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ICT and the Developing Countries: Implementing Trade-Related Aspects of Intellectual Property Rights

Jin GUO
ehi14jgu@student.lu.se

Abstract: This study utilizes a panel data of 69 developing and developed countries to analyze the impacts of Trade-Related Aspects of Intellectual Property Rights (TRIPS) on the innovation outcomes of the Information and Communication Technology (ICT) sector. The panel analysis is assisted with detailed observations on successful cases that have achieved impressive innovation outcomes over the years, in order to provide a more comprehensive discussion on the issue. The TRIPS Agreement has been promoted as the key to stimulating innovations in the developing countries. However, there have been disputes on TRIPS around a number of issues, including the inequality between developed and developing countries, as well as a mismatch between the strict regulations of TRIPS and the need of developing countries to have a flexible intellectual property right (IPR) environment. Results from this study suggest that IPRs are not a significant factor on innovation outcomes in the ICT sector for the developing countries. Combined with experience from successful cases, evidence suggests that developing countries should be empowered to tailor IPRs according to their specific needs.

Key words: TRIPS, ICT, innovation, economic development, developing countries

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1. Introduction

The topic of the thesis is the impacts of Trade-Related Aspects of Intellectual Property Rights (TRIPS) on the Information and Communication Technology (ICT) sector. Particularly, the thesis is interested in whether the impacts are different on the least developed, developing and developed countries. The TRIPS Agreement has been promoted as a method to transform economies of developing countries through encouraging IPR-protected innovations. The World Trade Organization (WTO) explicitly states that despite the basic principles, such as national treatment and most-favored-nation, one of the important principle of TRIPS Agreement is that "intellectual property protection should contribute to technical innovation and the transfer of technology. Both producers and users should benefit, and economic and social welfare should be enhanced" (WTO, Intellectual Property: protection and enforcement). Based on a panel data of innovation outcome in the ICT sector of both developing and developed countries, the paper aims at answering the question of whether TRIPS truly benefits the rich and the poor at the same time. It also tries to analyze whether the same minimum standards of TRIPS meet economic needs of countries at different stages of economic development.

The World Trade Organization's (WTO) Agreement on TRIPS has been a major step in international rule-making regarding the protection of IPRs (UN, 2010:3). It was the first time that WTO introduced intellectual property rules into the worldwide trading system, involving all its members regardless of their stages of development or primary needs of development. It is a significant event also because it "adds a significant number of new or higher standards" of IP protection that did not exist in previous conventions (WTO, Intellectual Property: protection and enforcement). It establishes minimum levels of IP protection that all WTO members must comply to. The agreement was negotiated in the 1986-94 Uruguay Round. Disputes between developed and developing countries on the agreement has never stopped. Even after it took effect on January 1995, several amendments have been introduced out of the requests of developing countries. For instance, transition periods for the least developed countries has changed 2 times (from the original deadline in 2006 to July 2013, and in 2013 it further extended to July 2021), which directly reflects that

countries at different level of development require different arrangements of IP protection (WTO, Intellectual Property: Least Developed Countries).

Two decades after TRIPS took effect, the IP protection is even more relevant at present because of the rapid transformations brought by the ICT sector. Developments in ICT have triggered a revolution in how ideas, information and knowledge spread, while ideas, information and knowledge have become an increasingly important component of trade. Its importance can be reflected by the amount of total trade in the ICT sector worldwide. In 2012, world imports of ICT goods, such as mobile phones, smartphones, laptops, integrated circuits and other goods amounted to almost $2 trillion according to the UNCTAD data. They accounted for 11% of world merchandise trade, even exceeding trade in agricultural products (9.2%) and motor vehicles (7.2%) (CNUCED, 2014). Digital technology and emerging global information superhighway boost global trade and push our world towards an increasingly integrated global economy. Global trade requires a harmonized international IPR regime to go smoothly, however, the whole concept of intellectual property rights is territorially limited (McMains, 1996:211). In an era of information and globalization, the uncertainty and difficulty of encouraging innovation through protecting IP makes it necessary to explore the relationship between IP protection and ICT innovation.

Contrary to our impression, the digital/Internet era not only brings the unprecedented educational and informational opportunities, but is also seriously threatening access to information. In the hard copy era, one could photocopy and share materials and there was no way to prevent the sharing. However, digital technology combines self-help protection with passwords, encryption technologies and even contracts with users, enabling copyright-protected or even non-copyrighted contents to be fenced. As a result, traditional limitations on the rights of copyright owners and the fair use defense against exclusive copyrights are useless in front of ICT technology (Denicola, 2000:195-196). Inevitably, countries that cannot afford to pay for access will suffer from a further barrier built by digital technologies, leading to an even greater divide between the “information-haves” and the “information-have-nots” (IFLA).

Fundamentally, the question of whether we should or not promote intellectual property rights has never been conclusive. Moreover, it should never be forgotten that

the very purpose of introducing IPRs is to serve "the instrumentalist function of satisfying social goals and values: the creation, spread and sharing of knowledge and information, and public use and access" (Story, p.4). Developing countries agreed to protect IPRs particularly in exchange for potential technology transfer to compensate for the large amount of fees they pay (WTO, Intellectual Property: Protection and Enforcement). As a result, it is relevant to research on whether developing countries can achieve technology developments by strengthening intellectual property rights under the one-size-fits-all arrangements of TRIPS, in an era when ICT makes IPRs especially relevant.[1]

2. Aim and research questions

Through an empirical study of a panel data set, the aim of the paper is to explore whether the TRIPS' arrangements of IP protection can serve the goal of promoting innovation in the ICT sector in all countries. On the one hand, academics have pointed out that there is considerable controversy in the current international regime of protecting key information technologies (Maskus, 1998:109-110). On the other, previous quantitative studies have shown that "universally imposed minimum standards for patent protection are not likely to contribute to increased growth in countries below a certain threshold in terms of level of development" (Kumar, 2003: 210). As previous empirical studies on the relation between TRIPS and innovations mainly focus on total innovation activities or more concerned sectors, such as pharmaceuticals and biotechnology, it remains interesting to explore the ICT sector.

The research question is what impacts IP protection has on ICT innovation activities of countries at different levels of development. Do the same arrangements of IP protection have the same impacts on all countries? Are the impacts of IPRs significant and positive on innovation outcomes in ICT? As it is rather complicated to look into the actual implementation of the TRIPS agreement in all WTO members, we analyze the impacts of TRIPS by pointing to the essence: the relationship between IPR protection and innovation outcomes. In other words, rather than directly looking at actual implementation of TRIPS, our research relies on ratings of intellectual property rights protection index. If higher ratings in the IPR index comes with better ICT innovation performance for developed as well as developing countries, we have evidence to support TRIPS "one-size-fits-all" arrangements.

3. Theory and Hypothesis

3.1 Theoretical discussion: the nexus of economic development, innovation, IPR and ICT

Why we protect intellectual property rights

In a previous study (GUO 2015), we have discussed in details about the theoretical relevance and importance of IPR protection in the ICT sector. To avoid duplication of efforts, here we summarize what has been discussed before.

In summary, the theoretical supports for promoting innovations is the chain of causal relationships along IPR, innovation and economic developments. In short, IPR encourages innovation, while innovation is the essence to achieve economic growth. Long-term economic growth and job creation can only be realized by improved productivity, and innovation is what it requires to improve productivity (Hargreaves, 2011). Correspondingly, growth theories, such as endogenous growth theory and evolutionary approach, have established the significance of innovation and technology for economic growth (Verspagen, 2005:492). Empirically speaking, from 0.79 billion in 1750 to 6.79 billion in 2010 (UN report, 2004), world population has grown to approximately 8.6 times what it was in the first industrial revolution. Without major technological innovations and revolutions, it would have not been possible to raise all the population on our planet.

As innovation is so important, economists have been exploring what promote economic developments, and the answer they found has been intellectual property right protection. The World Intellectual Property Organization (WIPO) defines intellectual property as “creations of mind”, it ranges from inventions, literary and artistic works, as well as symbols, names and images used in commerce. Generally, intellectual property is divided into two categories: industrial property and copyright. Industrial property includes patents of inventions, trademarks, industrial designs and geographical indications. Copyright includes but is not limited to computer programs, databases, literary works, films, music, artistic works and architectural design.

IPR is a handy solution to the tough but crucial problem of finding a balance between the interest of innovators and the benefits of societies. Economists that

support IPR, for instance, Arrow (1962), argue that patent protection is one of the means to address the problem of inability to appropriate sufficient returns of the R&D investments of private firms. In addition, patent protection also promotes innovation as it requires disclosure of information, which "accelerates the diffusion of patented technical information, and may reduce duplicate R&D, induce substitute technologies (through "inventing around" an important patent), stimulate new ideas, direct R&D efforts to opportunity-rich areas or bottleneck problems, provide a basis for bench-marking and competitive intelligence and stimulate technology exchange and cooperation" (Granstrand, 2005). The fundamental benefits of IP protection have always been its long-term contributions to society. The mechanism of IPR system is to exchange short-term costs to long term benefits for society, as holders must disclose their creations and inventions after the period of protection expires.

Why we protect intellectual property rights internationally by introducing TRIPS

There are primarily reasons supporting a harmonized international IPR regime. Firstly, developments in ICT have made knowledge a crucial component in trade, and knowledge is a product that particularly needs IP protection. Knowledge has characteristics of a public good, which means it is both non-rivalrous and non-excludable. These features render knowledge products extremely easy and simple to spread without much cost, meaning a huge loss in revenue for the inventors. Therefore, without IP protection, there may be a lack of motivation to innovate.

Secondly, in order to benefit from technology transfer, countries may need to smooth the channels for export and import, as well as foreign investments. A discrepancy in IP regulations among countries would generate disputes in trade. Discrepancies in IPRs may also hinder high-technology companies to operate in countries with weak protection, as these companies would face risks of cheaper counterfeiting products in countries of destiny and losses of revenue.

Why we question the validity of positive impacts of IPR protection and TRIPS

Theoretically speaking, rather than promoting innovations, IPRs are possible to impede developments in innovations. An over-emphasis on IPR can lead to "over-fencing of the public knowledge commons", blocking the positive spillover

effects from already-existing innovations. “Even the greatest minds in history depend on already existent knowledge” (Schaefer et al., 2014), the advanced knowledge possessed by the developed countries can contribute to a great extend to the catching-up of developing countries. On one hand, patent holders in the developed countries have already grabbed profits in their markets, as they all have constructed IPR protection systems and had a long history of protecting the interests of innovators. On the other, the developing countries are short of resources and wealth, and the least developed countries can barely even raise their population. With stronger IP protection, developing countries can no longer take advantage of reverse engineering or cheap counterfeiting products.

In addition, besides IPRs, there are also other methods to promote innovations, and IPRs are not necessarily the most effective way to attract technology transfers into developing countries. For example, Lerner (2001) and Branstetter et al. (2004) both use patent applications as indicator of domestic innovation, and their empirical research found no or little increase in innovation with strengthened IPR protection. The fact that foreign direct investments have flourished into high-growth, large-market developing economies with weak IPRs in East Asia, rather than sub-Saharan Africa or East Europe implies that stronger IPRs are not sufficient incentives for firms to operate in a country (Maskus, 2000).

Consistent with the analysis above, the major criticism that TRIPS receives is about its capability to even wider the knowledge gap between developed and developing countries. As industrialized countries are the main producers of copyright-protected works, they “have also been the nearly exclusive beneficiaries of expanded intellectual property protection” (Story, 4). The IPR regime under TRIPS is totally western-style that does not meet the need of development for developing countries, which means they are at least not ready for them (Dutfield, 2003:3).

The very intention of the developed countries to introduce TRIPS is also suspicious. It is questionable whether the aim of developed countries was to serve their own needs instead of promoting innovation in general for all members. On the one hand, only three “circles of consensus” really mattered in the TRIPS negotiations, including the circles of US and Europe; US, Europe and Japan; and Us, Europe, Japan and Canada (Drahos, 2002:367). The results of negotiations are imposed on all members of WTO, the majority of whose members are developing countries.

However, all developing countries were left out from the process of initiating process, thus it is a hierarchical rather than democratic management, and indeed a result of coercion from the inner circle to the outer developing countries. If TRIPS actually aimed to serve the interests of developing countries equally to developed countries, it would not have excluded all developing countries, even the key "influential" players. What the developed players did was to reach a compromise among themselves in a "black box" and developing countries have no choice but to agree to the result as long as they want to take part in the global trade system.

Further, it is suspicious to include the least developed countries. These countries simply lack the necessary capacities and infrastructures to develop technology, and thus it is hard to see how simply introducing IPR can magically promote innovations there. Although the LDCs mattered little from a commercial viewpoint, they were still included, for the practical reason that "by securing strong IP laws in small countries, the larger, more competitive and less-malleable developing countries were isolated" (Deere, 2009:116). It is hard to see what immediate aim and impacts that an international IPR regime has other than to expand markets and profits for IP holders in the developed countries.

Why the ICT sector deserves special attention

The 2007 OECD document defines the ICT sector as the production of (goods and services) an industry that is "primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display" (OECD, 2007:15). It is generally divided into three categories: ICT manufacturing industries, ICT trade industries and ICT service industries.

Vast developments in the ICT sector have brought more challenges and disputes to current IPR regime and to TRIPS.

Firstly, rapid developments in the ICT sector is an extraordinary phenomenon in our era, where the word "revolution" is truly appropriate (European Commission, 1999). ICTs transform knowledge into "pure" public goods: it almost cost nothing for information to spread worldwide. With the assistance of the Internet, everyone with a

device with access to the Internet can acquire online information, and the knowledges themselves will never become less or be damaged because of people reviewing them.

For developing countries, ICTs bring enormous potential in economic development, because ICTs are a "general purpose technology (GPT)" that benefits the upgrading of its downstream sectors. Over the long run, a reorganization of production based on the use of ICT goods by producers in other sectors will lead to an economy-wide rise in total factor productivity (Bayoumi and Haacker, 2002). Therefore, introducing ICT to the developing countries may result in systematic upgrading in productivity.

However, compared to the long history of IP protection, which can be traced back to 1474 when Venice introduced the first formal patent code (Granstrand, 2005), ICTs are a totally new concept that requires corresponding adaptions in IP systems. Under TRIPS agreement, computer programs and databases are ensured to be protected as literary works under Berne Convention (WTO, Copyright and Related Rights). If the main purpose of introducing IPR is actually to serve the goal of technology transfer to developing countries, it is hard to see why TRIPS protects computer programs and databases as copyright, as copyright enjoys the longest protection among all kinds of intellectual properties.

In fact, copyright is not appropriate for products like computer software. Copyright under Berne was introduced in an era when authors, not large multinational corporations were the principal rights holders. Individuals with few resources would need the protection, not Multinational Enterprises (MNEs) (Story, 18). The monopoly power by large companies in developed countries can be reflected in two aspects. First of all, protecting software under copyright was just an outcome of the lobbying by some sections of the software industry (Story, 19). Secondly, as the weaker side in the world trading system, developing countries, especially the LDCs have very weak bargain power against software monopolies. Developed countries will simply impose or threat to impose sanctions on developing countries, for instance the U.S. Special 301 report, out of domestic pressures by software multinationals.

As mentioned before, knowledge can be perceived as a public good, thus sharing knowledge through the Internet to LDCs would not diminish access by developed countries. Therefore, providing access to copyright-protected online materials to

LDCs will only bring a great amount of knowledge to them that are not possible without Internet. If providing online materials to developing countries like China or India are likely to result in counterfeiting product, it is not likely in the LDCs. As they do not have the capability to imitate high technologies, this would not result in lost revenues for rights holders in developed countries (Story, 5).

Moreover, offering authorized free access to software might even benefit right holders. The simple fact is that the per capita GNI of LDCs is less than $1,045 in 2014, while the price of Windows 10 Pro is $199.99, which is almost one fifth of their annual income. As the LDCs simply cannot afford authorized software, most computers there currently run on unauthorized software, and thus these countries form a market for counterfeiting products. Removing market demands for cheaper substitute might discourage counterfeiting activities and benefits copyright holders.

In summary, although ICT belongs to the category of advanced "high technology", it is relevant to the developments of less advanced developing countries. With unclearness and disputes around the appropriate methods of protecting IPRs and impacts of protecting IPRs, it is necessary to look at this issue in detail.

4. Literature review

This section focuses on researches on the benefits and importance of promoting ICT technologies, as well as previous empirical researches on the relationship between IPR protection and innovation outcomes.

4.1 Importance of ICTS on speeding economic developments in developing countries

For developing countries, resources to utilize are scarce, and they must decide how to best allocate these sources to improve economic development. Developing countries are inclined to take ICT investments as a luxury, which should only be provided after investments in the important sectors, including agriculture, water and roads, have been made. However, as mentioned in the theoretical sector, ICT is a GPT with enormous potential to push developments. With assistance of ICT technologies, transaction costs can be reduced, the scope of markets can be expanded, and thus competition and efficiency will be increased. A series of previous empirical studies have supported that "expanded telecommunications investment is essential, not only

for growth, but also to remain competitive within the increasingly information-oriented global economy", and failure to develop telecommunication systems will increase the development gap between developing countries and industrialized countries (Alleman et al., 1994:5).

As early as the 1980s, the relevance of information and communication technologies for developments was emphasized. *The Missing Link*, a study of telecommunications and development of International Telecommunication Union (ITU) concluded that telecommunications can be regarded as "an essential component in the process of development – a complement to other investments – which can rise the productivity and efficiency of agriculture, industry, commerce (including international trade and tourism) and the social services, and enhance the quality of life in the developing world" (ITU, 1984:8). It was even regarded as "an engine of growth and a major source of employment and prosperity" in the industrialized world at that time, when these countries were experiencing an extremely high pace of technological innovations in telecommunications and benefiting in a broad sense from these developments (ITU, 1984:3).

In spite of case oriented studies, statistical researches on the direction of causality have also been done. For instance, causal analyzes undertaken by Hardy (1980), DRI/McGraw-Hill (1991) and Norton (1992) have shown that the growth of investments in telecommunications is a statistically significant predictor of economic growth. Meanwhile, indicators of economic growth are also significant predictors of telecommunications investment. As a result, telecommunications is considered both a cause and a consequence of economic growth (Alleman et al, 1994). Their studies reflect that developments in technologies of the dissemination of knowledge can facilitate economic growth. On the other hand, as long as the countries have the money to invest in "luxury" ICT technologies, they will develop infrastructures in this sector.

Input-output analyzes have also shown the importance and significance of ICT technologies. A report commissioned by BellCore, DRI/McGraw-Hill (1991) used input-output modeling to measure efficiency gains attributable to telecommunications. The study is based on the data of the U.S. in the period of 1962-1983. Their study showed that a small portion of a business's total inputs (an average of 3 percent) led to enormous efficiency gains. For instance, their report estimated some $46.5 billion

"in resource savings due to increased efficiency in the supply of telecommunications service and equipment" (Teleconsult, 1993: II-12). It is an illuminating lesson for current developing countries, as it shows that investments in ICTs are quite rewarding.

Obviously, ICT technologies alone are not sufficient to ensure economic development. However, previous research has already shown that lack of telecommunication investment can prohibit or even significantly restrain economic development (Alleman et al., 1994).

4.2 Empirical research of impacts of IPRs

Generally speaking, the impacts of IPRs have not been clear, especially for the developing countries, thus it is still relevant to contribute more on this topic. Reviewing existing researches on intellectual property rights, Dutfield summarized that "it is far from self-evident that the existence of strong IPR protection is a precondition for transformation of developing country economies into developed ones" (Dutfield, 2003:4). He also pointed out that for developing countries, the effects of intellectual property rights on innovation, creativity and economic development continues to be extremely unclear (Dutfield, 2003:7).

The main part of previous literature on the impacts of IP protection focuses on its influences on economic growth and FDI. Based on a sample data of thirty-three political units over a period of fifteen years, Kondo (1995) found no evidence of a positive relationship between patent protection and the amount of US manufacturing FDI a country received. In other words, his research implies that there is no reason to assume FDI is affected by patent protection. Similarly, an empirical study by Kumar (1996) found that the level of intellectual property protection in developing countries does not appear to influence R&D investment by US Multinational Enterprises (MNEs). Rather, larger domestic markets, local technological resources and infrastructure are important factors in attracting R&D investments from MNEs (Kumar, 1996). However, Maskus (1998) found evidence that strengthening IPRs can effectively attract additional inward FDI, though he emphasizes IPRs is only one component among a series of important factors (Maskus, 1998).

The main division of standpoints of TRIPS has been between developed and developing countries. Supporters believe that strong IPR protection and enforcement

are an indispensable element in our modern economy, and the developing countries need to promote IPRs to transform their outdated industry-based economies into knowledge-based economies. Others argue that IP systems are just another device for the developed countries to acquire revenues, making the rich countries richer and the poor poorer (Dutfield, 2003:7). By a simple comparison between the per capita income of major industrial countries when they adopted pharmaceutical patent protection and current income of developing countries, Birdshall, Rodrik and Subramanian argue that TRIPS and similar agreements are forcing developing countries to abide by TRIPS 50-100 years premature (Birdshall et al, 2005:144). Critics also argue that the current system of intellectual property rights was designed more than 100 years ago to meet the simpler need of an industrial era, which is now an ineffective one-size-fits-all to face fundamental shifts in technology (Thurow, 1997).

There is an increasing body of literature pointing out that the impacts of IP vary considerably between countries, "particularly depending on the level of (technological) development of the economy in question" (UN, 2010:1). It is acknowledged by developing countries that every country that has caught up in history has done so by copying (Thurow, 1997). For instance, applying differential historical analyzes, Schiff compared Switzerland (1850-1907) with simultaneous developments in patent-granting countries, as well as with itself after Switzerland adopted patent laws. He finds that there was a vigorous inventive activity in Switzerland during and after the patentless period, showing that a country can develop rapidly without a national patent system (Johan, 1972). The research of Chen and Puttitanun (2005) is based on a panel sample of 64 developing countries in the period from 1975 to 2000. Their empirical analysis suggests that stronger IPR protection has more significant impact on encouraging innovation in countries with higher level of development. Also analyzing a panel data, Schineider (2005) looked at 47 developed and developing countries from 1970 to 1990. The results support that IPRs have a different impact on innovation between developed and developing countries. While stronger IPRs have a positive impact on innovation in developed countries, it is negative and often significant on innovation measured by US patent applications made by residents of developing countries.

Similarly, averaging measurements from 1970 to 1985, Thompson and Rushing (1996) found that strong and effective protection of intellectual property leads to more rapid economic growth in countries with an initial level of GDP greater than or equal to $3, 400 (1980$) (Thompson and Rushing, 1996). Their research in 1999 also found that the positive impact of patent protection on total factor productivity is only significant on high-income countries. This relationship can neither be found in low-income countries, nor in the full sample (Thompson and Rushing, 1999).

As previous empirical studies mainly analyze general innovation activities, and the ICT sector's importance is growing, a study on TIRPS and ICT innovations can contribute to the broader topic of development and shed some lights on feasible routes towards knowledge-based economy.

Based on the literature reviewed above, we derive two hypotheses to test in this thesis.

$Hypothesis_1$: The impacts of IPR protection are only significant on high income countries, not on the low and middle income developing countries.

$Hypothesis_2$: For the high income countries, those with stronger IPR protection tend to have better innovation outcomes, i.e. more patent application in the ICT sector.

5. Empirical Analysis

5.1 Experience of Successful Cases

Over the past decade or so, ICT has promoted profound economic and social change (OECD Guide, 2011:12). We analyze a relatively late period: 2006 to 2014. A period when there is more data available, and also more relevant for the ICT sector.

This paper is interested in the secret of success in the ICT sector, i.e. progresses in ICT innovations. In order to learn from the experience from successful cases, we choose countries with impressive ICT innovation outcomes over the period, namely an enormous increase in number of patent applications in ICT over the 9 years from 2006 to 2014. More specifically, we include all countries (with patent data available)

whose yearly ICT innovation outcomes are sizable in 2014 (more than 100 patent applications in ICT), and whose growth rate in the number of patent applications is more than 10% from 2006 to 2014. Growth rates in the number of patent applications are calculated by the difference of 2014 and 2006 numbers divided by 2006 numbers. According to this standard, we end up with ten countries, which include Austria, Belgium, China, India, Japan, the Republic of Korea (South Korea), Luxembourg, Malaysia, Singapore and Spain. The numbers of patents applications in the ICT sector in 2014, as well as growth rates of the number of ICT patents applications of the ten countries are summarized in table 1 below.

Table 1 Numbers of patent applications in ICT and growth rates from 2006 to 2014

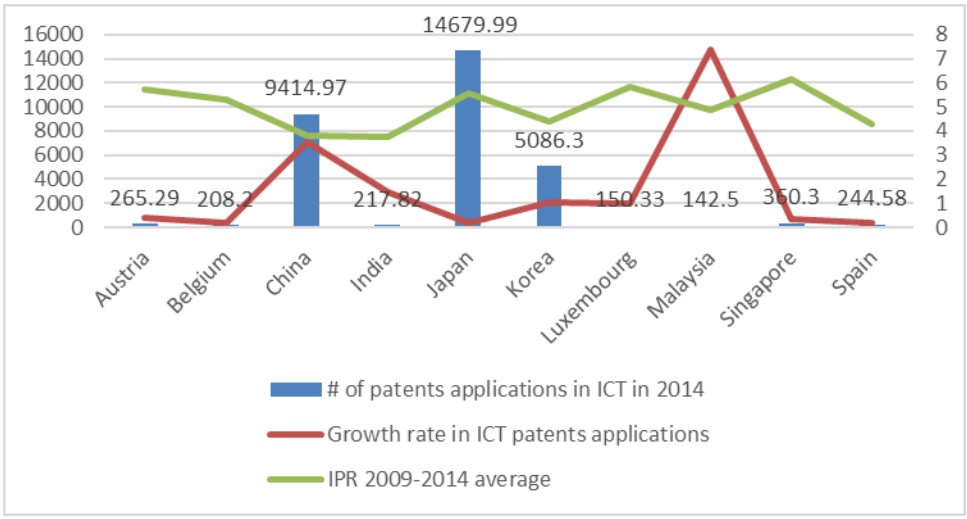
Country	2014 #	Growth rate in ICT patents applications	Country	2014 #	Growth rate in ICT patents applications
Austria	265.29	0.41	Korea	5086.3	1.01
Belgium	208.2	0.17	Luxembourg	150.33	0.98
China	9414.97	3.56	Malaysia	142.5	7.38
India	217.82	1.44	Singapore	360.3	0.34
Japan	14679.99	0.16	Spain	244.58	0.21

*Source: OECD Statistics and author's own calculation

*Decimals of the numbers of patent applications in ICT are found because that some of the applications are co-applied by several countries.

Here we present the contents in table 1 above into Figure 1, together with their average ratings of WEF IPR index over the years. We can see directly that the top three countries with largest numbers of ICT patents applications are Japan, South Korea and China. And the top three countries with biggest growth rates in numbers of ICT patents applications from 2009 to 2014 are Malaysia, China and India. Therefore, we include Japan, South Korea, China, India and Malaysia as cases for the detailed analysis later. But first we compare performances of the ten countries together.

Figure 1 Comparison of numbers of patent applications in ICT, growth rates and IPR protection

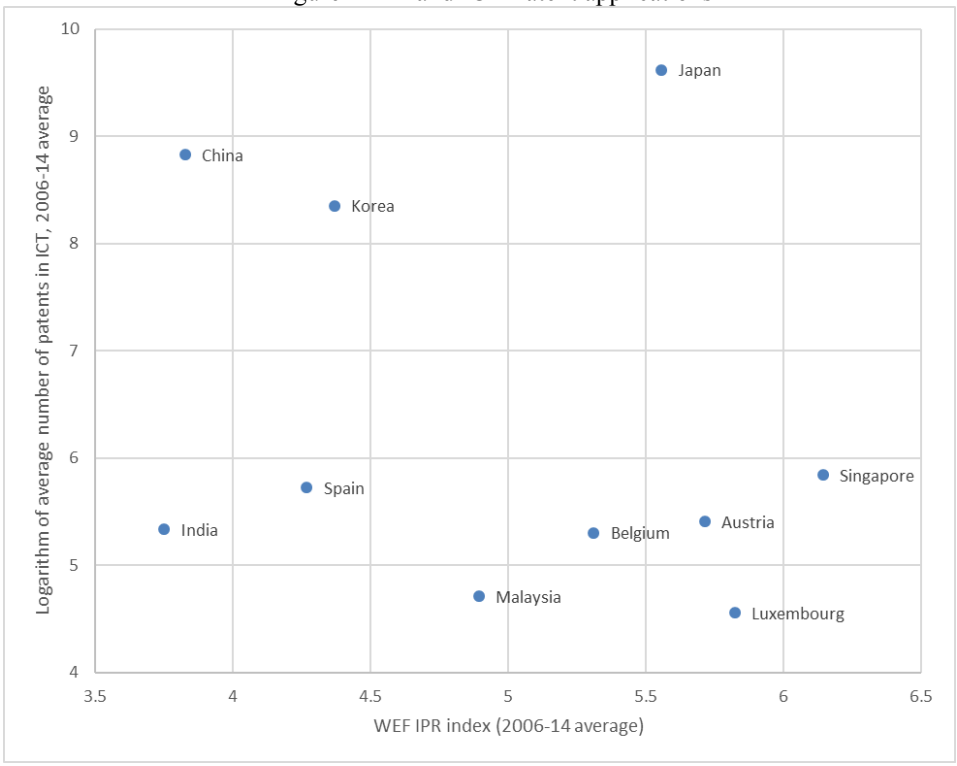


Sources: OECD Statistics, WEF, and author's own calculation

5.1.1 A general observation over the connection between IPR and ICT performance

From Figure 1 above and Figure 2 below we can see that there is a huge difference in the net numbers of ICT patent applications among the countries, which cannot be explained by the strengths of IPR protection. For instance, China and India are among the three countries with lowest IPR protection levels. However, China has the 2nd largest average number of ICT applications over the years, while India ranks the third regarding growth rates. In addition, for the seven high income countries, except for Korea and Spain, the rest of the countries all have similar strength of IP protection. Japan does not have the strongest IPR protection, while its ICT patents applications are more than 70 times to its counterpart Belgium, who has basically the same average ratings of WEF IPR index as Japan does. While South Korea is one of the two countries that has weakest IPR protection among the high income countries, it has the largest growth rates in the high income group, and its size of applications ranked 2nd. South Korea's number of ICT applications over the years is more than 20 times that of Belgium, while the latter's IPR protection is significantly stronger.

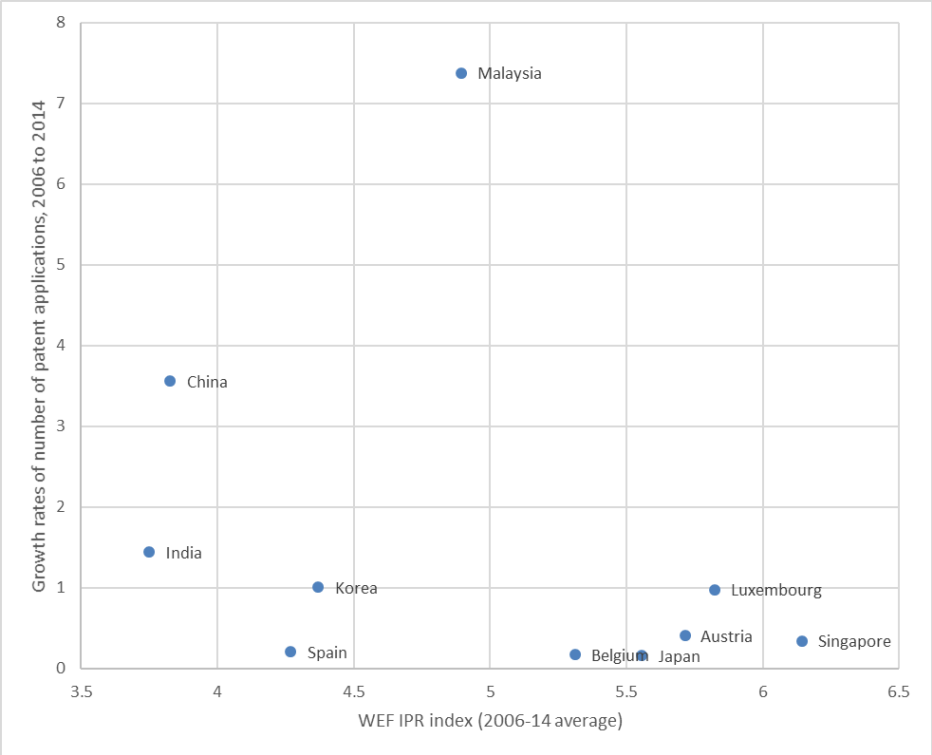
Figure 2 IPR and ICT Patent applications



Sources: OECD Statistics and WEF

Undoubtedly, it is not rigorous to simply compare innovation outcomes according to IPR index alone, as various factors can influence the size and prosperity of the ICT market in a country. It can only roughly show you that high level of IPR protection cannot guarantee a high level of innovation activities, especially cannot explain the extremely large amount of innovation outcomes alone. It may not be the most important factor in determining the size of innovation activities in the ICT sector. In addition, if IPR protection is such an important factor in promoting innovations, it should have more influence, or stronger correlation with growth rate of number of patent applications. If the theories supporting IPR is true, a strong correlation should be visible, considering the small sample we present here are the top 10 countries with best performances in the ICT sector. It is reasonable to assume that these countries have created a friendly environment for ICT innovations, and the impacts of an important factor on growth rates should thus be significant. From Figure 3 below, we find that intellectual property protection is far from a decisive factor of growth rates of innovation activities in the ICT sector in these countries. Though for the three developing countries, higher level of IP protection does come with higher growth rates.

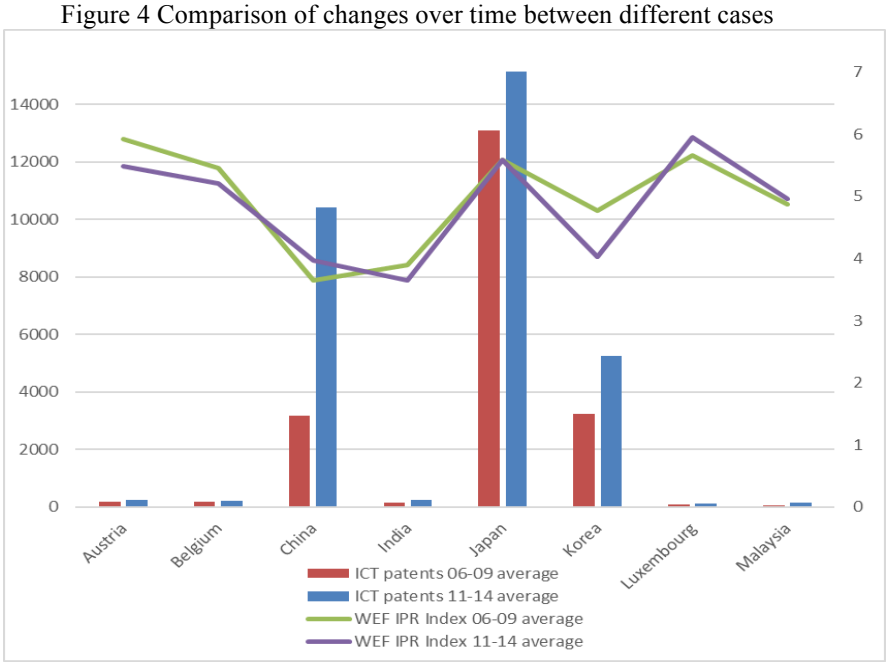
Figure 3 IPR and growth rates of number of patent applications in ICT



Sources: OECD statistics and author's own calculation, WEF

Figure 4 below shows even more clearly that a weakening of IPR protection has not hindered any country in this group from expanding their innovation activities. By the same token, an improvement in IPR protection does not necessarily lead to an increase in the number of patent applications. Comparisons are between 2006 to 2009 averages and 2011 to 2014 averages. Even the high income countries, including Austria, Belgium, South Korea have weakened their IPR protection over the years. South Korea has the most significant drop in strength of protecting IPRs.

Figure 4 Comparison of changes over time between different cases



Sources: OECD Statistics; WEF

Next, we look into detailed discussions.

5.1.2 Position and Implementation of TIRPS in countries at different income levels

By looking into implementations of TRIPS Agreement by the cases we choose, we have the opportunity to investigate what expectations these countries have on IPRs and whether strong IPR protection was there when the ICT sector develops in these countries. Are they actively complying to TRIPS, or simply making compromises in exchange for other benefits?

Firstly, we discuss the general information about implementation of TRIPS agreement by all ten countries. The dates that TRIPS was introduced into force in these countries are listed in table 2 below. Except for China, all countries are one of the first signers of the treaty, and the TRIPS agreement has taken effect since 1995. Among these countries, the developed country members "have had to comply with all of the provisions of TRIPS Agreement since 1 January 1996". Thus in theory, Japan should be the first one of these countries to comply with TRIPS arrangements. In contrast, for developing countries, "the general transitional period was five years, i.e. until January 2000" (WTO: Transitional arrangements). Although both Korea and Singapore are high income countries, they belong to the group of developing countries according to WTO. Together with India and Malaysia, these four countries had to apply the TRIPS Agreement's provisions by 1 January 2000 (WTO, FAQ). As

for China, the five-year transitional period after its accession to the WTO ended on December 11, 2006 (WTO Transitional Period Ends, 2006).

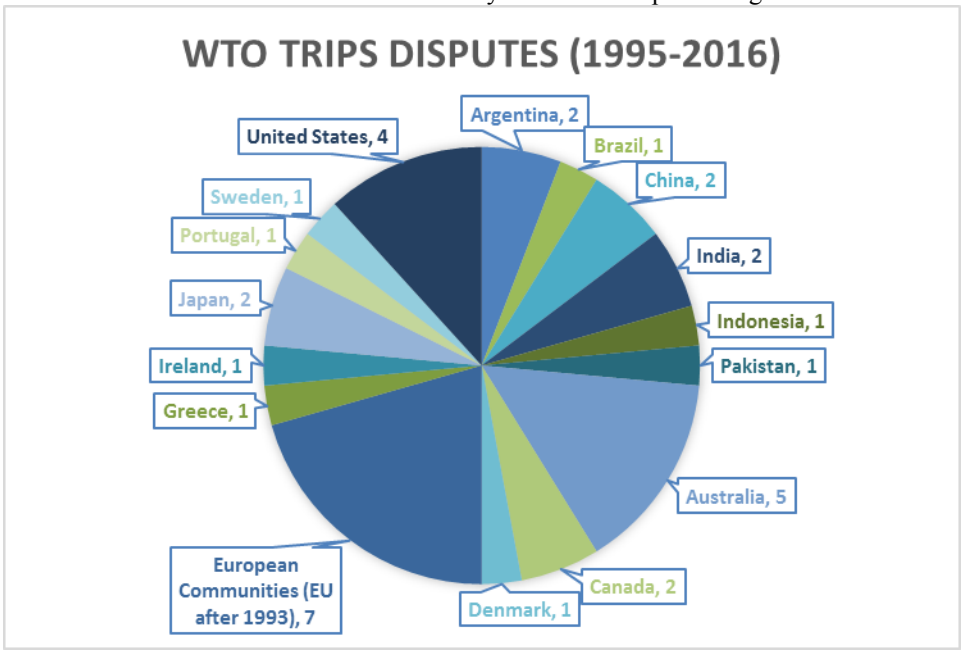
Table 2 Signing dates of TRIPS Agreement

Signatories	In force	Signatories	In force
Austria	Jan. 1, 1995	Korea	Jan. 1, 1995
Belgium	Jan. 1, 1995	Luxembourg	Jan. 1, 1995
China	Dec. 11, 2001	Malaysia	Jan. 1, 1995
India	Jan 1, 1995	Singapore	Jan. 1, 1995
Japan	Jan 1, 1995	Spain	Jan. 1, 1995

Source: WIPO

Except for China, all these successful cases were among the first countries to sign TRIPS agreement. However, these countries are not a class-one group regarding IPR protection. From 1995 to 2016, there have been 34 cases of WTO trade disputes involving TRIPS Agreement. Figure 5 below shows the numbers of times that a country has been complained by other WTO members. Contrary to our expectations, only about one quarter of the cases were targeted against developing countries. Except for Pakistan, all countries that have been complained about are either developing countries with outstanding achievements in economic developments, or developed countries. It indirectly supports the fact that IPRs are actually more relevant in countries with technological capacity. Except being allied by the developed countries to isolate the more vocal developing countries, those less influential low income countries with a lack of technological capacity and a minimal size of market are invisible in this "game" of protecting revenues overseas.

Figure 5 Distribution of number of times a country has been complained against under WTO TRIPS



Source: WTO, Disputes by TRIPS Agreement

The 2011 Global Software Piracy Study of Business Software Alliance (BSA) reported the commercial value of pirated PC software and piracy rate in each of the countries. Piracy rate is calculated as unlicensed software units divided by total software units installed. All of the five countries ranks top 20 globally with regards to the commercial value of pirated PC software in 2011. The report also presents values of legal sales. As a comparison, we also present data of 2011 GDP per capita in current US dollars, 2011 Internet penetration rate, as well as the price of Windows 8 pro as a percentage of the 2011 GDP per capita of each country. Except for India, piracy rate declines with increase in per capita GDP, while Internet penetration rate increases with increase in per capita GDP. This reflects that with higher income and further spreading of technologies, stronger wills to protect copyrights in the population grow. For a low income country like India, an authorized Windows system can cost as much as more than 10 per cent of the annual income of a national. Without availability of counterfeiting or pirated products, or with implementation of TRIPS, these kinds of software would be off-limits for the poor countries. Why cannot we release free software accesses in the low income countries and low income regions, considering the use in the poor regions would not cost any loss in revenues in the higher income countries? The low-income people in the world simply cannot afford to buy authorized products, do they deserve to be deprived of access to all the knowledge brought by technologies because they are poor? Placed in between by a lack of technological capacity and obligations to implement TRIPS, how do we expect them to develop?

Table 3 Value and rate of PC Software Piracy and GDP per capita, 2011

	Pirated Value ($ Million)	Legal Sales ($ Million)	Piracy Rate	GDP per capita (current US$)	Win 8 pro price (% of GDP per capita)	Internet Penetration Rate
China	8,902	2,659	77%	5,574.2	3.59%	38.3%
India	2,903	1,721	63%	1,471.7	13.59%	10.07%
Malaysia	657	538	55%	10,427.8	1.92%	61%
South Korea	815	1223	40%	24,155.8	0.83%	83.76%
Japan	1,875	7,054	21%	46,203.7	0.43%	79.05%

Sources: BSA; World Bank; Laptopmag

One may say that these countries do not need cheap access to high-tech products. They can attract FDI by strengthening IPRs. In 2011, the same year with our software data, the OECD countries take 52% of the total world. Together, Argentina, Brazil, China, India, Indonesia, Russia, Saudi Arabia, and South Africa (the all eight non-OECD G-20 Countries) take another 25 per cent of world inflow of FDI. In other words, 34 OECD countries take more than half of the world FDI, while the eight non-OECD G-20 countries take half of the rest half. The remaining 25% of FDI were shared by more than 150 developing countries in the world. Argentina, Brazil, China India, and Indonesia all have a reputation of infringing IP conventions, yet they attract enormous amounts of FDI (OECD, 2013). Clearly, other factors, such as size of markets, or infrastructures are more relevant factors than IPRs. As a result, technology transfer through FDI is not a practical option for the majority of developing countries, if the only comparative advantage they have is stronger IPRs.

In fact, all Asian countries in these ten countries group are among the "East Asian Miracle" countries. Has IPR been the secret of their rapid and sustained growth and developments? Evidence suggests that it is actually weak IPR regimes that have facilitated their technological and economic development.

Table 4 Countries listed in the U.S. Special 301 report

	1995	98	2000	05	06	07	08	09	10	11	12	13	14
Japan	×	×											
South Korea	×	×	×	×									
Malaysia			×	×	×	×	×	×	×	×			
China	×	×	×	×	×	×	×	×	×	×	×	×	×
India	×	×	×	×	×	×	×	×	×	×	×	×	×

*Source: Special 301 Reports in 1995, 1998, 2000 and 2005 to 2014

*Malaysia was not mentioned in 1995 and 1998

*Countries that were under monitoring under Section 306 of the Trade Act of 1974 or placed on the Special 301 Priority Watch List

*Countries that were placed on the 301 Watch List

Japan and South Korea

Japan is a unique case in this group. Before the initiations of TRIPS Agreement, Japan was a major target by the U.S. as a competitor. But Japan was one of the first countries to climb the ladder from a developing to developed country, and its role in promoting IPR protection also changed from being pressured to promote to imposing pressure on other countries to conduct IP reforms.

Japan is unique because it was one of the initiators who set up the TRIPS and belonged to the "core group". The original motive of the developed countries was to protect their advantage in the world economy. Just before the starts of TRIPS negotiations, there was a rapid growth in IP related exports in the U.S.. For instance, exports by U.S. information services companies increased by 9 percent between 1982 and 1983, and the U.S. software industry reported an increase in exports that accounted to 30 percent of total sales by 1982. In addition, the U.S. exports of computers and equipment increased by 21.2 percent between 1978 and 1982 (Office of Technology Assessment, 1986). Meanwhile, with the growth with technological production in the developed countries, cheap piracy and counterfeiting products in East and South East Asian countries like Singapore and South Korea also grew. As a result, concerns to maintain competitiveness grew in the developed counties, and governments in these countries begin to "attach increasing importance to the strategic

role of technology and the protection of intangible assets for their economic growth and trade prospects" (Deere, 2009: 108).

Japan is a unique case also because it was a developing country before, and it took advantage of a weak IPR protection regime during its "catching-up" period. Although Japan was one of the initiators of TRIPS agreement, it was on the watch list on the U.S. 301 report after TRIPS took effect, and was even on the priority watch list in 1995. Section 301 is a U.S. national trade enforcement tool, allowing it to withdraw the benefit packages of trade agreements or to impose duties on goods from other countries (Drahos, 2002). According to the U.S. 301 report in 1995, the narrow scope and interpretation of patent claims in Japan, as well as weak enforcement against computer software piracy and retroactive copyright for sound recordings had been a continuing IP problem in Japan (1995 Special 301 Report).

In fact, Japan "is known to have greatly benefited from intellectual property generated in other developed countries in the early stages of its development" (Kumar, 2003: 214). For example, Japan introduced the Utility Model Law in 1905 in order to "provide protection to adaptations or improvements over the imported machinery or equipment by domestic inventors that were considered too minor to be patented primarily", and as many as 99.9 per cent of utility models were granted to Japanese nationals over the 1905 to 1979 period (Kumar, 2003: 214). By allowing firms in Japan to receive utility model protection, they were able to design patents "on technologies that were only slightly modified from the original invention" (Maskus and McDaniel, 1999: 560). This method was effective for Japan to grow its own technical capacity: "the number of domestic applications for utility models tripled between 1960 and 1987 before falling sharply" (Maskus and McDaniel, 1999: 563) In a technological "catch-up" period, diffusion and imitation are more important than pure innovation. With regulations such as pre-grant disclosure, first-to-file (rather than first to invent) and utility model, Japan ensured a channel of technology transfer through the application process.

By the 1970s, Japanese enterprises "had developed their technological capability adequately and hence needed protection for their own innovative activity" (Kumar, 2003: 214). Signed by expanding the scope of patent system to cover chemical and pharmaceutical products, Japanese IP regime transformed to strong protection (Kumar, 2003). However, in the relevant new high-tech sectors, Japan still kept rather weak IP

protection at the beginning. In 1995, Japan was on priority watching list of U.S. 301 report because of its weak protection on biotechnology and weak enforcement against computer software (1995 Special 301 Report). In 1998, Japan remained on the watch list of the 301 report because of U.S. concerns in its protection of software and trade secrets, and it called for Japanese government to strengthen its enforcement of antipiracy laws (1998 Special 301 Report).

Similar to Japan, South Korea also took weak IP protection at its early stage of development, and transformed into strong protection after its position and interests regarding intellectual property rights changed. The foreword section of U.S. 301 report in 2014 summarizes that Korea has achieved significant progress during the 25 years since the first Special 301 Report was published in 1989. Korea was on the priority watch list in 1989, but has "has transformed itself from a country in need of intellectual property rights enforcement into a country with a reputation for cutting-edge innovation as well as high-1quality, high-tech manufacturing" (2014 Special 301 report). In 1995, one of the major problems criticized by the U.S. on Korea was large amounts of end-user software piracy, "particularly by large conglomerates" (1995 Special 301 Report, p.5). U.S. was also concerned by Korea's permission to computer software de-compilation (1995 Special 301 Report). Even in 2000, Korea was elevated to the Priority Watch List, partially because of piracy of U.S. computer software in Korea and the amendments to Computer Programs Protection Act (CPPA) passed by Korean National Assembly. These issues were considered by the U.S. as failing to comply with its bilateral and international obligations (2000 Special 301 Report). Nevertheless, with a whole set of innovations now, South Korea has even adopted a broad range of TRIPS-plus standards.

Consistent with Japanese experience, "Korea has also followed an IPR regime that facilitated adaptations and imitative duplication of foreign technologies by domestic enterprises through utility models and industrial designs" (Kumar, 2003: 214). Clearly, Korea has also gone through a stage of imitation. During that period, "the government tried to minimize IPR protection to help domestic firms use foreign intellectual property" (Lee, 2000:284). Summarizing the Korean experience for developing countries, Kim (2000) points out the new challenge brought by changes in the international environment of IPR protection. With the binding rules of WTO, international IPR regulations such as TRIPS agreement "pre-empt duplicative

imitation of foreign technologies" (Kim, 2000: 29). Reverse-engineering of foreign products for duplicative imitation, an important strategy to absorb advanced technologies, "will be more difficult and costly for developing countries than it was for Korea in the 1960s and 1970s" (Kim, 2000: 29).

China, India and Malaysia

Generally speaking, China, India and Malaysia do not have particularly strong protection of IPRs in the group of developing countries. However, they have made outstanding achievements in the ICT sector as we have discussed above.

India and China have carried the reputation of poor IPR protection for a long period. The annual U.S. 301 Report effectively poses pressures of transforming IPRs on the developing countries, as there is perceived credibility of its threat to impose sanctions or withdraw trade concessions (Deere, 2009:166). China and India are two of the six countries (the rest of them include Chile, Indonesia, Thailand and Turkey) that have been listed every year over the 25 years of U.S. annual 301 reports (2014 Special 301 report). India was on the Priority Watch List every year from 1995 to 2007. In the "negotiation" period of TRIPS, India was one of the developing countries with a strong resistance in the multilateral negotiations. With this consistent infringement on western style IPRs, China and India still manage to achieve remarkable outcome in the ICT sector. This should have pose strong enough reason for us to reconsider what is the true promoting factor in encouraging innovations.

The experience of these successful cases has been to try to delay their accession into international IPR regimes as late as possible. The Paris Convention was adopted in 1883, applying to industrial property in the widest sense, the international agreement was the first major step taken to ensure that creators intellectual works were also protected in other countries (Paris Convention). However, key players of the developing countries, including China (joined in 1984), India (joined in 1998) and Malaysia (joined in 1988) all delayed their adherence to international IP conventions and joined the Paris Union only in the 1980s, when the Convention had been introduced for more than 100 years.

In addition, different from many other developing countries, India and Malaysia first adopted intellectual property quite early. India acquired a patent law in 1856

under British colonial rule, even long before many European countries. Belonging to the Empire of United Kingdom, Malaysia adopted the British 1911 Copyright Act (Deere, 2009:35). Even with this long tradition of protection intellectual property and knowledge about implementing IPRs, these two countries were still slow at protection IPRs after they got independence. It supports the argument that it is not in consistent with the interests of developing countries to promote IPRs at their current stage of development.

It is not difficult to understand why the developing countries are unwilling to implement the TRIPS to a full extend. In the World Bank's 2002 report, it was estimated that the full implementation of TRIPS would result in enormous net losses from paying patent rents for major developing countries, including South Africa, Korea, Mexico, India, Brazil, and China. It was estimated to be a net loss of over US$15 billion (in 2000 dollars) for Korea, US$5.1 billion for China, US$0.9 billion for India (World Bank, 2002:133, table 5.1). In spite of direct losses in revenues, by adopting TRIPS Agreement, technologically undeveloped countries block themselves from "following the strategy (which many developed countries once pursued) of absorbing the world's knowledge base and coming up to technological speed before protecting foreign intellectual property" (Dreyfuss and Lowenfeld, 1997:303). As a result, developing countries that enter into the TRIPS Agreement at this stage without a creative community in place, are possibly to increase the costs of acquiring the knowledge it needs (Dreyfuss and Lowenfeld, 1997).

In summary, the lesson we can learn from the Asian countries is to tailor the IPR regime, and to make it meet the needs of the current stage of development. With developments in technologies, countries will naturally have the motivation to introduce stronger IPRs when it is necessary and benefiting. For instance, in India, prosperity in software and film industries "spurred some companies to voice a preference for stronger and more effective IP protection both at home and abroad" (Deere, 2009:209). Another example is South Korea. Signed on October 1 2011, the Anti-Counterfeiting Trade Agreement (ACTA) is the highest-standard plurilateral agreement ever achieved concerning the enforcement of intellectual property rights. The United States, Australia, Canada, Korea, Japan, New Zealand, Morocco and Singapore signed ACTA, which is perceived as "an important step forward in the

international fight against trademark counterfeiting and copyright piracy" by the Office of the United States Trade Representative (USTR) (USTR, 2011). Korea signed the treaty even before the European Union and Switzerland.

5.2 Panel Analysis

5.2.1 Data and Methodology

In the remaining part of this paper, we analyze the impacts of IPRs on innovation in the ICT sector through a panel data. Panel data analysis is better than a cross-sectional analysis on the mean value of variables of the years because the former have much more observations, ensuring better precision and higher power.

To compare impacts of IP protection on countries at different level of development, in this research countries are divided into developed countries, developing countries and the least developed countries. As we are interested in developments of countries over the period, countries are classified according to a standard before the start of the period. The 69 countries included in the analysis are classified according to the "classification of countries" in the Human Development Report 2005. More specifically, countries are classified according to their GNI per capita in 2003: those countries whose GNI per capita are equal to or less than $765 are low income countries, those between $766 to $9, 385 are middle income countries, and those equal to or more than $9, 386 are high income countries. The merit of this classification is its accuracy. However, it is also an abrupt division. Those countries around the threshold may not have much difference. Higher income cannot guarantee better technological capabilities, with the oil countries as an obvious example.

The paper analyzes the full sample and four sub-samples. The full sample include all 69 countries, while the four sub-samples include low and middle income countries, high income countries, low and middle income countries excluding net exporters of fuel or natural resources, and high income countries excluding net exporters of fuel or natural resources respectively. More specifically, panel models are built on the group of "high income" countries and the combined group of "middle income" and "low income" countries, as there are too few observations in the "low income" group. To eliminate the specialty of resource exporting countries, such as oil

exporting countries, we also conduct analysis on the 2 groups without resource exporting countries. More samples can also present more accurate estimations of coefficients. The number of countries in each class and each sample are summarized in the 2 tables below. A list of countries in each class is provided in the Appendix.

Table 5 Sample and sub-sample composition

Low income	Middle income	Low and middle income resource exporting countries	High income	High in come resource exporting countries
5	34	10 (Algeria; Chile; Colombia; Ecuador; Egypt; Nigeria; Saudi Arabia; Trinidad and Tobago; Venezuela; Zimbabwe)	30	2 (Kuwait; United Arab Emirates)

Low and middle income sample	High income sample	Low and middle income without resource exporting countries sample	High income without resource exporting countries sample	Full sample
39	30	29	28	69

Source: Human Development Report 2005

Table 6 below summarizes variables and sources of data included in the panel analysis. Every variable has data of all 69 countries, covering a 9-year period from 2006 to 2014.

Table 6. Summary and sources of variables

	Expected Sign	Measurement and Transformation	Sources
I Dependent Variable			
Number of Patents		Natural logarithm	OECD Statistics
II Independent Variable			
IPR protection	+	Index, 1-7; natural logarithm	World Economic Forum: reports.weforum.org
III Control Variables			
GDP per capita	+	Natural logarithm	UN: unctadstat.unctad.org
GDP growth rate	+	Levels	The World Bank: data.worldbank.org
Infrastructure	+	Levels	The World Bank: data.worldbank.org
Human capital	+	Dummy, 4 categories	UN: hdr.undp.org
Openness to trade	+	Natural logarithm	UN: unctadstat.unctad.org
Economic freedom	+	Dummy, 4 categories	FRASER INSTITUTE: www.freetheworld.com
Year dummies		Dummy variable used for years 2006-2014	

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

The dependent variable is the logged number of patent applications filed under the Patent Co-operation Treaty (PCT) in the ICT sector, and the numbers are calculated by applicant's country of residence. PCT grants protection for an invention in 148 countries throughout the world (PCT). The data comes from OECD statistics. The unit of measure used is number, and the indicator used here is patent counts by technology. In addition, we count by the application date rather than granting date, as it can take a long time before a patent get granted, and thus applications can better

reflect innovation activities in the corresponding year. Furthermore, the ICT-related patents are identified according to the 8th edition of the International Patent Classification (IPS), including telecommunications, consumer electronics, computers, office machinery and other ICT (OECD: Concepts & Classification).

There are mainly two kinds of measures of innovation that have been adopted. One measures the input of innovation, which is R&D expenditures. The other measures innovation output, i.e. the number of patent applications or patents granted (Chen and Puttitanun, 2005). As the paper focuses on the impacts of IPRs on developing countries, and data on R&D expenditures are generally not available for developing countries, we use the number of patent applications in the ICT sector instead. Innovation has always been difficult to measure, and as software and databases are protected under copyright, patent numbers cannot cover all innovation activities in ICT. However, it is still a consistent measure that can reflect the intensity of innovations.

The independent variable that we are interested in is the strength of IPR protection. It is rather difficult to directly analyze the effects of TRIPS Agreement on different countries, as we would have to develop a measurement for implementation of the agreement in each country. Instead, we rely on IPR protection index to account levels of IPR protection in each country. If promoting IPR is indeed helpful, countries with stronger protection should have more innovations every year. Most of the previous researches use the patent rights index developed by Ginarte and Park for 110 countries for the period 1960 to 2005 (GP Index) to conduct empirical analysis. However, the latest data of GP Index ends in 2005, and it is broken down into 5 years' intervals, therefore it is not feasible for our panel. Therefore, we use the indicator of 1.02 Intellectual Property Protection constructed by the World Economic Forum (WEF), which is released every year since 2006.

The WEF IP index measures the strength of the protection of intellectual property, including measures of anti-counterfeiting, patent strength, and copyright piracy in each country. An advantage of this index is that it focuses on the degree of actual IP protection, not simply the strength of IP laws (Deere, 2009:100). It's score ranges from 1 to 7, a score of 1 means extremely weak protection, while a score of 7 means extremely strong protection. The variable is logged. In addition, there is a lack

of data in the year 2010. To compensate, we take the mean of 2009 and 2011 as the IPR score of 2010.

Beside the dependent and independent variables, we also introduce 6 control variables, two of which are dummy variables.

As mentioned above, the size of the market in a country influences the profitability of investments in a country, thus the variable of market size should have a positive correlation with innovation activities. We use GDP per capita as a proxy for market size in a country, reflecting the demand factor. It is measured by US dollars at current prices and current exchange rates per capita and the values are logged.

The variable of GDP growth rate measures macroeconomic stability. It is defined as the annual percentage growth rate of GDP at market prices based on constant local currency, and the aggregates are based on constant 2005 US dollars. As GDP growth rate is already a ratio, we do not take natural logarithm.

A countries ability to absorb foreign technology and produce its own innovations might rely on its level of infrastructure (Schneider, 2005). As we are interested in developments in the high-technology ICT sector, related infrastructure should be an important factor. We include a variable of infrastructure defined as Internet users per 100 people. Internet users are defined as those individuals who have used the Internet (from any location) in the last 12 months. Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc. As this variable is already a ratio, we do not take natural logarithm.

The variables of human capital and economic freedom are 2 dummy variables. As human capital is one of the main factors pushing economic and social development, it should be an explanatory variable Human capital is measured by average number of years of education received by people aged 25 and older. Differences in education level lie primarily in difference of levels of education, for example primary and secondary school, not of specific lengths. Thus treating it as a dummy variable is feasible. More specifically, according to the standards of United Nations Human Development Reports every year, countries are categorized into “very high human development”, “high human development”, “medium human development”, and “low human development”.

As for the variable of economic freedom, research has shown that economic freedom can promote prosperity and other positive outcomes (Islam, 1996; Ali, 1997). Economic Freedom of the World (EFW) index measures the degree of economic freedom in five major areas: size of government; legal system and security of property rights; sound money; freedom to trade internationally and regulation. The scale of measurement is 0 to 10, with a higher score indicating a higher level of economic freedom, and the total score is the average of ratings of these 5 areas (Chen and Puttitanun, 2005: 484). In accordance with the index, countries belong to the first quartiles are categorized into "very high economic freedom", the second quartiles "high economic freedom", the third quartiles "medium economic freedom" while the fourth quartiles "low economic freedom". For both variables, countries are classified every year by corresponding standards of division that year. As with the index of IPR protection, the problem of using an index is that the weight of each component is arbitrary. However, to conduct a quantitative empirical analysis in order to analyze our research question, the paper needs to rely on these indexes.

Lastly, we have the variable of openness to trade. This variable is different from the component of "freedom to trade" of the economic freedom variable. The latter measure restraints affecting international exchange: tariffs, quotas, hidden administrative restraints and controls on exchange rates and the movement of capital (EFW 2015 Annual Report, 2015:6). The variable of openness to trade is defined as the sum of exports and imports of goods and services measured in US dollars at current prices and current exchange rates in millions. The variable is also transformed into natural logarithms.

5.2.2 Descriptive Statistics

From the minimum and maximum values of the variables, we can see that countries have quite different conditions and performances. The correlation coefficient between numbers of patent application and patent protection suggests that they are positively correlated with each other. All variables have relatively sizeable correlation coefficients with the variable of patent applications, supporting the relevance of these control variables.

Table 7. Summary Statistics of the Variables

Full Sample	N	Min	Max	Mean	Std.Dev
1.Patent (ln_pat)	621	0	10.07	3.50	2.78

2.IPR (ln_ipr)	621	0.49	1.87	1.41	0.29
3.GDP (ln_gdp)	621	6.06	11.66	9.48	1.24
4.GDP growth rate (gdpgr)	621	-17.67	15.24	2.86	3.72
5.Infrastructure (infra)	621	2.54	98.16	52.73	26.37
6.EDU (edu_cat)	621	0	3	1.91	0.85
7.Openness (ln_open)	621	8.53	15.46	12.17	1.49
8.Economic Freedom (eco_cat)	621	0	3	2.02	1.09

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

Table 8 Pairwise Correlation coefficients

Full Sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) ln_pat	1.00							
(2) ln_IPR	0.70	1.00						
(3) ln_GDP	0.62	0.70	1.00					
(4) GDP_gr	-0.14	-0.18	-0.30	1.00				
(5) infra	0.63	0.72	0.87	-0.33	1.00			
(6) edu_cat	0.49	0.57	0.70	-0.24	0.70	1.00		
(7) ln_open	0.84	0.48	0.53	-0.05	0.48	0.32	1.00	
(8) eco_cat	0.42	0.66	0.62	-0.17	0.60	0.60	0.27	1.00

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

The table 9 compares rankings of countries by average numbers of patent applications in ICT and average ratings of IPR protection across the years 2006 to 2014. Countries belong to top 20 by both patents and IPR protection are labeled with a star in the front. An interesting finding is that, the "Asian Miracles", including China, Korea, and India all ranks top 20 according to patent applications in ICT, yet they do not belong to the top regarding IPR protection. It implies that for the developing countries, IPR may not be as influential in promoting innovation activities.

Table 9 Rankings of countries by Patents and IPR

Rank	Patent	IPR
1	*US	Finland
2	*Japan	Singapore
3	China	Switzerland
4	Korea	New Zealand
5	*Germany	Netherlands
6	*France	Sweden
7	*Sweden	Luxembourg
8	*Netherlands	Germany
9	*UK	France
10	*Finland	Denmark
11	*Canada	UK
12	*Switzerland	Austria
13	Israel	Norway
14	*Australia	Australia
15	Italy	Ireland
16	*Singapore	Japan
17	Spain	Canada
18	*Austria	Hong Kong
19	*Denmark	Iceland
20	India	US

*Sources: patent (OECD), IPR (WEF)

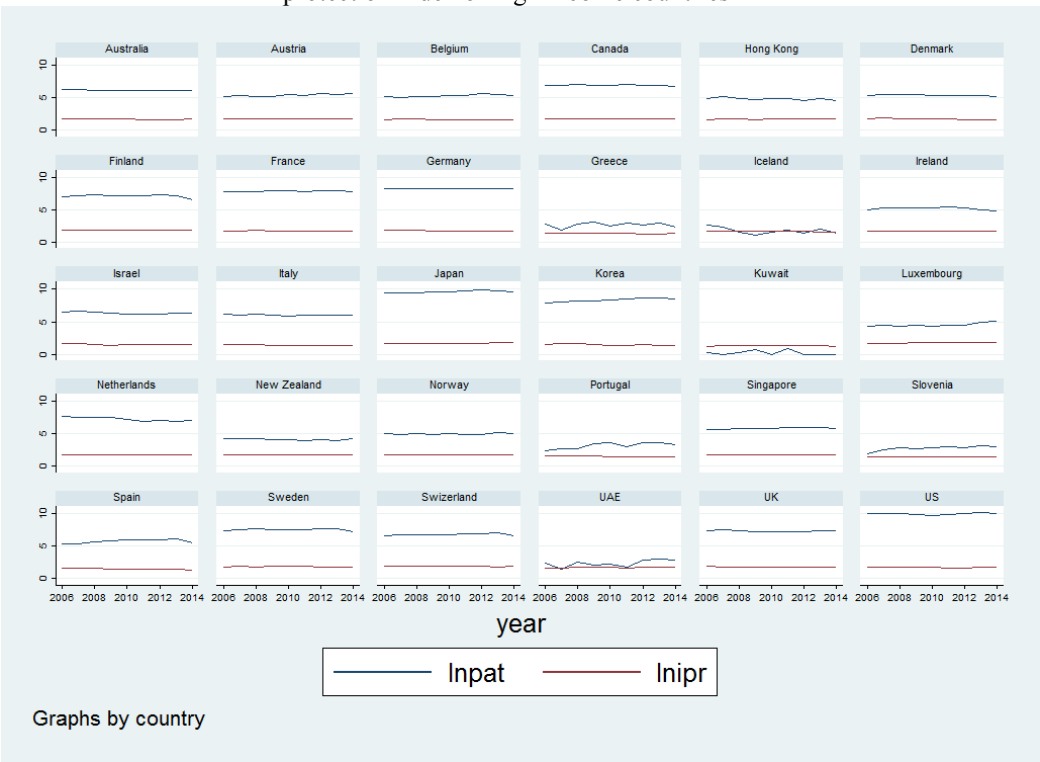
*Countries belong to top 20 by both patents and IPR protection are labeled with a star in the front.

Next, we plot the time series of ICT patent applications and IPR protection index for the two groups. Generally, the panel data looks stationary. For the low and middle income developing countries, there seem to be no clear relation between IPR and patents. Within this group, in most of the cases number of patent applications evolves without much change in IPR protection. Compared to the developing countries whose mean of numbers of patent applications is only 6.36 ($e^{1.85}$), the mean level across high income countries over the period is 281.46 ($e^{5.64}$). Although the lines are almost horizontal for the high income countries, they actually suggest a more positively correlated relationship between the two variables: stable level of one accompanies stable performance of the other variable. More specifically, as these advanced countries have already set up high levels of IPR protection, maintaining in the high protection level sustains the prosperity of their innovation activities. What is interesting is that within the group of high income countries, only for South Korea the trends of patents and IPR protection seem to move in opposite direction.

Figure 6. Time-Series Plots of logged numbers of patent applications in ICT, and ratings of IPR protection index of low and middle income countries

Sources: Patents (OECD), IPR (WEF)

Figure 7. Time-Series Plots of logged numbers of patent applications in ICT, and ratings of IPR protection index of high income countries



Sources: Patents (OECD), IPR (WEF)

5.2.3 Methods and Model

Firstly, we take formal panel data unit root tests on all variables. Specifically, for the full sample, we look into three tests: Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and Maddala and Wu (MW) tests. As the time span of our data is only 9 years, considering the results of multiple results can help us reach more reliable conclusion. The statistics listed in table 10 below suggest that for the majority of the cases, we do not have unit root. Where we find signs of unit root in levels, there is no unit root in first differences.

Table 10 Panel Data Unit Root Test

Full Sample	LLC		IPS		MW	
	t-star	p-value	statistic	p_value	L-star	p-value
ln_pat	-11.99	0.00	NA		-6.07	0.00
Ln_IPR	-13.84	0.00	-3.25	0.00	-7.23	0.00
ln_GDP	-4.06	0.00	-1.4e+2	0.00	-24.88	0.00
GDP_gr	-27.76	0.00	-17.89	0.00	-29.43	0.00
infra	-1.41	0.08	-2.8e+2	0.00	-9.82	0.00

ln_open	-6.14	0.00	-19.9203	0.00	-23.73	0.00

Note: All tests include 2 lags and a constant.
For the Im-Pesaran-Shin (IPS) test, the variables of ln_GDP, infra and ln-open include trend.
For the Maddala and Wu (MW) test, the variables of ln_GDP, infra and ln-open include trend.
Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

For the four sub-samples, we report the results of LLC test as an example. The results are similar with the full sample tests. In short, we have the problem of first order autocorreation in some variables.

Table 11 Levin-Lin-Chu Panel Unit Root Test

	Low and middle income sample		Low and middle income without resource exporting		High income sample		High income without resources exporting	
	t-star	p-value	t-star	p-value	t-star	p-value	t-star	p-value
ln_pat	-5.85	0.00	-4.67	0.00	-11.82	0.00	-11.75	0.00
Ln_IPR	-5.71	0.00	-3.48	0.00	-18.24	0.00	-18.13	0.00
ln_GDP	-4.67	0.00	-85.75	0.00	-400	0.00	-390	0.00
GDP_gr	-19.39	0.00	-16.58	0.00	-23.92	0.00	-23.29	0.00
infra	-640	0.08	-560	0.00	-13.49	0.00	-13.60	0.00
ln_open	-7.34	0.00	-7.28	0.00	-36.16	0.00	-35.46	0.00

Note: All tests include 2 lags and a constant.
For the first sample in table 11, infra include trend.
For the second sample, IPR, ln_GDP and infra include trend.
For the third sample, ln_GDP and ln_open include trend.
For the fourth sample, ln_GDP and ln_open include trend.
Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

The method we choose is the Generalized Method of Moments (GMM) model. We do not use the fixed-effects regression analysis because the prerequisite of it is that "there is no endogeneity problem and the lagged dependent variable is not included in the analysis" (Ulku, 2004:13). However, in our case there is endogeneity. For instance, the strength of IPR protection may well be partially determined by economic performance, as it at least takes abundant resources to build and maintain the institutions. GMM estimation is suitable for "small T, large N" panels, which applies to our case here, as we have a 69 countries and 9 years' panel. It is also established for situations where independent variables are not strictly exogenous, where there is fixed effects (cross section country fixed effects) and were there are even heteroscedasticity and autocorrelation within individuals. In addition, GMM uses first differences of the series, which fix the first order autocorrelation problem in some of the variables. For a model robustness test, we also report the result of the GMM estimator with Windmeijer finite sample correction on the full sample.

Windmeijer correction is developed to solve the problem of underestimation of the standard errors (Leger, 2006).

The GMM model is a dynamic model, where the lagged dependent variable is used as a regressor:

$$y_{it} = \alpha y_{i,t-1} + \beta x'_{it} + u_{it}$$

$$u_{it} = \gamma_i + \epsilon_{it}$$

The GMM yields consistent estimators as long as residuals do not have AR(2) and the regressors are not correlated with the error term (Ulku, 2004:17). The results of test of serial correlation in the first-differenced errors at order two (AR(2) test), as well as Hansen tests of the correlation between regressors and the error term are reported at the end of each model. The null hypothesis of AR(2) test is zero autocorrelation in first-differenced errors, and the null of Hansen test is exogeneity. Therefore, at 5% significance level, we accept the null of AR(2) and Hansen test, and conclude that our GMM models yield consistent estimators.

5.2.4 Results of panel analysis

Table 12 General Methods of Moments (GMM) Regression Analysis of ICT Innovation Performances

	Full sample (1)	Full sample (GMM with Windmeijer correction) (2)	Low and middle income sample (3)	Low and middle income sample (without resource exporting countries) (4)	High income sample (5)	High income sample (without resource exporting countries) (6)
Ln_PAT_L1	0.68** (0.00)	0.67** (0.00)	-0.04 (0.83)	0.37** (0.01)	0.87** (0.00)	0.84** (0.00)
Ln_IPR	2.45** (0.05)	2.36 (0.12)	2.75 (0.27)	2.10 (0.26)	0.69 (0.44)	2.13** (0.01)
Ln_IPR_L1	-2.60** (0.05)	-2.91* (0.06)	-1.25 (0.51)	-0.43 (0.81)	-1.62 (0.16)	-1.76 (0.10)
Ln_IPR_L2	1.67** (0.00)	1.59** (0.01)	1.49 (0.16)	0.16 (0.85)	1.32** (0.03)	1.23** (0.05)
Ln_GDP	-0.73 (0.37)	-0.94 (0.41)	-0.80 (0.39)	-0.45 (0.35)	-0.07 (0.52)	-0.15 (0.36)
Ln_GDP_L1	0.52 (0.51)	0.83 (0.45)	---	---	---	---
GDPgr	0.04* (0.10)	0.04 (0.27)	0.08 (0.19)	0.10** (0.02)	0.02 (0.22)	0.02 (0.19)
GDPgr_L1	-0.04** (0.04)	-0.03 (0.23)	---	---	---	---
infra	-0.06** (0.00)	-0.06** (0.02)	-0.02 (0.64)	-0.04 (0.24)	-0.02 (0.26)	-0.00 (0.78)
infra_L1	0.07** (0.00)	0.06** (0.02)	0.07 (0.19)	0.07* (0.05)	0.02 (0.41)	-0.00 (0.95)
Ln_open	-0.73 (0.49)	-0.71 (0.60)	1.38** (0.00)	0.65** (0.05)	0.21** (0.03)	0.31* (0.08)
Ln_open_L1	2.37*	1.91	---	---	---	---

	(0.06)	(0.23)				
Ln_open_L2	-1.27 (0.11)	-0.75 (0.45)	---	---	---	---
Low Human Capital	-0.83 (0.20)	-0.89 (0.26)	-1.11 (0.45)	-0.48 (0.69)	omitted	omitted
Medium Human Capital	-0.32 (0.53)	-0.75 (0.17)	-0.47 (0.73)	0.10 (0.91)	-0.41* (0.10)	-0.68** (0.00)
High Human Capital	0.01 (0.98)	-0.01 (0.99)	-0.32 (0.76)	0.15 (0.80)	-0.10 (0.31)	-0.15 (0.12)
Very High Human Capital	reference	reference	reference	reference	reference	reference
Low Economic Freedom	0.70 (0.13)	0.55 (0.23)	1.22 (0.28)	0.64 (0.34)	-0.14 (0.67)	0.47 (0.30)
Medium Economic Freedom	0.65* (0.10)	0.60 (0.17)	0.47 (0.62)	0.40 (0.63)	-0.01 (0.97)	0.49* (0.07)
High Economic Freedom	0.38 (0.21)	0.39 (0.16)	0.44 (0.44)	0.56 (0.11)	-0.01 (0.97)	0.37* (0.06)
Very High Economic Freedom	reference	reference	reference	reference	reference	reference
Year dummies	…	…	…	…	…	…
constant	-3.62 (0.12)	omitted	-12.51 (0.03)	-6.36* (0.10)	omitted	omitted
Hansen test (*p-value)*	0.99	0.99	1.00	1.00	1.00	1.00
AR (1) test (*p-value)*	0.00	0.00	0.02	.00	0.02	0.01
AR (2) test (*p-value)*	0.23	0.31	0.78	.77	0.19	0.98
Observations	483	483	273	203	210	196
Number of countries	69	69	39	29	30	28

** significant at 5%; *significant at 10%

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

Table 12 above reports the results of GMM models. They address the endogeneity problem by including instrumented lagged dependent variable in the analysis. The coefficients of lagged patent application are significant and sizable, except for the sample of low and middle income countries. For instance, for the full sample, a 10% increase in number of patent applications in the previous year leads to around 7% increase, suggesting a country's current capacity of innovation has a strong influence on its future performance. As for the coefficients of IPR, they are only statistically significant for the sample of high income countries. For these countries, a 10% increase in the score of IPR protection index in the present year leads to around 21% increase in ICT patent applications. At the 10% level of significance, a negative effect of the first lag of IPR protection is detected. Although the size is smaller than the present year, it is still difficult to explain. However, the second lag of IPR protection is both significant for the 2 samples of high income countries. We can see that the size of impact of IPR protection decreases over time, but the total effect of the 3-year period is positive for the high income countries.

Contrary to levels of per capita GDP, the variable of GDP growth rate has a positive and significant impact in both of the sample of low and middle income and high income countries without resources exporters (model (4) and (6)). It suggests that compared to wealth, the pace of development in a society has more significant influence on ICT innovation activities, especially for the developing countries. For these countries, one-unit increase in GDP growth rate (e.g. 1% to 2%) leads to around 10.5% increase in number of ICT patent applications. As for infrastructure, it does not have statistically significant effects on the high income countries, possibly because these countries have already reached a very high level of Internet penetration. For the low and middle income countries without resource exporter group, the first lag of infrastructure variable is positive and significant. A one-unit increase in Internet penetration rate leads to around 7% increase in ICT patent applications. The coefficients of economic openness are significant and sizable for all sub-samples. The variable of human capital dummies is only significant for high income countries. For these countries, higher education level of the population is positively correlated to innovation outcomes. In contrast, the variable of economic freedom index is generally not statistically significant.

As for robustness of our models, the size and significance of the coefficients of the 2 models (with or without Windmeijer correction) on the full sample is quite similar. In addition, the signs and statistical significance for the coefficients on the full sample and four sub-samples are basically the same, and the coefficients are especially similar for the statistically significant ones. The results suggest that our models are relatively robust. However, there are clearly weaknesses in the analysis. The GMM model uses first differences of the data, thus it might cause loss of information. Although the results of the two models on the full sample is quite similar, there are still some coefficients that are less significant with the model with Windmeijer correction. This may well be due to the fact that the size of the data set is small, and the time span is quite short. To achieve more concrete conclusions, we will need more data available.

The results suggest that innovation, measured by the number of ICT applications, strongly correlates to past level of innovation outcomes in the ICT sector in both the group of low and middle income countries and the group of high income countries.

The size of this effects are more significant in the high income group. This could be due to the fact that current capacity of innovations is an important factor in determining the innovation capacity next year. This is reasonable, as it is hardly possible that a country can equip itself with the important resources and capacities that do not exist before in a short term of one year. The influence of past innovation outcomes is more than twice sizable in the high income countries than they are in the developing countries. This shows that the size of innovation outcomes in the ICT sector are more stable in the high income countries. In contrast, ICT innovations are experiencing more rapid changes and developments in the developing countries. For example, we have shown that the number of ICT applications in Malaysia grew to more than 7 times in 2014 that it was in 2006. It suggests that developing countries are at a crucial stage, when rapid developments are happening in the ICT sector. It thus further emphasizes the importance of deriving appropriate policies to keep this high pace of development in these countries.

The results also suggest that other factors, such as infrastructure and economic openness are more important and significant factors in promoting ICT innovations in the developing countries. Therefore, instead of allocating resources to build institutions for IPRs, developing countries should prioritize the needs to improve infrastructures, including telecommunication devices in order to promote ICT developments. In addition, the results also support the theory that it is beneficial and strategic to operate as an open economy. In the context of globalization and worldwide trade, developing country should open their channel to the outside world, which will also open up opportunities for technology transfer.

Consistent with previous studies, the result of our panel analysis also suggest that the impacts of IPR protection vary considerably between countries, and the impacts indeed depend on the level of development of the economy in question. More specifically, by looking at 69 developing and developed countries for the period of 2006 to 2014, the results support that IPRs have a different impact on the size of ICT innovation outcomes in the high income developed countries and the low and middle income developing countries. Although stronger IPRs have positive and significant effects on the number of ICT applications in developed countries, the mechanism is insignificant in the group of developing countries.

The panel analysis thus suggests that not only for the broader issues of total FDI, economic growth rate or total patents applications in all sectors, the impacts of IPR protection also varies between countries in the specific ICT sector. The difference we find supports the lesson we have learnt from the successful cases in the previous section. The developing countries need to tailor the IPR regulations in order to serve their needs of development at current stage. Strengthening intellectual property right protection is not a goal in itself; the ultimate goal is to promote innovations and developments. After they gained the innovative technologies and capacities, the demands to protect IPRs will naturally appear. At that time, strong protection on IPRs will provide necessary incentives for innovators to spend efforts and invest on R&D.

If intellectual property rights protection is not a significant driver of ICT developments in the developing countries, what factor is? There is no clear-cut answer, but it revolves around issues of state strategy and investments. Telecommunications authorities are state enterprises in most countries (Alleman et al., 1994: 1-2). On the one hand, it requires state-wise efforts to construct telecommunications infrastructures, such as broadband facilities. On the other, national strategies can play a crucial role in promoting developments in the ICT sector. India is a typical example of state-oriented success. Since the early 1980s, the Indian state has played a major role in setting strategic plans in ICT. The Tenth Five-year Plan of India in 2001 identifies telecommunications as a critical component of infrastructure in an emerging knowledge-based economy (Bajwa, 2003). State oriented projects, such as India Health Care Project (began in 1994), Warna Wired Village, and Land Records Computerization Programme, are all efforts initiated by Indian government to increase efficiency, as well as to provide support, knowledge and information to rural areas by using and carrying forward penetration of ICT (Bajwa, 2003). Together with a strategic approach towards IPRs, India has become the world's largest exporter of ICT services and ICT enabled services, as well as the main supplier for business process outsourcing (BPO) (UNCTAD, 2007: xxviii). It is hard to imagine how a low income country can afford to take off in a high-technology sector and become a key player in the world, if it has followed strict rules of the international IPR regime.

Developing countries require an equal position in negotiations in international IPR regimes, and they also need flexibility with regards to implementing IPR

regulations in order to adapt exogenous rules to local needs. In an official statements announced by Group of 77 and China, developing countries emphasized that "greater policy space for innovation, adaptation and improvement of technology in the light of local conditions and requirements is crucial without being unduly constrained by requirements arising from the application of intellectual property rights and other obligations such as TRIPS agreement" (Group of 77 and China, 2003:10) They urge United Nations Conference on Trade and Development (UNCTAD) to analyze on whether the strengthening of intellectual property including TRIPS are effective on "transfer of technology to developing countries, protection of traditional knowledge, genetic resources, and folklore, and fair and equitable benefit sharing" (Group of 77 and China, 2003:30-31). The inequality and inflexibility for developing countries have even been admitted and opposed by some developed countries. For instance, in 2001, the Dutch Minister for Development Cooperation argued that developing countries must be allowed to make us of TRIPS "without rich countries putting a knife on their throat", and that "the whole point of multilateral agreements is to protect countries from the bilateral jungle where the strongest always win" (Deere, 2009:175).

6. Conclusion

Relying on experience of successful models in ICT and a panel data set, the objective of this paper is to evaluate whether there is a positive relationship between IPR protection and innovation outcomes in the ICT sector. The results of my study suggests that improving IPR protection is only positive, and statistically and economically significant for the high income countries (excluding resource exporters). For the low and middle income developing countries, factors of macroeconomic stability, infrastructure, and economic openness are more important and influential on innovation outcomes in the ICT sector. For the high income countries, higher level of IPR protection means more patent application in the ICT sector. In contrast, for the low and middle income countries, the positive impact of IPR protection is not statistically significant. Consistent with previous researches of TRIPS's impacts on general economic growth and innovation outcomes, the analysis here also suggests that the impacts of TRIPS vary between developing and developed countries.

Economic development is an urgent yet complex issues. We cannot expect any one method to be the magical key to advancements in innovations, especially when the method is a one-size-fits-all solution like TRIPS Agreement. The Agreement is imposed on all countries regardless of specific conditions and demands of each country. We cannot expect what serves the interests of the IP holders in the high income countries to also meet the interests of IP users in developing countries. Historical experience from several developed countries, as well as more recent experience from the Asian Miracle countries have all gone through a phase of weak IPRs when they were catching up technologically.

Most importantly, one of the principle of the TRIPS Agreement is to benefit both producers and users of technology, and to contribute to technical innovation and the transfer of technology. The very intention and ultimate goal of introducing intellectual property rights is to disseminate knowledge and to enhance social welfare. Therefore, the very intention and ultimate goal of introducing TRIPS should also be to transfer technology to IP users in the developing countries, as well as to enhance social welfare in the poorer regions of the world. For most of the developing countries, the only chance they possess to be equally treated is through multilateral international platforms. International rulemakings such as TRIPS must avoid being manipulated by the strong powers or serving the interests of a few under a delicate disguise. For TRIPS to promote innovations in developing countries, and for developing countries not to be further left behind in the ICT round of developments, flexibilities to meet the various needs of these countries should be considered by TRIPS.

Endnote

[1] The first four chapters draw on my course paper with the same title as the present thesis.

Appendix

I. Country Classification

Table 13. Country classification

Low income	Middle income	High income
India	Algeria	Australia
Kenya	Argentina	Austria
Nigeria	Brazil	Belgium
Pakistan	Bulgaria	Canada
Zimbabwe	Chile	China, Hong Kong SAR
	China	Denmark
	Colombia	Finland
	Costa Rica	France
	Croatia	Germany
	Czech Republic	Greece
	Ecuador	Iceland
	Egypt	Ireland
	El Salvador	Israel
	Estonia	Italy
	Guatemala	Japan
	Hungary	Korea, Republic of
	Jamaica	Kuwait
	Jordan	Luxembourg
	Malaysia	Netherlands
	Mexico	New Zealand
	Morocco	Norway
	Peru	Portugal
	Philippines	Singapore
	Poland	Slovenia
	Saudi Arabia	Spain
	Slovak Republic	Sweden
	South Africa	Switzerland
	Sri Lanka	United Arab Emirates
	Thailand	United Kingdom
	Trinidad and Tobago	United States
	Tunisia	
	Turkey	
	Uruguay	
	Venezuela (Bolivarian Republic of)	

II. Descriptive statistics and correlation table

Table 14. Summary Statistics of the Variables

Low and middle income sample	N	Min	Max	Mean	Std.Dev
1.Patent (ln_pat)	351	0	9.41	1.85	1.88
2.IPR (ln_ipr)	351	0.49	1.70	1.23	0.21
3.GDP (ln_gdp)	351	6.06	10.16	8.61	0.90
4.GDP growth rate (gdpgr)	351	-17.67	14.19	3.86	3.74
5.Infrastructure (infra)	351	2.54	84.24	35.70	20.04
6.EDU (edu_cat)	351	0	3	1.52	0.81
7.Openness (ln_open)	351	8.53	15.36	11.50	1.33
8.Economic Freedom (eco_cat)	351	0	3	1.49	1.08

Low and middle income sample (without resource exporting countries)	N	Min	Max	Mean	Std.Dev
1.Patent (ln_pat)	261	0	9.41	2.13	1.99
2.IPR (ln_ipr)	261	0.85	1.90	1.26	0.19
3.GDP (ln_gdp)	261	6.55	10.03	8.62	0.85
4.GDP growth rate (gdpgr)	261	-14.72	14.19	3.83	3.61
5.Infrastructure (infra)	261	2.54	84.24	37.19	20.81
6.EDU (edu_cat)	261	0	3	1.60	0.84
7.Openness (ln_open)	261	9.25	15.36	11.57	1.39
8.Economic Freedom (eco_cat)	261	0	3	1.66	0.99

High income sample	N	Min	Max	Mean	Std.Dev
1.Patent (ln_pat)	270	0	10.07	5.64	2.26
2.IPR (ln_ipr)	270	1.24	1.87	1.66	0.15
3.GDP (ln_gdp)	270	8.39	11.66	10.61	0.51
4.GDP growth rate (gdpgr)	270	-9.13	15.24	1.57	3.29
5.Infrastructure (infra)	270	27.88	98.16	74.87	14.50
6.EDU (edu_cat)	270	1	3	2.43	0.60
7.Openness (ln_open)	270	9.36	15.46	13.04	1.21
8.Economic Freedom (eco_cat)	270	0	3	2.71	0.58

High income sample (without resource exporting countries)	N	Min	Max	Mean	Std.Dev
1.Patent (ln_pat)	252	1.10	10.07	5.96	1.98
2.IPR (ln_ipr)	252	1.27	1.87	1.67	0.14
3.GDP (ln_gdp)	252	8.39	11.66	10.60	0.52
4.GDP growth rate (gdpgr)	252	-9.13	15.24	1.46	3.15
5.Infrastructure (infra)	252	27.88	98.16	75.62	14.00
6.EDU (edu_cat)	252	1	3	2.49	0.55
7.Openness (ln_open)	252	9.36	15.46	13.08	1.23
8.Economic Freedom (eco_cat)	252	0	3	2.70	0.59

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

Table 15 Pairwise Correlation Table

Low and middle income sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) lnpat	1.00							
(2) IPR	0.41	1.00						
(3) lngdp	0.23	0.22	1.00					
(4) gdpgr	0.16	0.05	-0.18	1.00				
(5) infra	0.23	0.31	0.78	-0.25	1.00			
(6) edu_cat	0.04	0.31	0.66	-0.18	0.59	1.00		
(7) lnopen	0.81	0.16	0.33	0.19	0.22	-0.01	1.00	
(8) eco_cat	-0.08	0.40	0.37	-0.11	0.37	0.52	-0.20	1.00

High income sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) lnpat	1.00							
(2) IPR	0.40	1.00						
(3) lngdp	0.11	0.39	1.00					
(4) gdpgr	-0.01	0.15	0.05	1.00				
(5) infra	0.32	0.56	0.43	-0.01	1.00			
(6) edu_cat	0.49	0.33	0.24	0.02	0.42	1.00		
(7) lnopen	0.77	0.20	-0.01	0.04	0.09	0.22	1.00	
(8) eco_cat	0.36	0.60	0.26	0.26	0.22	0.17	0.39	1.00

Low and middle income sample (without resource exporting countries)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) lnpat	1.00							
(2) IPR	0.31	1.00						
(3) lngdp	0.21	0.26	1.00					
(4) gdpgr	0.19	0.00	-0.27	1.00				
(5) infra	0.18	0.30	0.82	-0.29	1.00			
(6) edu_cat	-0.06	0.32	0.67	-0.18	0.58	1.00		
(7) lnopen	0.85	0.13	0.26	0.19	0.19	-0.06	1.00	
(8) eco_cat	-0.37	0.16	0.28	-0.19	0.29	0.49	-0.44	1.00

High income sample (without resource exporting countries)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(9) lnpat	1.00							
(10) IPR	0.28	1.00						
(11) lngdp	0.17	0.57	1.00					
(12) gdpgr	0.06	0.22	0.04	1.00				
(13) infra	0.25	0.53	0.48	0.02	1.00			
(14) edu_cat	0.34	0.18	0.30	0.07	0.37	1.00		
(15) lnopen	0.82	0.13	0.00	0.05	0.03	0.15	1.00	
(16) eco_cat	0.45	0.68	0.27	0.29	0.26	0.20	0.40	1.00

Sources: OECD Statistics; WEF; UNCTAD statistics; World Bank; UN Human Development Reports; Fraser Institute

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