaneous equation model by estimating their model on a cross-section of 55 developed and developing countries over the period 1975-1990. The model is a system of three equations with average growth of GDP per capita, the ratio of TFP from 1975 to 1990 and the Rapp and Rozek index as the three dependent variables. They estimate this system for the full sample of countries, but also split the sample in two, depending on initial GDP. The results once again suggest that patent protection only has a positive and significant impact upon TFP for the most advanced countries, with insignificant coefficients found for the full sample and the sample of developing countries.

Park and Ginarte (1997) create an index of patent rights for 110 countries for the period 1960–1990. The index is used to examine what factors or characteristics of economies determine how strongly patent rights will be protected. The evidence does indicate that more developed economies tend to provide stronger protection. But the underlying factors which influence patent protection levels are the country's level of research and development (R&D) activity, market environment, and international integration, which are correlated with its level of development. The results qualify, however, that R&D activity influences patent protection levels after a nation's research sector reaches a critical size. An implication of this is that to raise patent protection levels in weakly protecting countries, it is important to foster a significant research base in those countries and thereby create incentives for protecting patent rights.

Falvey, Foster and Greenaway (2004) investigate the impact of IP protection on economic growth in a panel data of 80 countries using threshold regression analysis. They show that the impact of IP protection on economic growth depends on the level of development, namely IP protection is positively and significantly related to growth for low-income or high-income countries, but not for middle-income countries. They suggest that, while IP protection encourages innovation in high-income countries and technology flows to low-income countries, middle-income countries may have offsetting losses from reduced scope of imitation.

Maskus and McDaniel (1999) investigate empirically how the Japanese patent system has affected post-war growth in Japanese total factor productivity. The post-war Japanese patent system before 1988 has been recognized as a mechanism for promoting technological catch-up and diffusion through incremental innovation. Given certain patent procedures, such as pre-grant disclosure, single-claim requirement, first-to-file, and lengthy pending periods, the Japanese patent system has enabled a channel of technology transfer through the application process. Maskus and McDaniel (1999) find that technology diffusion through utility model applications had a positive impact on

Japan's post-war productivity growth, but their findings are based on Granger-causality analysis, which cannot be used to verify their arguments.

2.3 Summary

The above overview of the economic research on patent system has underlined some practical issues that deserve policy makers' attention, especially for those in developing countries.

First, patent protection is a double-edged sword, with a positive and negative side. Patents are usually effective in stimulating inventions, encouraging disclosure of new technologies, and facilitating market transactions over technologies, but they also generate costs to society because of monopoly and barriers to access and use of knowledge. On the other side, competitive rents, in the absence of patent protection, might be sufficient to compensate innovators in certain circumstances. For instance, when secrecy is a feasible means of protection, or first mover advantages arising from seizing the market are important and the cost of imitation is high, patents may not be necessary to encourage innovation. Thus, an optimal patent system should be in a good balance between private and public interests.

Second, patentability requirements, such as novelty, non-obviousness, and industrial applicability, are important instruments to avoid the grant of unqualified patents that increase the social cost of the patent system. Moreover, they are also effective measures to prevent too broad patent protection scope, which may deter further innovation and improvement.

Third, under the current globalization context, such as TRIPS and other international patent agreements, a nation often has limited leverage in making its own patent law and policy, for instance, the statutory patent life should be at least 20 years and patent protection should cover almost all technologies, such as pharmaceuticals and etc., which may not be in the interests of some developing countries since it blocks the shortcut to successful industrial development by imitation.

Fourth, econometric studies seem to support the theoretical importance of patent institution in promoting trade, attracting FDI, and facilitating technology transfer including imports of goods at least under some conditions. However, the net impact on technology transfer to developing countries under the current international patent framework is still ambiguous and lacks concrete evidence.

Fifth, cross-country analyses seem to show that intellectual property or patent protection has a positive and significant contribution to the economic growth in high-income countries, while for low-income and middle-income countries, the net impact is ambiguous.

Sixth, an optimal national patent system should be in line with the economic and technological development level of the nation. Cross-country analyses seem to show that intellectual property or patent protection has a positive and significant contribution to the economic growth in high-income countries, while for low-income and middle-income countries, the net impact is ambiguous.

Therefore, in reality, the relationship between patents and economic development in developing countries is more complex than that in developed countries. In the short term, developing countries may suffer from being disadvantaged in filing competitive patents, and developed countries may take advantage of their technology advancement in securing their innovation and market power in developing countries. In the long term, it depends on many internal factors of developing countries, such as the size of internal market, domestic enterprises' competitiveness, and their government administration. Nonetheless, they have to learn fast and compete with multinational companies under an international framework that is in favour of stronger technology innovators.

It is necessary and important to empirically examine the economic impacts of the patent system in developing countries at both macro and micro levels. However, regrettably there are still few empirical studies dealing with such issues in developing countries. China, as the largest developing country in the world, has a lot of merits deserving a thorough examination of the interaction between its patent system and economic development. First, China's patent system was established in 1984, not long after the adoption of its economic reform and opening-up policies. Second, China has experienced a fast economic growth and a dramatic increase of patent applications especially since 1999. Third, now China is in its critical transition period of industrial development from the quantity expansion stage to quality improvement stage, thus, the patent system is playing a more and more important role in its economic development. As we can see from this literature review, there are plenty of unsettled patent-related economic research issues, but it is impossible to tackle with all of them in one or two papers. Therefore, the following study is just a start of the long journey. More research effort should be devoted in this area.

III. Economic Analysis of the Patent Institution in China

3.1 What Are the Major Determinants of Patenting in China?

3.1.1 Introduction of the Chinese Patent System

China promulgated the first modern Chinese patent law on 12 March 1984, which came into effect on 1st April 1985. Up to now, the law has been amended three times. The first revision, undertaken in 1992, extended the patent length from 15 to 20 years for invention patents and from 5 to 10 years for patents on utility model and industrial design, expanded patent protection scope to include pharmaceuticals, food and drinks, and chemical products, and adopted some other measures to strengthen patent protection.

The second revision, which was completed in September 2000, eliminated the provisions under the old law that prevented state-owned enterprises from trading their patents in technology markets, introduced new provisions designed to make it more rewarding for employees to innovate, and amended some provisions that were not in line with the WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), such as extending patent protection to offering for sale of patented products. After two revisions, today's patent law in China is pretty much in line with the international standard.

In 2008, the Chinese Patent Law was further revised for the third time. The main points of the third revision include the following: enhancing the threshold of patentability by changing the criteria of novelty from relative novelty to absolute novelty, one of the three factors (novelty, inventiveness and industrial applicability) of patentability in China; providing regulations on the protection of genetic resources;

improving industrial design system; improving the confidentiality examination system for applications to a foreign country; invalidating the designation of foreign-related patent agencies; increasing SIPO's responsibility for the distribution of patent information; endowing the right holders of industrial design the right of offering to sell, introducing a pre-litigation preservation measures, and including the cost of the right holder incurred for stopping the infringing act to the calculation of damage compensation; codifying prior art defence; allowing parallel import; providing exceptions of drug and medical apparatus experimentation; improving the compulsory license system, and so on.

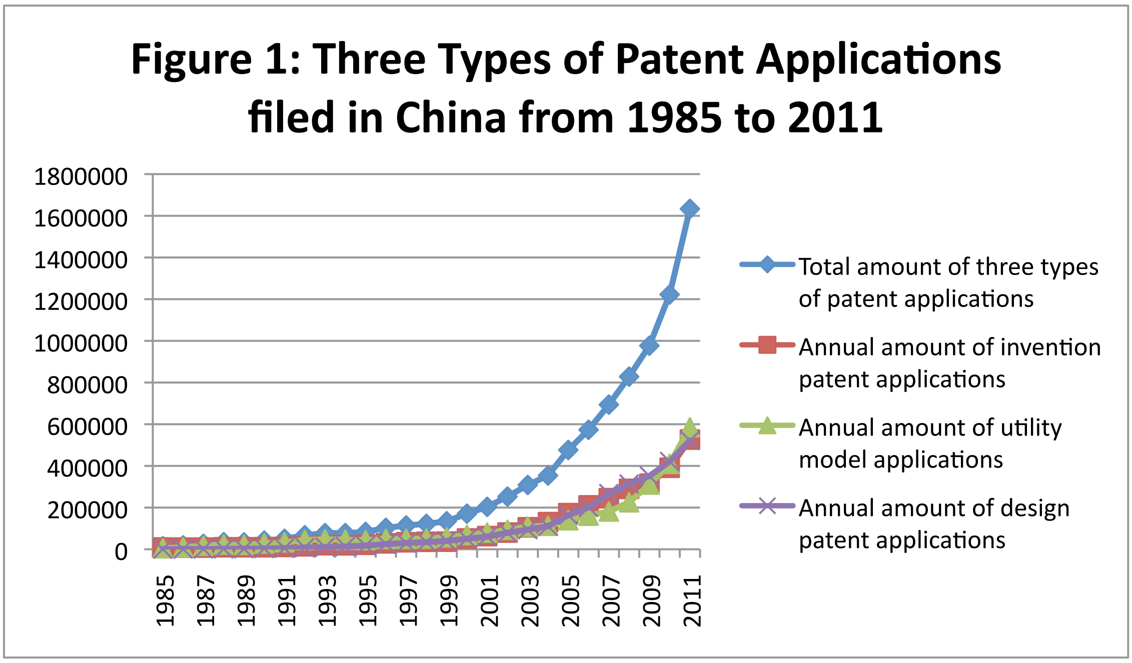
Through the last three revisions, the Chinese Patent Law has been further strengthened towards a pro-patent direction and fully in line with the WTO requirements and standards. In addition, China has also acceded to some other international patent treaties, such as joining the Paris Convention on the Protection of Industrial Property in 1984 and the Patent Cooperation Treaty in 1992.

According to the Chinese Patent Law, there are three types of patents, namely invention, utility model, and design patents. “Invention” in the Chinese Patent Law means any new technical solution relating to a product, a process or improvement thereof. “Utility model” in the Chinese Patent Law means any new technical solution relating to the shape, the structure, or their combination of a product, which is fit for practical use. “Design” in the Chinese Patent Law means any new design of the shape, the pattern or their combination of the colour with shape or pattern, of a product, which creates an aesthetic feeling and is fit for industrial application. However, in most countries, patents only refer to the invention patents in the sense of the Chinese Patent Law. For example, the United States does not have a utility model system, and its utility patents are virtually equivalent to invention patents in the Chinese Patent Law. Some other countries do not treat utility models and designs as patents but rather as independent types of intellectual property rights. According to the Chinese Patent Law, the statutory protection term for invention patents is 20 years from application date, while that for utility models and designs is 10 years from application date.

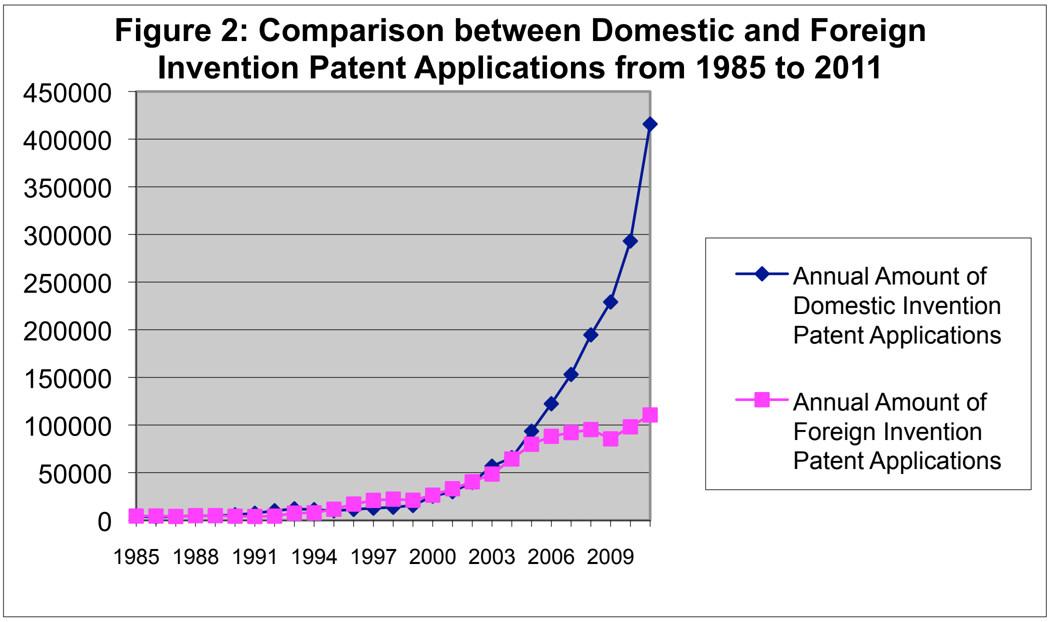
Since the Chinese Patent Law was implemented on April 1, 1985, the number of patent applications, filed at the Chinese Patent Office by both Chinese and foreign entities, has increased tremendously. Especially since 2000, the average annual growth rate has been more than 20%. A question naturally arises as to what is behind the recent explosion of patent applications in China.

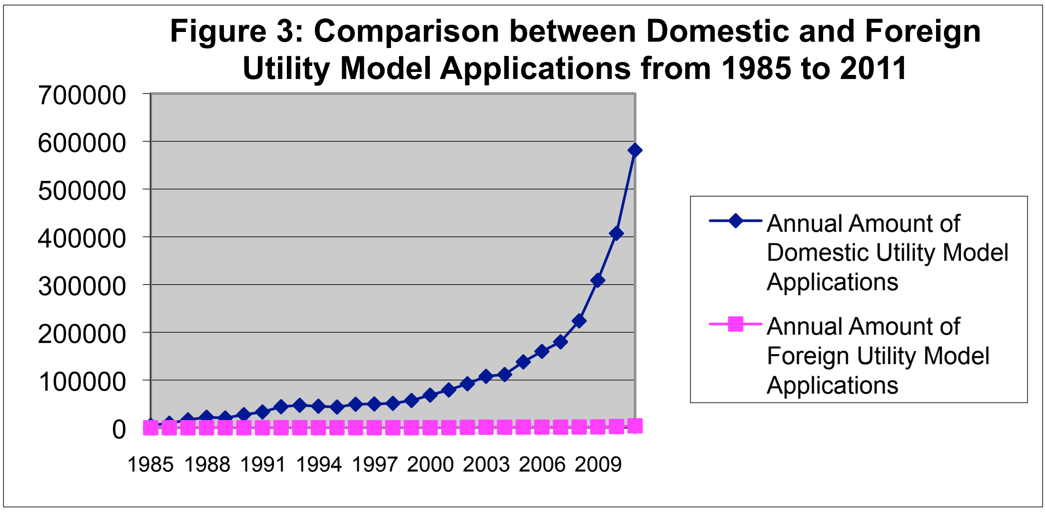
Studying the patent applications in China is important for several reasons. First, patents have long been used as an indicator of innovative activity and technological change in both micro- and macro-economic studies. Second, if the increase in patenting is due to legal changes, for example, a substantially broadened patent protection scope, it is necessary to analyse whether the legal changes affect patent applications significantly. Third, an increase in foreign patenting in China may reflect an increase in innovative activities in foreign countries that spill over into China. Does the increasing foreign direct investment account for this rapid rise in patent applications? Fourth, identifying the determinants for both foreign and domestic patenting may suggest whether further reforms of the Chinese patent system are needed.

Figure 1 shows the change of the annual patent applications for each type of patents from 1985 to 2011. From Figure 1, we can see that since 1999 patent applications have increased more rapidly, with an average increasing rate over 20%.



However, if we distinguish the patent applications by foreign and domestic ones, we can see some different growth patterns for the three types of patents as shown in Figure 2, 3, and 4. From Figure 2, 3, and 4, we can tell that foreign patent applications mainly are inventions, while domestic patent applications are rather balanced in the amount of the three types. Domestic invention patent applications started to increase faster than foreign ones in 1999 and surpass them in 2003.





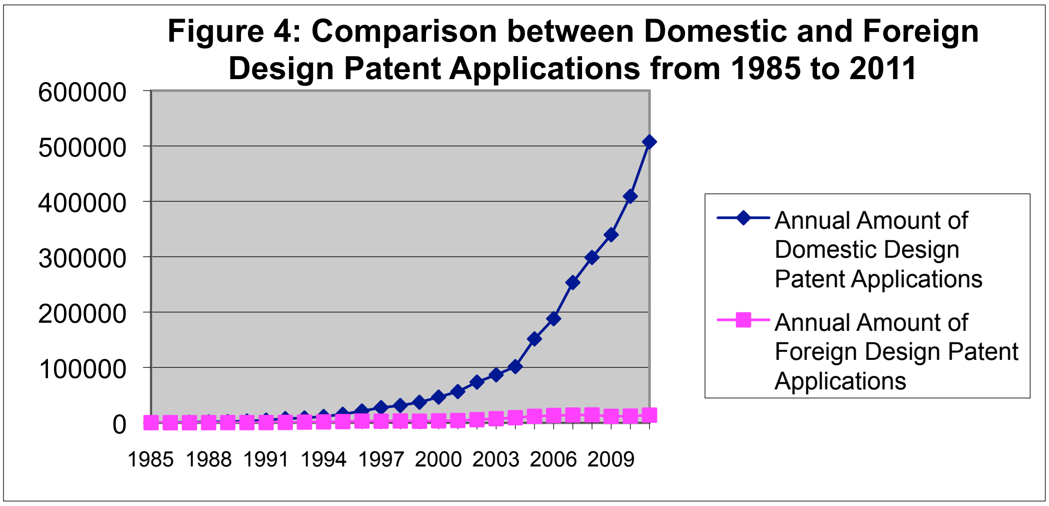
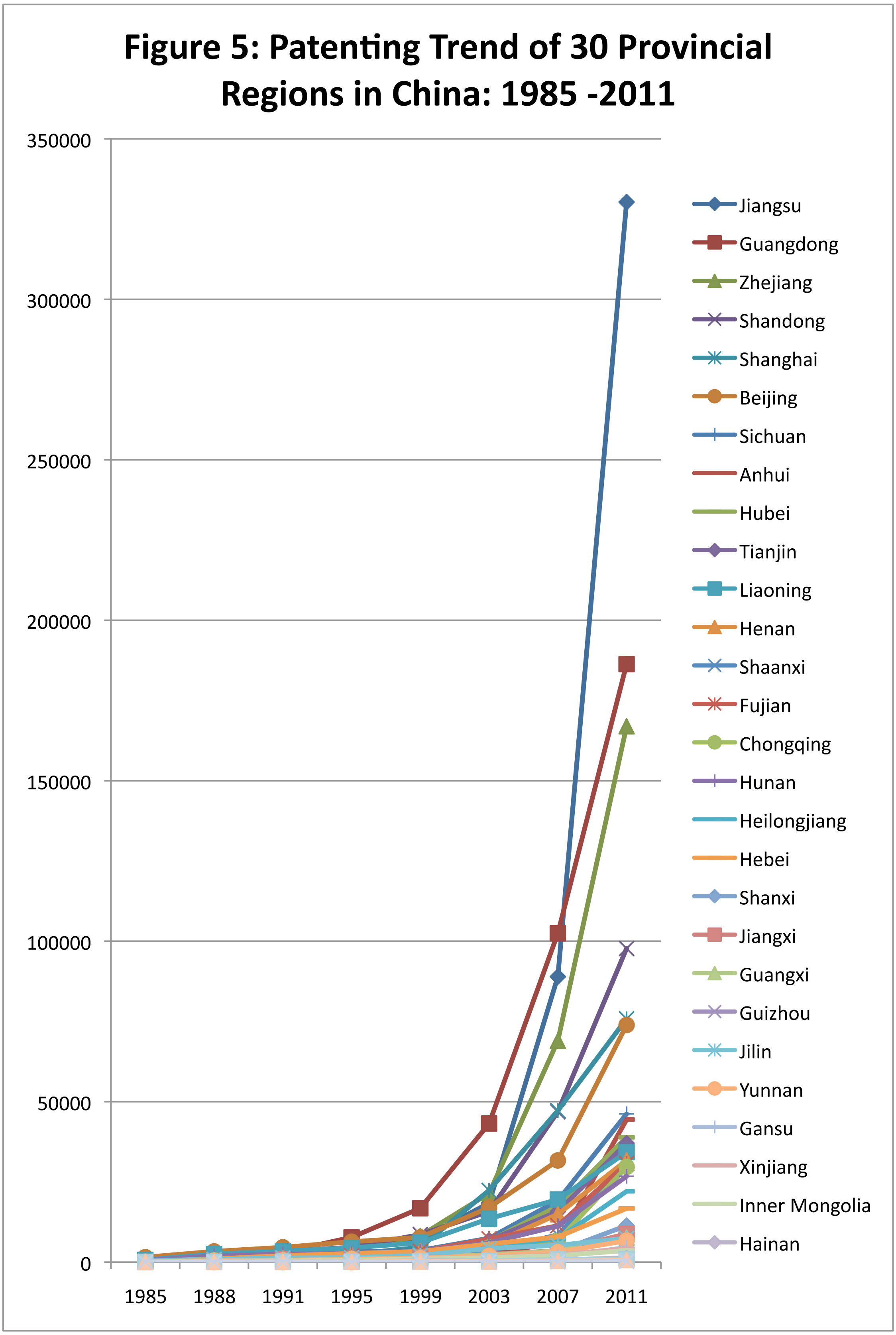


Figure 5 shows the patenting trend of 30 provincial regions in China from 1985 to 2011. We can see that the most applications are filed from coastal regions and they are also the areas where the applications increased most rapidly.



By identifying the features of patent applications filed at the Chinese Patent Office, this study tries to find the factors that account for China's patent boom, empirically explore the relationship between patent applications and innovation inputs and FDI, and the relationship between granted patents and economic or productivity growth, and then provide some policy suggestions accordingly. It can be seen from the above statistical analysis that at the macro level the patent boom can be attributed to two large sources, the one is from domestic applicants, while the other is foreign. Thus, this study will focus on provincial and foreign country level data.

3.1.2 Hypotheses, Approaches, and Expected Results (Part I)

Hypotheses

Based on the above discussions of patent-related literature review and some features of the Chinese patent institution, I postulate the following hypotheses:

$H_{1.1}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 played a significant role in encouraging domestic patent applications filed in China.

$H_{1.2}$: The intensification of R&D in China led to an increase in patentable technologies in China.

$H_{1.3}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 also increased the domestic R&D's propensity to patenting in China.

$H_{1.4}$: International economic integration, particularly the vast inflow of foreign direct investment, raised the stakes for Chinese domestic firms who can use patents as a strategic tool to compete with firms with foreign funds and technologies, suggesting a knowledge spillover effect of inward FDI in China.

$H_{1.5}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 also enhanced the spillover effect of inward FDI, reflected by an increased patenting activity by domestic applicants contributed by inward FDI in China.

$H_{1.6}$: The higher the level of marketization a province has, the larger the patent applications it files.

Approach

Based on the Kortum-Lerner and Rafiquzzaman-Whewell approaches, I assume that the number of patentable inventions generated in province *i* mainly depends upon the R&D input (expenditure or personnel) in that province. The probability of and/or propensity to patenting, that an invention from province *i* will be filed as a domestic patent application in year t, depends on whether there is such an economic and technological necessity to protect this invention in China, which is measured at the provincial aggregate level by the following factors (1) the annual amount of foreign direct investment flowing into province i, (2) each province's marketization level, which is proximately reflected by the market economy intensity index, and also (3) time trend to capture the general trend. To include the above factors, I get the following estimation equation:

$$\ln P_{it} = \alpha_0 + \alpha_1 \ln R\&D_{it} + \alpha_2 \ln FDI_{it} + \alpha_3 Y_1 + \alpha_4 Y_1 \ln R\&D_{it} + \alpha_5 Y_1 \ln FDI_{it}$$

$$+ \alpha_6 Y_2 + \alpha_7 Y_2 \ln RDE_{it} + \alpha_8 Y_2 \ln FDI_{nit} + \alpha_9 Market_{it} + \alpha_{10} T + \mu_{it},$$

(Equation 1)

where $\ln P_{it}$ is the natural log of domestic patent applications from province i in year t; $\ln R\&D_{it}$ is the natural log of the R&D expenditures of a provincial region in year t;

$\ln FDI_{it}$ is the natural log of the realized value of foreign direct investment in provincial region *i* in year t; Y_1 is a dummy variable that equals to 1 if the year t is between 2000 and 2008, and 0 if between 1996 and 1999 or between 2009 and 2012; Y_2 is another dummy variable that equals to 1 if the year t is between 2009 and 2012, and 0 if between 1996 and 2008; $Y\ln R\&D_{it}$ and $Y\ln FDI_{it}$ are interactive variables between year dummy Y and $\ln RDE_{it}$ and between Y and $\ln FDI_{it}$; T is the time trend; and μ_{it} is an error term.

I will try this model on each of the three types of patents and the total. Since this is a pooled cross-section longitudinal dataset, there might be unobserved province-specific components that could correlate with R&D expenditure, FDI, and patenting in China. Thus, it is necessary to check both fixed effect and random effect models and use Hausman test to see which one is more appropriate. In addition, the appropriate lag structure of R&D expenditure and FDI will also be explored during the research.

<u>Expected Outcome</u>

Hypothesis 1.1 implies that the estimated coefficient of dummy Y is positive and significant. Under Hypothesis 1.2 the coefficient of $\ln R\&D_{it}$ is expected to be positive and significant, indicating that the Chinese domestic R&D at the provincial level also plays a very important role in raising patent applications. Hypothesis 1.3 implies that the coefficients of the interactive variable $Y\ln R\&D_{it}$ should be positive and significant. Under Hypothesis 1.4 $\ln FDI_{it}$ is expected to have a positive and significant coefficient, while for this spillover effect may become stronger after the pro-patent amendments of the Chinese Patent Law in 2000 and 2008 as indicated in Hypothesis 1.5, the estimated coefficient of $Y \ln FDI_{it}$ is expected to be positive and significant.

For Hypothesis 1.6, the estimated coefficient of marketization degree is expected to be significantly positive.

It will also be interesting to expect the comparisons among the three types of patents so as to compare the spillover effects of FDI on three types of patents in China. Theoretically speaking, the spillover effect of FDI on design and utility model patents might be larger than that pm invention patents, while the effects of R&D input are stronger for invention and utility model patents than design patents. In addition, I also expect a_{10} to be positive and significant, indicating a general increasing trend of domestic patenting in China.

3.2.2 Hypotheses, Approach, and Expected Results (Part II)

A similar model will be examined to analyse invention patent applications filed by foreign applicants. I postulate the following hypotheses:

$H_{2.1}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 played a significant role in attracting foreign patent applications into China;

$H_{2.2}$: The intensification of R&D in the world led to an increase of patenting in China.

$H_{2.3}$: International economic integration, particularly the vast inflow of foreign direct investment, raised the stakes for foreign firms to protect their patent rights in China.

$H_{2.4}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 also increased the foreign R&D's propensity to patenting in China.

$H_{2.5}$: The pro-patent amendments to the Chinese Patent Law in 2000 and 2008 also increased the inward FDI's propensity to patenting in China.

Approach

Based on the Kortum-Lerner and Rafiquzzaman-Whewell approaches, I denote China as the only destination country (n) and select a random sample of foreign countries (i) filing patents in China. I assume that the rate at which a country produces patentable inventions, R_{it}, mainly depends upon the R&D expenditure, RDE_{it}. The probability of and propensity to patenting, that an invention from country *i* will be filed as a patent application in China in year t, depends on whether there is such an economic and technological necessity to protect their invention in China, which is measured at the national aggregate level by the following factors (1) the annual amount of foreign direct investment from country i into China, (2) the distance between country i and China, (3) and also time trend to capture the general trend. I get:

$$\begin{aligned}\ln\text{P}_{nit} = {} & \beta_0 + \beta_1 \ln\text{RDE}_{it} + \beta_2 \ln\text{FDI}_{nit} + \beta_3 \text{DIS}_{ni} + \beta_4 \text{DIS2}_{ni} + \beta_5 \text{Y}_1 + \beta_6 \text{Y}_2 + \beta_7 \text{T} + \\ & \beta_8 \text{Y}_1 \ln\text{RDE}_{it} + \beta_9 \text{Y}_1 \ln\text{FDI}_{nit} + \beta_{10} \text{Y}_2 \ln\text{RDE}_{it} + \beta_{11} \text{Y}_2 \ln\text{FDI}_{nit} + \mu_{nit},\end{aligned}$$

(Equation 2)

where $\ln\text{P}_{nit}$ is the natural log of patent applications from a source country to China in year t; $\ln\text{RDE}_{it}$ is the natural log of the R&D expenditure of a source country in year t; $\ln\text{FDI}_{nit}$ is the natural log of the foreign direct investment from country i into China in year t; DIS_{ni} is the distance in kilometres from Beijing, the capital of China, to other countries' capitals, while $\text{DIS2}_{ni} = (\text{DIS}_{ni} - \text{mean of DIS}_{ni})$^2; Y_1 is a dummy variable that equals to 1 if the year t is between 2000 and 2008, and 0 if between 1996 and 1999 or between 2009 and 2012; Y_2 is another dummy variable that equals to 1 if the year t is between 2009 and 2012, and 0 if between 1996 and 2008; $YlnRDE_{it}$ and $YlnFDI_{nit}$ are multiplicative variables between year dummy Y and $lnRDE_{it}$ and between Y and $lnFDI_{nit}$. D is another dummy that equals to 1 if the source country is a developed country, and 0 if a developing country; T is the time trend; and μ_{nit} is an error term.

As R&D and FDI have lagged effect on patenting, it may be more reasonable to use stock form of R&D and FDI in empirical research. I estimate stock of R&D and FDI by perpetual inventory method. Or I can use flow form of annual data of R&D and FDI in empirical research, but we seek to capture the lagged effect of R&D and FDI on patenting by adding lag structure of R&D and FDI in equation (1). As the maximum lagged effect of R&D many scholars consider is 4 years, we examine the impact of R&D and FDI on patenting from 0~4 years lagged from the year of application.

Since this is a pooled cross-section longitudinal dataset, there might be unobserved country-specific components that could correlate with R&D expenditure, FDI, and patenting in China. Thus, it is necessary to check both a fixed effect and random effect model and use Hausman test to see which one is more appropriate. In addition, the appropriate lag structure of R&D expenditure and FDI will be explored during the research.

Expected Results

Hypothesis 2.1 implies that the estimated coefficients of dummy Y should be positive and significant. Under Hypothesis 2.2 the coefficient of $lnRDE_{it}$ is expected to be positive and significant, indicating that the R&D level plays a very important role in raising patent applications. Moreover, I also expect that the coefficients of YlnRDE_{it} are positive and significant, verifying Hypothesis 2.3 that the pro-patent amendments reinforced the productivity of R&D intensification in terms of an increased R&D propensity to patenting. Hypothesis 2.44 implies that lnFDI_{nit} has a positive coefficient, while the coefficients of YlnFDI_{nit} are also expected positive and significant, indicating Hypothesis 2.5 that after the pro-patent revisions in 2000 and 2009 inward FDI has a higher propensity to patenting.

In addition, I also expect β_3 to be negative and significant, showing that technological diffusion between countries falls as the distance between them increases but β_4 is expected to be positive, together with β_3, indicating an increase in the distance between countries decreases the technology diffusion at a diminishing rate.

3.2 Measuring the Contribution of Patents to Economic Growth

China has kept a fast economic growth pace since the economic reform started in late 1978. One of the areas that the Chinese economy differs from the other emerging economies is the rapid rise of the Chinese total factor productivity (TFP). However, some studies find that capital input and labour input are the main factors driving China's fast economic growth, while the contribution of TFP (total factor productivity) is relative limited (e.g. Madisson, 1998; Chow and Li, 2002; Zheng et al., 2009). To achieve continuous high GDP growth, China will in the longer run have to rely more on TFP growth and less on capital deepening than in recent years. Moreover, some recent studies indicate that the contribution of TFP to China's economic growth after mid-1990s is lower than that during the period 1978 to mid-1990s (Zheng and Hu, 2006; Zheng et al., 2009). Therefore, China should transform the extensive economy growth mode to maintain economy growth continuously in the future.

Endogenous economic growth theory shows that enhancing knowledge stock is very important for continuous economic growth (Rome, 1986; Lucas, 1988), and innovation and human capital are the core factors affecting TFP. In recent years, many scholars have done empirical studies to examine the effect of innovation on TFP, but most focus on the effect of R&D input and “spillover” (Coe and Helpman, 1995; Verspagen, 1995; Hu and Jefferson, 2004; Zhou and Xia, 2010). However, Crépon et al. (1998) point out the factor directly affecting productivity is innovation output (new invention and new knowledge such as patent) rather than innovation input, which indicates that if innovation output cannot be well transformed into real productive force, the role of innovation input will not be adequately played. Therefore, I seek to capture the effect of patents on the TFP of China.

As Figure 1 shows that the number of China’s domestic patent applications has increased rapidly since 1999. The amount of total patent applications increased from 109,958 in 1999 to 1,504,670 in 2011, with an average annual growth rate of 22%, indicating that China’s national innovation capacity has increased very fast since 1999. However, the proportion of China’s domestic invention patents which are thought to have much higher quality and potential economic value than utility model patents and design patents was always less than 30%, and the share of foreign-resident’s invention patents in china mainly owned by OECD countries was 86% during the period 1988-2009. This phenomenon suggests that though China’s total domestic patents enhance sharply recently, the quality of which is still not high.

As we know, there exists obvious gap of economic development and industrialization level between coastal China and inner China. In fact, the innovation diversity between these two regions is also very significant. I find that coastal regions in China have possessed about 80% of China's total domestic patent applications during 1996~2011, indicating that patenting activity of China highly clusters in the coastal regions. These data descriptions suggest that coastal China and inner China are at different development stage.

Based on the feature of China's domestic patents and economy development discussed above, I concentrate on following issues: How have the patents in China affected its TFP? How have different kinds of patents affected TFP? Is the effect of Chinese domestic patents various between coastal China and inner China? Does patents' effect differ in various development stage of China?

3.2.1 Model

I use Cobb-Douglas production function to calculate the TFP of China. Under the hypothesis of constant return to scale, the model can be expressed as follows:

$$Y_{it} = A_{it} K_{it}^{a} L_{it}^{1-a} \qquad (3),$$

where *Y* is gross economic output; *K* is capital stock; *L* is labour input; *A* is TFP; *i* denotes a provincial region; *t* denotes time. Following the research of Solow (1957), we can express A_{it} as equation (4):

$$A_{it} = A_{i0}\, e^{bt} \qquad (4).$$

By corresponding mathematics transformations, we can easily get an estimation equation:

$$Ln(Y_{it}/L_{it}) = LnA_{i0} + bt + aLn(K_{it}/L_{it}) + \varepsilon_{it} \qquad (5).$$

I can estimate capital output elasticity coefficient, a, in equation (5) based on the panel data of 30 provinces in China from 1996 to 2011, and then calculate TFP of each province by the transformation of equation (3): $A_{it} = Y_{it} / (K_{it}^{a} L_{it}^{1-a})$.

As TFP may be influenced by many factors such as technology progress, management innovation and structural upgrade, it is difficult to include all the affecting factors. Considering the reality of China's economy, I select human capital, industry structure, openness degree, private economy degree as the key control variables. I can get the empirical model as in equation (6):

$$TFP_{it} = \beta_0 + \beta_1 HC_{it} + \beta_2 IS_{it} + \beta_3 PE_{it} + \beta_4 M_{it} + \beta_5 IP_{it} + \beta_6 UP_{it} + \beta_7 DP_{it} + \varepsilon_{it} \quad (6),$$

where *HC* is human capital; *IS* is industry structure; *PE* is private economy degree; *M* is marketization degree; *IP* is the number of invention patents; *UD* is the amount of utility model patents; and DP is the number of design patents. As patents might have lagged effect on TFP, it may be more reasonable to use stock form of patents in empirical research. However, the patent data of stock form is not available. Meanwhile, it is different for us to estimate patent stock accurately by perpetual inventory method in selecting depreciation ratio for great quality discrepancy among three kinds of Chinese patents. Therefore, i still use flow form of annual data in empirical research, but I seek to capture the lagged effect of patents on TFP by adding lag structure of patents in equation (6). As the maximum lagged effect of patents many scholars consider is 4 years (Ernst, 2001), we examine the impact of China's domestic patents on TFP from 0~4 years lagged from the year of authorisation.

3.2.2 Expected Results

It is expected to find that patents have a significant positive effect on China's TFP, and hence on economic growth. I also expect to find that the impact of invention patents on economic growth is larger than that of utility model and design patents, which is reflected by β_5 is significantly larger than β_6 and β_7.

3.3 Data Source and Schedule of Data Collection

The sample in my empirical study includes 30 provincial regions in Mainland China. The statistical data of all variables can be obtained from China Statistical Yearbook, statistical yearbook of each province, China Science and Technology Statistical Yearbook and China Patent Statistical Yearbook. For example, data on the annual invention patent applications originating from a sample of countries and filed in China from 1996 to 2012 can be collected from the Yearbooks of the State Intellectual Property Office of China. The data on annual R&D expenditure at country level from 1996 to 2012 can be collected from the World Development Indicators 2013, while the provincial R&D data can be obtained from the China statistics yearbooks. The data on the annual foreign direct investment (FDI) from a source country to China from 1992 to 2012 can be collected from China's Statistical Year Books, which is measured in nominal US$. The data on R&D expenditures and FDI can be further transformed to real terms and calculated into stock number using perpetual stock method.

Next, I will start to collect relevant data and plan a fieldwork in China to further collect other necessary data from mid-June to mid-July for about one month. I expect to finish data collection for the first two macro-level studies by the end of July 2013. By the first half of 2014, I plan to finish all the data collection work and finish the drafting of the first two core research papers as well.

References

Bound, J, Cummins, C, Griliches, Z, Hall, BH, and Jaffe, A 1982, 'Who does R&D and who patents?', NBER Working Paper No. 908.

Chang, H 1995, 'Patent scope, antitrust policy, and cumulative innovation', *RAND Journal of Economics*, vol. 26, no. 1, pp. 34-57.

Cheung, KY and Lin, P 2004, 'Spillover effects of FDI on innovation in China: evidence from the provincial data', *China Economic Review*, vol. 15, no. 1, pp. 25-44.

Chow, G. C. and Li, K-W. 2002, 'China's economic growth: 1952-2010', *Economic Development and Cultural Change*, 51, pp.247-256.

Coe, D.T. and Helpman, E. 1995, 'International R&D spillover', *European Economic Review*, vol. 39, pp.859-887.

Cornelli, F and Schankerman, M 1999, 'Patent rewards and R&D incentives', *Rand Journal of Economics*, vol. 30, no. 2, pp. 197-213.

Crépon, B., Duguet, E. and Mairesse, J. 1998, 'Research and development, innovation, and productivity: an econometric analysis at the firm level', *Economic of Innovation and New Techenology*, vol. 7, pp. 115-158.

Denicolò, V 1996, 'Patent races and optimal patent breadth and length', *Journal of Industrial Economics*, vol. 44, no. 3, pp. 249-265.

Falvey, R, Foster, N and Greenaway, D 2004, 'Intellectual property rights and economic growth', *Internationalisation of Economic Policy*, Research Paper.

Fink, C and Primo Braga, CA 1999, 'How stronger protection of intellectual property rights affects international trade flows', World Bank Working Paper No. 2051, the World Bank, Washington, DC.

Gallini, N 1992, 'Patent Policy and Costly Innovation', *RAND Journal of Economics*, vol. 23, no. 1, pp. 52-63.

Gilbert, R and Shapiro, C 1990, 'Optimal Patent Length and Breadth', *RAND Journal of Economics*, vol. 21, no. 1, pp. 106-112.

Gould, DM and Gruben, WC 1996, 'The role of intellectual property rights in economic growth', *Journal of Economic Development*, vol. 48, pp. 323-350.

Green, J and Scotchmer, S 1995, 'On the division of profits in sequential innovation', *RAND Journal of Economics*, vol. 26, no. 1, pp. 20-33.

Hall, BH and Ziedonis, RH 2001, 'The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995', *RAND Journal of Economics*, vol. 32, no. 1, pp. 101-128.

Hall, B H 2004, 'Exploring the patent explosion', NBER Working Paper No. 10605.

Hall, BH, Griliches, Z and Hausman, JA 1986, 'Patents and R&D: is there a lag?', *International Economic Review*, vol. 27, no. 2, pp. 265-283.

Hausman, JA, Hall, BH and Griliches, Z 1984, 'Econometric models for count data with an application to the patents – R&D relationship', *Econometrica*, vol. 52, no. 4, pp. 909-938.

Heller, M and Eisenberg, R 1998, 'Can patents deter innovation? The anticommons in biomedical research', *Science*, vol. 280, pp. 698-701.

Helpman, E 1993, 'Innovation, imitation, and intellectual property rights', *Econometrica*, vol. 61, no. 6, pp. 1247-1280.

Hu, G. A., Jefferson, G. 2004, 'Returns to research and development in Chinese industry: Evidence from state-owned enterprises in Beijing', *China Economic Review*, vol. 15, pp.86-107.

Klemperer, P 1990, 'How broad should the scope of patent protection be?', *RAND Journal of Economics*, vol. 21, no. 1, pp. 113-130.

Kortum, S and Lerner, J 1997, 'Stronger protection or technological revolution: what is behind the recent surge in patenting?', NBER Working Paper No. 6204.

Lanjouw, OJ, Pakes, AS and Putnam, J 1998, 'How to count patents and value intellectual property: the uses of patent renewal and application data', *Journal of Industrial Economics*, vol. 46, no. 4, pp. 405-432.

Lerner, J 1994, 'The importance of patent scope: an empirical analysis', *RAND Journal of Economics*, vol. 25, no. 2, pp. 319-333.

Lucas, R. E. Jr. 1988, 'On the mechanics of economic development', *Journal of Monetary Economies*, vol. 22, pp. 3-42.

Maddison, A.1998, 'Chinese economic performance in the long run'. OECD Publishing, Paris.

Maskus, KE 1997, 'The role of intellectual property rights in encouraging foreign direct investment and technology transfer', paper prepared for the Conference titled "Public-Private Initiatives After TRIPS: Designing a Global Agenda", Brussels, 16-19 July.

Maskus, KE and Penubarti, M 1995, 'How trade-related are intellectual property rights?', *Journal of International Economics*, vol. 39, pp. 227-248.

Maskus, KE and McDaniel, C 1999, 'Impact of the Japanese patent system on productivity growth', *Japan and the World Economy*, vol. 11, pp. 557-574.

Matutes, C, Regibeau, P and Rockett, K 1996, 'Optimal patent design and the diffusion of innovations', *RAND Journal of Economics*, vol. 27, no. 1, pp. 60-83.

Merges, R and Nelson, R 1990, 'On the Complex Economics of Patent Scope', *Columbia Law Review*, vol. 90, no. 4, pp. 839-916.

Merges, R and Nelson, R 1994, 'On limiting or encouraging rivalry in technical progress: the effect of patent scope decisions', *Journal of Economic Behaviour and Organization*, vol. 25, pp. 1-24.

Nordhaus, W 1969, *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change.* Cambridge, MA: MIT Press.

Nordhaus, W 1972, 'The optimal life of a patent: reply', *American Economic Review*, vol. 62, no. 3, pp. 428-431.

Pakes, AS and Schankerman, M 1984, ‘The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources’, in Z. Griliches (ed.), *R&D, Patents and Productivity*, Chicago: University of Chicago Press,.

Pakes, AS 1986, ‘Patents as options: some estimates of the value of holding European patent stocks’, *Econometrica*, vol. 54, pp. 755-784.

Pakes, AS and Griliches, Z 1984, ‘Patents and R&D at the firm level: a first look”, National Bureau of Economic Research Working Paper No. 561, in Z Griliches (ed.), *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, pp. 55-72.

Pakes, AS and Simpson, M 1989, ‘Patent renewal data’, *Brookings Papers on Economic Activity: Microeconomics*, pp. 331-410.

Park, WG and Ginarte, JC 1997, ‘Determinants of patent rights: a cross-national study’, *Research Policy*, vol. 26, pp. 283-301.

Rafiquzzaman, M and Whewell, L 1998, ‘Recent jumps in patenting activities: comparative innovative performance of major industrial countries, patterns and explanations’, NBER Working Paper No. 27.

Rapp, RT and Rozek, RP 1990, ‘Benefits and costs of intellectual property protection in developing countries’, *Journal of World Trade*, vol. 24, no. 5, pp. 75-102.

Romer, P. M.1986, ‘Increasing returns and long-run growth’, *Journal of Political Economy*, vol. 94, pp.1002-1037.

Sakakibara, M and Lee, B 2001, 'Do stronger patents induce more innovation? Evidence from the 1988 Japanese Patent Law reforms', *RAND Journal of Economics*, vol. 32, no. 1, pp. 77-100.

Schankerman, M 1998, 'How valuable is patent protection? Estimates by technology field', *RAND Journal of Economics*, vol. 29, no. 1, pp. 77-107.

Scherer, FM 1972, 'Nordhaus' theory of optimal patent life: a geometric reinterpretation', *American Economic Review*, vol. 62, no. 3, pp. 422-427.

Scotchmer, S and Green, J 1990, 'Novelty and disclosure in patent law', *Rand Journal of Economics*, vol. 21, no. 1, pp. 131-146.

Scotchmer, S 1991, 'Standing on the shoulders of giants: cumulative research and the patent law', *Journal of Economic Perspective*, vol. 5, no. 1, pp. 29-41.

Scotchmer, S 1996, 'Protecting early innovators: should second generation products be patentable?', *RAND Journal of Economics*, vol. 27, no. 2, pp. 322-331.

Scotchmer, S 1999, 'On the optimality of the patent renewal system', *Rand Journal of Economics*, vol. 30, no. 2, pp. 181-196.

Tandon, P 1982, 'Optimal patents with compulsory licensing', *Journal of Political Economy*, vol. 90, no. 3, pp. 470-486.

Thompson, MA and Rushing, FW 1999, 'An empirical analysis of the impact of patent protection on economic growth: an extension', *Journal of Economic Development*, vol. 24, no. 1, pp. .

Verspagen, B. 1995, 'R&D and productivity: A broad cross-section cross-country look', *Journal of Productivity Analysis*, vol. 6, pp.117-135.

Zheng, J., Bigsten A. and Hu, A. 2009, 'Can China's growth be sustained? A productivity perspective', *World Development*, vol. 37, pp. 874-888.

Zheng, J. and Hu, A. 2006, 'An empirical analysis of provincial productivity in China (1979-2001)', *Journal of Chinese Economic and Business Studies*, vol. 4, pp. 221-239.

Zhou, L. and Xia, L. 2010, 'How R&D investments influence TFP growth: Evidence from China's large and medium-sized industrial enterprises', *Frontiers of Economics in China*, vol. 5, pp.537-558.