Patent Rights and Economic Growth:

Evidence from Cross-Country Panels of Manufacturing Industries

Albert G.Z. Hu* and I.P.L. Png**

February 2009
This version: January 2010

Abstract

The objective of patent rights is to foster innovation and economic growth. However, to date, there is little robust evidence that patents "work".

Here, we applied a difference-in-differences strategy to study the impact of changes in patent rights within panels of up to 54 manufacturing industries in up to 72 countries between 1981-2000. We found that stronger patent rights were associated with faster growth among more patent-intensive industries.

During 1991-95, for an industry with average patent intensity, a one standard deviation increase in patent rights (equivalent to an increase from Hong Kong to Australia) was associated with an increase in growth of 0.69% points, or almost a fifth of the average industry growth rate of 3.7%.

The effect of patent rights on growth became stronger in the 1990s than in the 1980s. Patents "worked" through both encouraging factor accumulation and technical progress. Our findings were robust to alternative measures of both patent rights and patent intensity, specification of the growth equation and sample, and controls for various possible confounds, including financial development, trade openness, and human capital.

---

* ecshua@nus.edu.sg Department of Economics, National University of Singapore; ** ipng@nus.edu.sg NUS Business School, National University of Singapore, 1 Business Link, Singapore 117592, Tel: +65 6516-6807, http://www.comp.nus.edu.sg/~ipng/. We thank Bronwyn Hall, David Levine, Ashish Arora, Emeric Henry, Bernard Yeung, Matthew Henry, Minyuan Zhao, Josh Lerner, and participants in seminars at the University of Connecticut, Goizueta Business School, the H.K. University of Science and Technology, the 6th IOMS Workshop, Tuck School, the Conference on Empirical Legal Studies, the Australian National University, and the Pacific Innovation Conference for helpful discussions and advice and Kelvin Seah and Lim Zong Liang for able research assistance. Financial support from the NUS Academic Research Fund (R-122-000-091-112 and R-313-000-089-112) and the Lim Kim San Professorship at the NUS Business School is gratefully acknowledged.

1. Introduction

The basic rationalization of intellectual property (IP) rights is the tradeoff between static and dynamic efficiency (Nordhaus 1969; Scherer 1972). IP rights provide, ex ante, exclusivity in the commercial exploitation of innovations. In turn, such innovations – whether new products, processes, or creative works – provide the impetus of economic growth. However, ex-post, given existing inventions and creations, IP rights limit usage by end-users and also by follow-on creators and inventors, and hence, reduce welfare.[1]

Economic theorizing on the fundamental tradeoff in the design of optimal IP regime has flourished, and, the policy debate has been intense. By contrast, there is scant empirical evidence to validate the basic premise that IP rights have fostered or do foster invention and creative work, still less economic growth (Hall 2007; Hu and Jaffe 2007).

Changes in U.S. law and legal system over the 1980s, particularly, the passage of the Bayh-Dole Act, the establishment of the Court of Appeals for the Federal Circuit, and a revision in the legal standard for invalidation of a patent from "a preponderance of the evidence" to "clear and convincing evidence", strengthened the rights of patent holders. The legal changes provided an opportunity to examine empirically whether stronger IP rights lead to more innovation. However, the vast endeavor to uncover this linkage has yielded little robust evidence that would substantiate the link despite the "pseudo natural experiment" nature of these events and the rich data available to researchers (Jaffe 2000).

Other studies of the linkage between innovation and IP rights have used cross-country data, industry case studies, and historical archives. Most have focused on patents. The main challenge has been to address the possibility of reverse causality, i.e., richer or more innovative countries increase patent protection (Lerner 2002; Hall 2007).[2] The few studies which addressed the endogeneity of patent rights have focused on particular industries,

---

[1] Article 1, Section 8, Clause 8 of the U.S. Constitution (the so-called "Patent and Copyright Clause") provides that, "The Congress shall have power ... To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

[2] Maskus (2000) and Chen and Puttitanun (2005) demonstrated a U-shaped relationship between the strength of IP protection and GDP per capita.

countries, or historical episodes (Qian 2007; Sakakibara and Branstetter 2001; Moser 2005; Chen 2008).

While empirical support for the hypothesis that stronger IP rights lead to greater innovation is sparse, pressure to strengthen IP rights has been unrelenting. In 1994, members of the General Agreement on Tariffs and Trade concluded the Uruguay round of international trade negotiations, including the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). In 2000, members of the World Intellectual Property Organization agreed the Patent Law Treaty. TRIPS reformed substantive law and the Patent Law Treaty focused on harmonizing and streamlining procedures. Meanwhile, the United States continues to pressure various countries to strengthen their patent and copyright laws in exchange for access to freer trade.[3] Whether this wave of legal reforms, designed to strengthen IP rights, most of which are owned by residents of a few developed countries, has achieved their intended goals remains unproved and thus is the primary motivation of our research.

Here, we focus on one type of intellectual property rights – patents -- and investigate whether stronger patent rights have led to faster economic growth in a sample of countries that spans a wide spectrum of level of economic development. Motivated by Rajan and Zingales (1998), our key innovation was to address the possible endogeneity of patent rights by exploiting inter-industry variation in the importance of patents in appropriating the returns from proprietary knowledge. As patent rights change at the national level, industries *within* a country may react differently according the importance of such rights to the respective industries.

Rather than asking whether countries with stronger patent rights experience faster economic growth, we ask whether more patent-intensive industries grow relatively faster than less patent-intensive industries in countries with stronger patent rights. To the extent that

[3] Notably, under pressure to conclude free trade agreements (FTAs) with the U.S., Singapore, Chile, Australia, and other contracting countries revised their patent laws. See, generally, "USTR – Trade Agreements", http://www.ustr.gov/Trade_Agreements/Section_Index.html [Accessed, September 10, 2008]. Interestingly, FTA negotiations with Thailand deadlocked over patents in 2006, and have been stalled ever since (*Taipei Times* 2006; *San Francisco Chronicle* 2007). Bate and Porter (2008) described the typical U.S. pressure on would-be FTA contracting countries.

industries in which patents are a more important means of protecting innovations are more responsive to strengthening of national patent protection, the pharmaceutical industry, which relies heavily on patents to protect its proprietary knowledge, should exhibit a higher rate of growth in response to stronger patent protection than the food and beverage industry, where patents are less important in appropriating the returns from innovations.[4]

We constructed a measure of the strength of the patent regime of a country by incorporating both measures of completeness of patent laws on paper and subjective assessment of the degree to which such laws are enforced. Using a database that comprised four panels of up to 54 three-digit ISIC manufacturing industries in up to 71 developed and developing countries, we related the growth rate of industry value added to national patent rights interacted with industry patent intensity.[5]

We found that more patent intensive industries experienced higher growth as a result of stronger patent rights. For an industry with average patent intensity, a one standard deviation increase in patent rights (equivalent to an increase from Hong Kong to Australia) in 1990 was associated with an additional annual growth of value added of 0.69% in the subsequent 5-year period, or almost one-fifth of the average industry growth rate. We also found that the growth-promoting effect of patent rights became stronger in the 1990s than in the 1980s, and that the effect took place both through encouraging factor accumulation and technical progress. The findings were robust to multiple checks, including alternative measures of both patent rights and patent intensity, specification of the growth equation and sample, and controls for various possible confounds, including financial development, human capital, and trade openness.

The rest of the paper is organized as follows. Section 2 places our research in the context of related studies in the literature. We set up the empirical model and discuss estimation issues in Section 3, and describe the sources of data and construction of variables

---

[4] Rajan and Zingales (1998) studied whether national financial development facilitated economic growth. To deal with possible reverse causality, they focused on differences among industries in their relative dependence on external finance.

[5] These were panels organized by country-industry rather than country-year.

in Section 4. Then, we report and discuss estimates of the baseline model in and various robustness tests in Section 5. Section 6 concludes.

2. Previous Literature

The empirical investigation of whether stronger patent rights leads to higher rate of economic growth is predicated on two structural premises, i.e., stronger patent rights give rise to more innovation, and the latter, in turn, generate faster economic growth, through cost saving technologies and new products and services. Related to the first premise is the issue of whether stronger patent rights in developing countries lead them to secure greater inward technology transfer from developed countries. We will focus on the empirical studies that investigate these issues in a cross-country or international setting to which our study is most closely related.[6]

In an important contribution, Ginarte and Park (GP) (1997) compiled an index of patent rights for 60 countries between 1960-90. The GP Index focused only on patent rights, as published in law, with no attention to enforcement. Nevertheless, the index has been widely applied in subsequent studies as a measure of the strength of the national patent rights regime. Park and Ginarte (1997) used the index to study the relation of economic growth, investment, and R&D expenditure to patent rights. They found no relationship between stronger patent rights and economic growth. However, among richer countries (with above median income), stronger patent rights were positively related to investment and R&D. There was no such relation among poorer countries.

Focusing on 18 manufacturing industries in 21 OECD countries between 1980-95, Park (2003) found that both labor productivity and R&D expenditure increased with the GP Index. In a larger sample of countries, R&D expenditure did increase with patent rights, but labor productivity did not. Among 32 countries between 1981-90, Kanwar and Evenson

[6] See Hall (2007) for a comprehensive survey of academic scholarship on patents. Jaffe (2001) critically assessed the earlier literature on the U.S. patent policies and their consequences. In the context of development, an important question is how international harmonization of patent protection, i.e., increasing the level of patent protection in developing countries to that in developed countries, affects the welfare of developed and developing countries (McCalman 2001; Grossman and Lai 2004).

(2003) found that stronger patent rights, as measured by the GP Index, were associated with higher R&D intensity (ratio of R&D expenditure to GDP).

A serious limitation of these cross-section analyses by Park and Ginarte (1997), Park (2003), and Kanwar and Evenson (2003) is that the causality might run in both directions. A country's patent regime may be dependent on its level of economic development. Specifically, economic growth could have led to stronger political support for patent rights, which then materialized through the relevant law and procedures (Ginarte and Park 1997; Hall 2007). The reverse causation hypothesis is supported by empirical studies showing a U-shaped relationship between patent regime and GDP per capita (Maskus 2000, Chen and Puttitanun 2005) or an increasing relationship between the two (Lerner 2002).

Lederman and Saenz (2005) investigated the impact of patent grants and R&D expenditures on cross-country differences in economic growth. To account for patents granted and R&D expenditure possibly being endogenous, they used the Ginarte-Park index as an instrument. However, they did not consider that patent laws (as characterized by the Ginarte-Park index) themselves might be endogenous to national economic growth.

Utility models (also known as petty patents) are intended to protect small, incremental innovations. Generally, the application process for utility models is simpler and less rigorous than for patents.[7] Kim, Lee, and Park (2008) investigated the impacts of utility models and patents on economic growth, applying generalized method of moments estimation to address possible endogeneity. They found that stronger patent rights, as measured by the GP Index, were associated with greater R&D intensity only in developed countries. Among developing countries, the adoption of utility models was correlated with higher R&D intensity.

In independent work closest to ours, Vichyanond (2009) studied the impact of patent laws, as characterized by the GP index, on national exports from 24 three-digit SIC

[7] Most jurisdictions grant utility models on a registration basis without any substantive examination for novelty, non-obviousness, or usefulness. Utility models are viewed as being useful for rewarding incremental innovations for small and medium size enterprises and in developing countries, which are less capable of producing major innovations. For more on utility models, see the World Intellectual Property Organization: "Protecting Innovations by Utility Models" (http://www.wipo.int/sme/en/ip_business/utility_models/utility_models.htm, accessed February 8, 2009).

manufacturing industries. To account for endogeneity, Vichyanond followed Rajan and Zingales (1998). Using the NBER Patent Database Database (Hall, Jaffe, and Trajtenberg 2001) he constructed a measure of patent intensity for each industry as the number of U.S. patents weighted by citations divided by the average value of U.S. production. He then regressed exports by industry-country on the interaction between the GP index and patent intensity. The analysis revealed a non-monotone relationship between exports and patent laws. Below a threshold, exports increased with stronger patent laws, while beyond the threshold, exports fell with stronger patent laws.

Focusing on the pharmaceutical industry, Qian (2007) identified 26 of 92 countries as introducing pharmaceutical patents between 1978 and 2002. She controlled for the possible endogeneity of patent regime by identifying, for each country that introduced pharmaceutical patents, a control country that either already had such patents or did not introduce such patents. Stronger patent protection was associated with higher domestic R&D only among economically advanced countries.[8]

Using historical panels of 15 Western countries over several centuries, Chen (2008) showed that enactment of patent law was associated with higher rates of scientific discoveries, inventions, and innovations.[9] Although Chen did apply country-level fixed and random effects, his estimation methods still left open the possibility that countries which experienced faster technological progress were more likely to enact patent laws.

Other studies of the impact of patent laws on innovative activity focused on particular countries or historical episodes. Moser (2005) studied innovations exhibited at 19th century World Fairs. Countries without patent laws focused innovations on industries where patents were less important, hence, apparently, patent laws had a significant effect on the direction of technological innovation. Sakakibara and Branstetter (2001) examined the effects of Japan's expansion of the scope of patent protection in 1988. They hypothesized that, if the increase

[8] In her main sample, including both developed and developing countries, Qian (2007) used U.S. patents granted and pharmaceutical exports to the U.S. as proxies for R&D expenditure in the absence of data on R&D itself. The dependent variable was R&D expenditure only for a sub-sample of OECD countries.

[9] One sample comprised 1012 major scientific discoveries, inventions and innovations between 1750–1950, while the other sample comprised 115 major inventions between 1590–1900.

in patent scope had increased the return to innovation, it would have lead to higher R&D spending and more patents, but they found no evidence for either outcome.[10]

To summarize, while limited studies of particular countries, industries, or historical episodes have shown that stronger patent rights were related to greater patenting or R&D, the link from the latter to economic growth was missing. On the other hand, the studies that tried to relate patent rights to economic growth left open the issue of reverse causality.

3. Empirical Strategy

Our research question was whether stronger patent rights promote economic growth. We addressed the possible endogeneity of patent rights by following Rajan and Zingales (1998) and specifying the linear regression model,

$$\begin{aligned}\Delta\log(VA_{ic}) = \alpha_0 + \alpha_1\log(VA_{ic,0}) + \alpha_2 \text{Patent Rights}_{c,0} \times \text{Patent Intensity}_i \\ + \beta_c D_c + \beta_i D_i + \varepsilon_{ic},\end{aligned} \tag{1}$$

where *i* represented industry and *c* represented country. The dependent variable, $\Delta\log(VA_{ic})$, was the growth of value added in industry *i* of country *c* over a period of time; Patent Rights$_{c,0}$ represented the strength of the country's patent rights at the beginning of the period; Patent Intensity$_i$ characterized the importance of patents to industry *i*, relative to other industries, in appropriating the returns from innovations. We assumed that the relative patent intensity of industries was the same across all countries.[11] Vectors, D_c and D_i, were country and industry fixed effects. We also included the initial level of value added as a control for time-invariant industry-country characteristics that might be correlated with the interaction of patent rights and patent intensity.[12] [13]

[10] Branstetter, Fisman, and Foley (2006) studied affiliates of U.S. businesses in 16 countries that reformed patent law between 1982 and 1999. They found that the reforms were associated with an over 30 percent increase in royalty payments for technology transfer. Concurrently, the affiliates increased R&D and patent filings, suggesteing that some of the increase in royalty payments reflected an increase in technology transfer.

[11] While equation (1) specifies patent intensity as varying by industry only, the specification does accommodate an additive country-specific element in patent intensity which is common across all industries in the country. In any estimation, this country-specific element in patent intensity would be absorbed by the country fixed effect.

[12] Following Rajan and Zingales (1998), our specification included country and industry fixed effects. Hence, we could not include patent intensity (which varied with industry but not country) or patent rights (which varied with country but not industry) as separate explanatory variables, since these

The identification of the effect of patent rights on economic growth as specified in equation (1) drew on variation in patent rights across countries and the assumption that the effect varied across industries within a country. By organizing the data as country-industry panels, we could control for both country- and industry- specific effects. It is this identification strategy that distinguishes our study from previous work.

Our primary interest was in the sign and magnitude of the coefficient of the interaction between patent rights and patent intensity, specifically, whether $\alpha_2 > 0$, i.e., whether, and the extent to which, more patent-intensive industries grew relatively faster in response to stronger patent rights in the country.

Before proceeding, we should explain why national patent laws should matter at all for production and value-added. One possible view is that patent laws should matter only in major markets, while the location of production would be determined simply by comparative advantage. By this argument, if China is a cheap place in which to produce electronics for the U.S. market, China's patent laws are not material. Only U.S. patent laws are material -- to prevent interlopers from selling infringing products in the U.S. However, the weakness in this reasoning is that it ignores that patents provide exclusivity over *processes* as well as products. If China's patent laws are weak, an interloper could copy a manufacturer's processes and produce in China and then export similar (but not infringing) products to the U.S. Indeed, of all patents granted by the U.S. Patent and Trademark Office, …% were for processes and ..% for products.

We emphasize that stronger patent rights, by providing inventors with greater exclusivity, need not necessarily imply faster industry growth. By strengthening exclusivity and market power, stronger patent rights could stimulate the *prospective* invention of new products and processes. However, by further limiting the usage of *existing* inventions,

---

would not be identified. Further, we specified the dependent variable as the growth of value added, rather than the level.

[13] It might be asked why we did not pool the data from the four periods into a single industry-country-year panel. The reason was that the industry mix in the countries varied substantially over time. To cope with this variation, it would be necessary to include separate country fixed effects for each time period, which would be equivalent to our procedure of estimating separate industry-country panels for each of the four periods.

stronger patent rights would curb usage and, in particular, reduce follow-on invention which would otherwise build on existing inventions (Bessen and Maskin 2009).

We should note that our identification strategy did depend on the assumption that industry specific shocks were not correlated with the choice of patent rights at the national level. In particular, it might be possible that, in countries where patent-intensive industries are growing relatively faster, these industries would lobby for stronger patent rights. We addressed this concern in two ways. One was to specify patent rights as at the beginning of each period, which would precede any industry specific shocks during the period. The other was to apply estimation by instrumental variables, using various measures that have been proposed as being deep determinants of national institutions.

4. Data and measurement issues

4.1. Industry value added

We used the World Bank Trade, Production and Protection database (Nicita and Olarreaga 2007) to compile data on the value added, employment, and gross capital formation by 3-digit manufacturing industry (ISIC (International Standard Industrial Classification, rev. 3), 151-372) for up to 100 countries between 1976-2004. The original source of the data was an annual survey by the United Nations Industrial Development Organization (Yamada 2005). However, data coverage varied by country and year. The industry value added was deflated using the corresponding U.S. value added deflator.[14] In the absence of a more appropriate deflator for capital goods, we also deflated the gross capital formation series using the value added deflator.

4.2. Effective patent rights

A major measurement challenge that we faced was how to quantify the strength of a country's legal infrastructure in enforcing patent rights so that we could track its changes over time and assess the strength of the national patent regime. As emphasized by economics research into the enforcement of law (Becker 1968; Mookherjee and Png 1992), law is

[14] The deflator was taken from the Groningen Growth and Development Centre, 60-Industry Database, September 2006, http://www.ggdc.net. This database is comparable to the OECD STAN database.

effective only to the extent to which it is enforced. Hence, the national patent regime comprises laws and their enforcement.

The patent rights index compiled by Ginarte and Park (1997) and Park (2008), hereafter "GP index" comprised five components: the extent of coverage of patent protection, membership in international patent agreements, provisions of loss protection, enforcement mechanisms, and duration of protection. Each country was assigned a score between 0 and 1 for each of these five components. The GP index was the unweighted sum of these individual scores and ranges from 0 to 5. The index covered up to 119 countries at five-year intervals from 1960 to 2005.

However, the GP index is subject to a serious limitation. It measures enforcement only to the extent that enforcement mechanisms existed *on paper*, e.g., whether the legal system provided for preliminary injunctions. As constituted, the GP index results in obvious anomalies. For instance, among developing countries, the 1990 index rated Malawi (3.24) and Nigeria (3.05) substantially ahead of Hong Kong (2.57) and Singapore (2.57). Evidently, the GP index did not reflect the actual state of patent rights, *as enforced*.

To our knowledge, no systematic, cross-country metric of enforcement of patent rights is available for the period of study. The closest is the Fraser Institute's index of legal system and property rights, which was reported on a scale of 0 to 10 for up to 141 countries at 5-year intervals from 1970 to 2000. From 1980 onward, the index was compiled from subjective measures of three aspects of the legal system and property rights: legal security of private ownership rights (risk of confiscation); viability of contracts (risk of government repudiation of contract); and rule of law (Gwartney et al. 2000). These subjective measures were compiled from surveys of international business executives as published in the *International Country Risk Guide*.[15]

[15] For 1970 and 1975, the Fraser index covered only the risk of confiscation and the risk of government repudiation of contract, and was based on subjective measures from Business Environment Risk Intelligence. The Fraser index covered the rule of law only from 1980 onward, and, so, we limited our study accordingly.

Drawing on the GP and Fraser indexes, we propose a new index of *effective* patent rights that accounts for both the state of patent laws and their enforcement. We constructed the new index as the product of the GP and Fraser indexes:

Patent rights index = GP x Fraser. (2)

This construction was motivated by economic research into the enforcement of law (Becker 1968; Mookherjee and Png 1992), which emphasizes that effective penalties are the product of the legal penalty and the enforcement rate. From the viewpoint of an inventor, a situation of complete patent laws with zero enforcement is the same as a situation of no patent laws at all. Equivalently, patent laws and enforcement are complements, and hence, it is reasonable to construct the index of patent rights as the product of the GP and Fraser indexes.

Our patent rights index depended on an assumption that enforcement of patent rights was correlated with enforcement of property rights in general, as measured by the Fraser index. While this crude approximation was necessitated by the limited data, we could not think of strong reasons or systematic evidence against it.

In Figure 1, we plotted the Fraser Index against the GP Index scaled up by a factor of two.[16] The two indices were highly correlated. Further, the pattern among OECD countries was markedly different from the non-OECD countries. The correlation between the two indices appeared to be weaker for the non-OECD countries, the correlation coefficients being 0.59, 0.65, 0.59 and 0.81 for 1980, 1985, 1990 and 1995 respectively. For OECD countries, the corresponding coefficients were 0.91, 0.90, 0.93 and 0.84. Towards the end of the sample, the correspondence between the two indices tended to converge among OECD and non-OECD countries. This is consistent with the thinking that the published law is much better enforced in economically advanced countries than in developing countries, and that the gap has narrowed.

We also drew a 45 degree line in Figure 1. A larger proportion of non-OECD countries fell below the line, which indicated that, in these countries, enforcement of laws lagged formal patent legislation. However, among non-OECD countries, Brazil, Hong Kong,

[16] The Fraser Index was produced on a 10-point scale of 10, while the GP was on a 5-point scale. Accordingly, for easier visualization in Figure 1, we scaled up the GP Index by a factor of 2.

Singapore and Taiwan were placed consistently above the line. Within the OECD, France, Italy, the U.K. and the U.S. scored higher on the GP index than the Fraser Index.

We produced a box chart of the patent rights index for each of the four years in Figure 2. The top of each box represents the 75th percentile, the solid line within the box represents the median, while the bottom of the box represents the 25th percentile of the patent rights index. The 1985 cross-section seemed to disrupt a general upward trend. The distribution sharply shifted upward and became much less skewed in 1995, compared to that in 1985 and 1990.

Table 1 presents the top and bottom five countries by our patent rights index.[17] The U.S. was ranked highest in all four years, while the Netherlands always placed among the top five countries. By contrast, Guatemala was consistently among the bottom five countries on the patent rights index.

[Insert Figure 1 here]

[Insert Figure 2 here]

[Insert Table 1 here]

We also decomposed the variance of the patent rights index into three components: between OECD and non-OECD, within OECD, and within non-OECD variations. These are plotted in Figure 3 along with the coefficient of variation of the index (plotted against the right axis). Clearly, the variation in the index shrunk towards the end of the sample. While there was more variation among non-OECD countries than OECD countries, both variations were dominated by that between the two groups, which consistently accounted for over 60% of the total variation in the patent rights index.

[Insert Figure 3 here]

In a set of robustness tests, we used an alternative index of effective patent rights, constructed as the sum of the GP and Fraser indexes, specifically,

[17] Owing to data limitations, not all of these countries were included in our sample.

$$\text{Patent rights index (alternative)} = 0.5 \times [\text{GP x } 2 + \text{Fraser}], \qquad (3)$$

rather than the product of the indexes. Since the GP index ranged from 0 to 5 while the Fraser index ranged from 0 to 10, we multiplied GP by 2 in order to give equal weight to patent laws and their enforcement. By contrast with the multiplicative construction (2), this additive construction, (3), of the effective patent rights index treated laws and enforcement as independent: the marginal effect of one was independent of the other. The ranking of countries by our preferred and alternative indexes of effective patent rights was quite similar.

4.3. Patent intensity

For each industry, we measured patent intensity by the ratio of the number of patents awarded to an industry to the industry's total sales. We used U.S. data to construct this measure of patent intensity by industry and assumed that this measure reflected the relative patent intensity across industries in all other countries. Our rationale for using U.S. data was similar to that of Rajan and Zingales (1998). The U.S. is the world's largest economy and has a highly developed technology base and intellectual property system, including a market for intellectual property. Hence, among the various jurisdictions, the observed patent intensities in the U.S. would provide a reasonable benchmark.

We should note that our use of U.S. patent intensities is conservative in the sense that it would bias downward any finding of an impact of effective patent rights on industry growth. Consider, for instance, furniture and medical appliances in the U.S. as compared with Indonesia. By our measure, in the U.S., the manufacturing of medical appliances is about 2.5 times more patent intensive than furniture (Appendix, Table A.1). In Indonesia, with relatively weak patent rights, it is likely that the manufacturing of medical appliances emphasizes pure assembly, which is a low value-added process, with manufacturing of key components, which is a much higher value-added process. done in the U.S. By contrast, the value-added in manufacturing of furniture might be similar in the U.S. and Indonesia. Accordingly, the actual difference in patent intensity between furniture and medical appliances would be smaller in Indonesia than in the U.S. Hence by comparing the difference in growth rates between furniture and medical appliances in Indonesia with the difference in U.S. patent intensity, we would be biasing against finding any relation.

While equation (1) specifies patent intensity as varying by industry only, the specification does accommodate an additive country-specific element in patent intensity which is common across all industries in the country. This country-specific element in patent intensity would be absorbed by the country fixed effects. Hence, our assumption was only that the *relative* patent intensity across industries was the same in all countries.

We compiled industry-level data from company-level data that we retrieved from the Compustat database. Sales of individual companies were aggregated to the 3-digit ISIC (rev. 3) industry level. [18] In the absence of an appropriate industry sales deflator, we used the value added deflator to deflate sales. Patents granted by the U.S. Patent and Trademark Office to the Compustat companies were obtained from the NBER Patent Database (Hall, Jaffe, and Trajtenberg 2001) using the CUSIP identification number. [19] Individual companies' patent grants were then aggregated to the same 3-digit ISIC level. Finally, we computed patent intensity as the ratio of aggregate industry patent grants to total deflated industry sales.[20] [21]

A major issue was the time over which to measure the patent intensity. The ratio of patents granted to sales might fluctuate with the year to year flow of patent grants. More seriously, during the sample period, following the establishment of the U.S. Court of Appeals for the Federal Circuit in 1982, U.S. patent law and procedure changed substantially: the scope of patents was expanded to encompass biotechnology, software, business methods, and to upstream scientific research tools, materials, and discoveries, and the rights of patent

---

[18] Compustat identified industries by North America Industry Classification System (NAICS). We mapped ISIC (rev. 3) to NAICS using the concordance provided by the U.S. Census Bureau: http://www.census.gov/epcd/naics/concordances/index.html

[19] The NBER Patent Database (http://www.nber.org/patents/) matched patent assignees to companies in the Compustat database by the CUSIP number in the year 1989.

[20] Compustat covers only publicly-listed U.S. companies. Our procedure omitted patents granted to companies not covered by the NBER Patent Database match, and any assignee which was not a U.S. listed company – individuals, unlisted businesses, non-profit organizations and foreign entities. However, the denominator in our measure of patent intensity was consistent with the numerator in the sense that both pertained to the same set of listed U.S. companies.

[21] Our procedure matched 298,000 patents granted to U.S. manufacturing businesses from 1979 to 2000. Over the same period, the USPTO granted around 1.11 million patents to "U.S. non-government organizations", which category is the closest to U.S. manufacturing businesses but was clearly over-inclusive. Hence, our procedure successfully matched at least 26% of patents issued to U.S. manufacturing businesses.

owners were strengthened in various ways (Martinez and Guellec 2004; Henry and Turner 2006; Hall 2007).

Obviously, these changes in patent law and procedure might have affected the incentive to file patents. More pertinent to our analysis, referring to Figure 4, where we plotted the various patent intensity measures, the changes might have had disproportionate effects on patenting *across industries*. For instance, in 1979-82, the patent intensity of "other chemicals" (ISIC 242), which category includes pharmaceuticals, was 0.0384. By contrast, the patent intensity of "office, accounting, and computing machinery" (ISIC 300) was far lower at 0.0001. However, by 1997-2000, the relative position was reversed, with the patent intensity of "other chemicals" having declined to 0.0204, and that of "office, accounting, and computing machinery" exploded to 0.2566. A major reason for the disparity might have been the expansion of patentability to software (Bessen and Hunt 2007).

[Insert Figure 4 here]

While striking, these apparent changes in patent intensity due to idiosyncrasies in U.S. patent law and procedure might not be directly relevant to productivity and growth in other countries. Accordingly, we specified patent intensity as the average over the entire sample period, 1979-2000, and hence, constant over time. Table 2 lists the average patent intensity of various industries. The measure seems to be intuitively reasonable: the patent intensity of other chemicals (ISIC 242), which includes pharmaceuticals, was 0.0249, an order of magnitude larger than that of food and beverages (ISIC 15), which was 0.0014. The patent intensity of accumulators, batteries, and (ISIC 314) was 0.1485, an order of magnitude larger than that of basic metals (ISIC 27), which was 0.0111.

[Insert Table 2 here]

Countries differed in their mix of industries, and this mix varied over time. Referring to Figure 5, we see that patent intensity was correlated with patent rights. Interestingly, countries which were dominated by patent intensive industries tended to have stronger patent rights. This correlation would not pose any challenge to our empirical strategy as our strategy was to test whether more patent-intensive industries grew relatively *faster* in countries where patent rights were stronger, as distinct from the question of whether more patent-intensive industries were relatively *larger* in countries where patent rights were stronger. Indeed, to the extent of diminishing returns or mean reversion, where patent-intensive industries were relatively larger, they would tend to grow relatively more slowly.

[Insert Figure 5 here]

By focusing on patent rights and patent intensity, we emphasized one form of intellectual property rights. Realistically, businesses might rely on any or all of patents, utility models, secrecy, copyrights, and trademarks to exclude others from the commercial exploitation of new technology. The relative importance of these rights varies from one industry to another.[22] Tackling the daunting task of measuring the importance of these various rights and the changes in the corresponding national legal regime was far beyond the scope of the current paper.

However, as an alternative to the patent intensity measure and constructed in a similar way, we used the average R&D to sales ratio over the period 1979-2000 in robustness tests. This was computed as the ratio of R&D to sales for each industry using the Compustat database. Patent intensity and R&D intensity were highly correlated: the unconditional correlation coefficient was 0.50; regressing patent intensity on R&D intensity yielded a statistically significant coefficient of 0.48 and an R^2 of 0.25. If a company's proprietary knowledge is largely an outcome of R&D, then the high correlation suggests that patent intensity captures well the inter-industry variation in the production of proprietary knowledge.

4.4. Other data and measurement issues

In robustness tests, we investigated the impact of patent rights on total factor productivity. To construct TFP, we used the gross capital formation series from the World Bank Trade and Production Database to compute a capital stock measure and so to estimate an industry production function. The capital stock was constructed using the perpetual inventory model (Jorgenson, Gollop and Fraumeni 1987). We assumed an investment growth rate of 5% and a depreciation rate of 10%. We also experimented with alternative rates.[23]

---

[22] See Levin et al. (1987) and Cohen et al. (2000) for results from the Yale Survey on the use of intellectual property rights among U.S. companies.

[23] Capital, k, was assumed to evolve according to the perpetual inventory model: $k_t = (1-\delta)k_{t-1} + I_t$, where δ was the depreciation rate of capital and I_t was gross investment. Initial

Finally, the intersection of the coverage of the patent rights index (5-yearly from 1980) and the NBER Patent Database (up to 1999, extended by Bronwyn Hall to 2002), limited our analysis to four 5-year intervals, viz., 1981-85, 1986-90, 1991-95, and 1996-2000. We related the growth of value added by industry over each of these intervals to the patent rights index for the year preceding the beginning of the interval, e.g., we related the growth of value added between 1981-85 to the patent rights index for 1980.

Table 3 presents summary statistics of the major variables used in our analysis.

[Insert Table 3 here]

5. Results and robustness checks

For a preliminary look at the issue, Table 4 contrasts the rates of growth among the three most vis-à-vis least patent-intensive industries in countries below and above the median of effective patent rights. Specifically, within each sub-sample, for each industry, Table 4 reports the residual growth rate after regressing the growth of value added on industry and country fixed effects.

[… commentary….]

5.1. Baseline

Table 3 presents estimates of our baseline specification, equation (1). The coefficient of the interaction between the industry patent intensity and the patent rights index was positive and statistically significant in all four periods. The effect also exhibited a trend of growing economic significance over time, increasing from 0.0141 and 0.0114 in the 1980s to 0.0397 and 0.0221 in the 1990s.[24] It is also notable that the impact of patent rights appeared to be the strongest during 1991-95, when the Uruguay round of trade negotiations and the TRIPS agreement were concluded.

---

capital stock was constructed as $k_0 = I_1 / (\delta + \gamma)$, where γ was the constant past growth rate of gross investment.

[24] We also estimated the baseline equation over two 10-year intervals, 1981-90 and 1991-2000. The results (unreported, for brevity) were similar: the coefficient of the interaction between national patent rights and industry patent intensity was higher in the 1990s than the 1980s.

[Insert Table 3 here]

These point estimates imply that, for example, in 1990, an increase in patent rights by one standard deviation, or, 9.71 – the equivalent of raising the index from the level of Hong Kong (16.04) to that of Australia (25.78) – would have contributed to an increase of the growth rate of value added by 0.69% points for an industry with the average patent intensity (0.018). Compared with the average industry growth rate of 3.7% in 1991-1995, the effect of strengthening patent rights on economic growth was substantial in economic terms. For the 1981-85, 1986-90 and 1991-95 periods, a one-standard-deviation increase in the patent rights of a country would have led to the annual growth rates of industry value added being higher by 0.21%, 0.18%, and 0.45% points, respectively.

In the baseline model, we had also included initial value added as a further control for country-industry heterogeneity. For all four periods, the coefficient of the initial value added was robustly negative, implying that smaller industries had been catching up with bigger ones. The model fitted the data reasonably well, explaining between 35-58% of the variation in industry growth.

5.2. Alternative measures of patent rights

Our index of effective patent rights measured variations in the completeness of patent laws and their enforcement. In the first robustness check, we used the alternative patent rights index, constructed as the average of two times the GP index and the Fraser index, according to equation (2).

Table 4 reports the estimates of equation (1), using the alternative patent rights index. The results were quite similar to those with the preferred patent rights index, constructed as the product of the GP and Fraser indexes. The coefficient of the interaction between industry patent intensity and patent rights was positive in all four periods and was statistically significant in three periods, viz., 1981-85, 1991-95, and 1996-2000.

The estimated coefficients implied that, for example, in 1990, an increase in patent rights by one standard deviation, or, 1.711 – the equivalent of raising the index from the level of Spain (7.139) to that of the U.S. (8.853) – would have contributed to an increase of the growth rate of value added by 0.81% points for an industry with the average patent intensity

(0.018). This was close to the estimated impact of 0.69% using the preferred patent rights index. We replicated all of the below robustness tests with the alternative patent rights index and obtained results that were similar to those with the preferred patent rights index.

[Insert Table 4 here]

In further tests of robustness with respect to the measure of patent rights, we estimated equation (1) using the GP and Fraser indexes separately as measures of patent rights. As reported in Tables 5 and 6, with both measures, the coefficient of the interaction of patent rights with patent intensity was positive, consistent with more patent-intensive industries growing relatively faster in countries with stronger patent laws.

The estimates using the Fraser index were more precise than those using the GP index. One possible explanation was the larger variation in the Fraser index, which in turn, might be due to its more nuanced assessment of actual enforcement. While the GP index simply compiled the state of patent laws, as published, the Fraser index, which was derived from subjective assessments by international business executives, might have more accurately reflected the actual state of patent rights.[25]

[Insert Tables 5 and 6 here]

5.3. Alternative measures of patent intensity

Besides measuring industry patent intensity as the ratio of patents granted to sales over the entire period 1979-2000, we also computed it as the ratio for the period 1979-82 only, before major reforms of U.S. patent law and procedure (Hall 2007).[26] As reported in Table 7, the pattern of results was similar to those obtained using the average of patent intensity over the

[25] Cohen et al. (2000) reported the share of businesses by industry that regarded patents as important for either product or process innovations. In another check of robustness, unreported for brevity, we estimated the baseline specification, (1), with patent intensity replaced by by Cohen et al.'s measure of patent importance. The results using the importance of patents for product innovation were consistent with our findings using patent intensity. However, Cohen et al.'s industry coverage was much more limited than ours, and so, the power of the estimates was weaker.

[26] Hall et al. (2001) identified 1979 as a turning point in the number of USPTO patent applications and 1983 as the year in which grants began to take off. Accordingly, we focused on the period 1979-82.

entire period, 1979-2000, but the coefficients and the implied marginal effects were smaller and only significant for the 1990s.

[Insert Table 7 here]

Instead of using patent grants, we also used patent applications to construct industry patent intensity. Table 8 reports estimates obtained using the ratio of patent applications to sales for the whole sample period of 1979-2000 as the measure of patent intensity. The pattern of results was similar. This is not surprising as patent applications were closely correlated with patents granted.[27]

[Insert Table 8 here]

By incorporating a general enforcement component, our patent rights index might also capture protection of other forms of intellectual property. Accordingly, in the next robustness check, we used the ratio of R&D to sales in place of patent intensity. To the extent that proprietary knowledge, including that which was protected by patents, is an outcome of R&D, the R&D to sales ratio provides a more comprehensive measure of the importance of intellectual property to an industry.[28]

Table 9 reports results obtained using R&D intensity (as measured by the average R&D to sales ratio for the period 1979 to 2000) in place of patent intensity. The estimates of the interaction of patent rights with R&D intensity were statistically significant in all but the 1986-1990 period. Compared with the baseline estimates reported in Table 3, the implied effects of strengthening patent rights were more moderate: a one-standard-deviation increase in the patent rights index would have led to 9.5%, 0.4%, 6.1%, and 11.1% increases in annual industry growth in the periods 1981-85, 1986-90, 1991-95, and 1996-2000 respectively.

[Insert Table 9 here]

[27] Yet another way to measure patent intensity would be to use the European Patent Office (EPO) or Japan Patent Office (JPO) as the source of patents granted or patent applications. The EPO or JPO patent profile across industries would not necessarily be more representative than the U.S. profile as both European countries and Japan revised patent law and procedure in the 1980s and 1990s (Martinez and Guellec 2004). Moreover, like the USPTO, the EPO and JPO classified patents by patent class rather than industry, so, we would also face the challenge of matching patents with industry.

[28] Arora, Ceccagnoli and Cohen (2008), for example, showed that R&D and patenting are highly correlated.

5.4. Factor accumulation and total factor productivity growth

Our baseline specification, (1), followed that of Rajan and Zingales (1998). The estimated effect of patent rights on industry growth incorporated the direct impact of changes in the strength of patent rights on productivity growth and the indirect impact through changes in investment and employment induced by stronger patent rights.

In the next test, we aimed to isolate the effect of patent rights on total factor productivity by estimating a Cobb-Douglas production function:

$$\begin{aligned}\Delta \log(VA_{ic}) = \alpha_0 + \alpha_2 \text{Patent Rights}_{c,0} \times \text{Patent Intensity}_i + \alpha_3 \Delta \log K_{ic} \\ + \alpha_4 \Delta \log L_{ic} + \beta_c D_c + \beta_i D_i + \varepsilon_{ic},\end{aligned} \tag{4}$$

where K_{ic} represents services of capital and L_{ic} represents labor input in industry i in country c. In this specification, the interaction of patent rights and patent intensity was assumed to affect only the growth of total factor productivity.

Owing to the limited availability of data on capital and labor, the sample size was reduced by more than 40%, so reducing the power of the statistical tests. Table 10 reports estimates of equation (4). The production function seems to have been properly identified: all but one of the elasticities of capital and labor were precisely estimated, of reasonable magnitude, and were not far from indicating constant returns to scale. Controlling for the contribution of factor accumulation, the growth of industry-level total factor productivity was positively associated with the interaction between patent rights and patent intensity in the periods, 1981-85 and 1996-2000.

[Insert Table 10 here]

In unreported estimates, we also estimated equation (4) with the capital stock constructed using various rates of depreciation of capital goods and past investment growth. All coefficient estimates were similar to those reported in Table 10. Clearly, the estimates were not sensitive to assumptions on the depreciation rate and investment growth rate.

In the 1981-85 and 1996-2000 periods, the coefficients of the interaction between patent rights and patent intensity were positive and significant. These results suggested that the growth promoting effect of stronger patent rights was channeled through higher productivity growth, possibly in addition to factor accumulation. Put differently, stronger patent rights had induced faster technical progress. By contrast, during 1986-90 and 1991-95, the statistically insignificant estimates suggests that our earlier finding that stronger patent rights promoted growth had largely worked through more rapid factor accumulation rather than faster technical progress.

Our research design did not allow us to identify whether the technical progress was achieved through indigenous innovation or technology diffusion from abroad, which could take the form of knowledge spillover from foreign direct investment in the host country. However, it is an encouraging finding that stronger patent rights had led to greater technical progress. Also, we could not distinguish whether the increase in factor accumulation was due to domestic or foreign direct investment.

5.5. Financial development

By showing that industries that were more dependent on external finance grew relatively faster in countries which were more advanced in financial development, Rajan and Zingales (1998) showed that financial development facilitated economic growth. Suppose that patent-intensive industries are also more dependent on external finance. Then, if financial development was correlated with the strengthening of effective patent rights, our estimates might be subject to omitted variable bias.

To check this possible bias, we obtained a measure of financial development (ratio of stock market capitalization to GDP) for the countries in our sample from Demirguc-Kunt and Levine (2001). We then estimated an augmented version of the baseline model including the interaction of financial development with patent intensity as an additional explanatory variable.[29] Owing to the limited availability of data on financial development, the sample was reduced by one-third or more.

[Insert Table 11 here]

[29] An econometrically equivalent approach would be to regress the patent rights index on financial development, recover the residuals, and then in a second stage, include the interaction of the residual with patent intensity as an additional explanatory variable in equation (1).

As reported in Table 11, the interaction of patent rights with patent intensity was positive and significant in three of the four periods even with the inclusion of financial development interacted with patent intensity. The additional variable had the interesting effect of causing the estimates of the interaction of patent rights with patent intensity to converge to between 0.027-0.0283 in three of the four periods. Financial development had a negative effect in the 1981-85 period and a marginally positive effect in the 1991-95 period. The positive impact in the 1991-95 period was consistent with our findings, as reported in Table 10, that the growth-promoting effect of stronger patent rights was realized mainly through more rapid factor accumulation in that period. When growth largely occurs through factor accumulation, access to external finance is more important.

5.6. Trade reform and openness

It has been variously shown that economic growth is correlated with liberalization of trade (Sachs and Warner 1995; Wacziarg and Welch 2008). Historically, many patent reforms were implemented together with trade liberalization, particularly among developing countries that acceded to the TRIPs agreement of the Uruguay Round of trade negotiations. Hence, it was important to distinguish the effect of trade liberalization from that of stronger patent protection on industry growth. We did this in the same way as we distinguished the impact of financial development from changes in effective patent rights. We used the measure of trade openness that was developed by Sachs and Warner (1995) and updated and modified by Wacziarg and Welch (2008).[30]

[Insert Table 12 here]

As reported in Table 12, the results were very similar to those including financial development. The interaction between effective patent rights and patent intensity was positive and significant in 1981-85, 1991-95, and 1996-2000. There was little evidence that patent intensive industries benefited more from trade openness than less patent intensive industries – the interaction term was positive and significant in only one period, viz., 1986-1990. Hence, we concluded that the association between stronger patent rights and more rapid growth in patent intensive industries could not be attributed to concurrent trade reform.

[30] The original Sachs and Warner (1995) measure of trade openness has been criticized for the collinearity between protectionist policies and other growth-retarding policies (Rodriguez and Rodrik 2000).

5.7 Human capital

The last potentially confounding factor that we considered was human capital. Patent-intensive industries are likely to benefit relatively more from human capital accumulation. To the extent of any correlation between patent reform and human capital accumulation, it is necessary to distinguish the impact of stronger effective patent rights from the effect of increases in human capital.

[Insert Table 13 here]

To construct our proxy of human capital, we drew on the education attainment database of Barro and Lee (2001) and we used the average years of male secondary and higher schooling (Barro and Sala-i-Martin 2004: 524). Table 13 reports the results. The inclusion of the interaction between human capital and patent intensity did not substantially affect the coefficients of the interaction between patent rights and patent intensity. Accordingly, our conclusion remained that patent intensive industries grew faster in countries with stronger patent protection and the growth promoting effect of strong patent rights became stronger in the 1990s than in the 1980s.

5.8. Potential sampling bias

Our last set of robustness tests focused on possible sampling bias. We repeated all of the specifications presented above using a restricted sample that excluded 1 percent of extreme observations, consisting of the largest and the smallest observations of the growth of the log of value added. The results, which, for brevity, are not reported, were quite similar to those with the full sample reported above: patent-intensive industries grew faster in countries with stronger patent protection; such effect was stronger in the 1990s than in the 1980s and was not diminished by accounting for the potentially confounding effects of financial development, trade openness, and education attainment.[31]

Finally, we investigated the impact of patent rights on industry growth in economically advanced countries. Previous studies had found significant effects of patent rights on R&D or investment only among advanced countries (Park and Ginarte 1997; Qian 2007; Kim, Lee, and Park 2008). We re-estimated the baseline specification, limiting the

[31] All unreported results are available from the authors upon request.

analysis to OECD countries. However, we could not find any growth promoting effect of stronger patent rights. Nor could we find any such effect for the non-OECD subsample. The absence of result was possibly due to insufficient variation in patent rights within the OECD and non-OECD groups, as indicated by Figure 1. For brevity, we do not report the estimates for the OECD and non-OECD sub-samples.

6. Concluding Remarks

We investigated whether stronger patent rights achieved their intended objective of stimulating economic growth. To the best of our knowledge, to date, there is no robust empirical evidence that stronger patent rights indeed stimulate growth, although the U.S. and other developed countries have aggressively exported their stringent intellectual property rights regimes to the rest of the world.

Using an ISIC 3-digit industry level database that spanned 54 manufacturing industries in over 72 countries between 1981-2000, we found evidence that stronger intellectual property rights were associated with faster industrial growth measured by value added. The impact of the stronger effective patent rights was both statistically and economically significant in the four periods we analyzed: 1981-85, 1986-90, 1991-95, and 1996-2000, and had become stronger in the 1990s compared to that in the 1980s.

Our analysis also showed that the stronger effective patent rights promoted industry growth through technical progress in the 1981-85 and 1996-2000 periods and through more rapid factor accumulation in the 1986-90 and 1991-95 periods.

In executing the empirical investigation, we had to deal with challenging measurement issues. Existing patent rights indices largely focus on completeness of patent laws but speak little to the actual enforcement of such laws. We constructed a patent rights index that combined both elements. However, in the absence of a measure of the enforcement of patent rights, we had to use an index of general law and property rights enforcement and made the assumption that this reflected the enforcement of patents. In addition, we had to assume that, within each country, the effective patent rights were the same for every industry.

Another limitation of our study is that we were able to say little about the mechanism by which stronger patent rights stimulated growth. It would be ideal to trace the impact of stronger patent rights on R&D expenditure and thereby through to economic growth. However, comprehensive data on R&D expenditure at the industry level across developed and developing countries is simply not available. Absent such data, the best we could do was to directly estimate the relation between patent rights and growth.

Another important direction for future work is to the study the impact of other forms of intellectual property – notably, copyright and trademark – on economic growth and innovation in general, and creative and inventive activity in particular. Absent a comprehensive resource like the NBER Patent Database, the challenge would be to compile measures of knowledge intensity. The challenge is especially great in the case of copyrights, as, by the Berne Convention, copyright need not even be registered.

References

Arora, Ashish, Marco Ceccagnoli and Wesley M. Cohen, "R&D and the Patent Premium", *International Journal of Industrial Organization*, Vol. 26 No. 5, September 2008, 1153-1179.

Barro, Robert J., and Jong-Wha Lee, "International Data on Educational Attainment: Updates and Implications", *Oxford Economic Papers*, 53, July 2001, 541-563.

Barro, Robert J., and Xavier Sala-i-Martin, *Economic Growth*, 2nd edition, Cambridge, MA: MIT Press, 2004.

Bate, Roger, and Karen Porter, "Health & Medicine: From Bangkok to the Beltway", *The American*, August 26, 2008.

Becker, Gary S. "Crime and Punishment: An Economic Approach", *Journal of Political Economy*, Vol. 76, March/April 1968, 169-217.

Bessen, James, and Robert M. Hunt, "An Empirical Look at Software Patents", *Journal of Economics & Management Strategy*, Vol. 16 No. 1, Spring 2007, 157-189.

Bessen, James, and Eric Maskin, "Sequential Innovation, Patents, and Imitation", *RAND Journal of Economics*, Vol. 40 No. 4, 2009, 611-635.

Chen, Qiang, "The Effect of Patent Laws on Invention Rates: Evidence from Cross Country Panels", *Journal of Comparative Economics*, Vol. 36 No. 4, 2008, 694-704.

Chen, Yongmin, and Thitima Puttitanun, "Intellectual property rights and innovation in developing countries", *Journal of Development Economics*, Vol 78 No 2, December 2005, 474-493.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh, "Protecting Their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or Not)," *NBER Working Paper 7552,* 2000.

Demirguc-Kunt, Asli and Ross Levine, *Financial Structure and Economic Growth: A Cross-Country Comparison of Banks, Markets, and Development*, Cambridge, MA: MIT Press, December 2001.

Branstetter, Lee G., Raymond Fisman, and C. Fritz Foley, "Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-Level Panel Data", *Quarterly Journal of Economics*, Vol. 121 No. 1, 2006, 321-49.

Gallup, John L., Jeffrey D. Sachs, with Andrew Mellinger, "Geography and Economic Development", Center for International Development, Harvard University, Working Paper No. 1, March 1999.

Ginarte, Juan Carlos, and Walter G. Park, "Determinants of Patent Rights: A Cross-National Study", *Research Policy*, Vol. 26 No. 3, October 1997, 283-301.

Grossman, G. and Lai Edwin, "International Protection of Intellectual Property", *American Economic Review*, Vol. 94 No. 5, December 2004, 1635-53.

Gwartney, James, Robert Lawson, and Dexter Samida, *Economic Freedom of the World: 2000 Annual Report*, Fraser Institute, Vancouver, BC, 2000.

Hall, Bronwyn H., "Patents and Patent Policy", *Oxford Review of Economic Policy*, Vol. 23 No. 4, Winter 2007, 568-587.

Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg, "The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools", Working Paper 8498, National Bureau of Economic Research, Cambridge, MA, October 2001.

Hall, Robert E., and Charles I. Jones, "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics*, Vol. 114, No. 1, February 1999, 83–116.

Henry, Matthew D., and John L. Turner, "The Court of Appeals for the Federal Circuit's Impact on Patent Litigation", *Journal of Legal Studies*, Vol. 35, 2006, 85-117.

Hu, Albert G.Z., and Adam B. Jaffe, "IPR, innovation, economic growth and development", Department of Economics, National University of Singapore, October 2007.

Jaffe, Adam B. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process", *Research Policy*, Vol. 29, 2000, 531-557.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni, *Productivity and U.S. Economic Growth*, Cambridge, MA: Harvard University Press, 1987.

Kangur, Alvar, "What Rules in the 'Deep Determinants of Comparative Development?" Department of Economics, University of Oxford, Discussion Paper No. 386, February 2008.

Kanwar, Sunil, and Robert Evenson, "Does Intellectual Property Protection Spur Technical Change?" *Oxford Economic Papers*, Vol. 55 No. 2, April 2003, 235-264.

Kim, Yee Kyoung, Kuen Lee, and Walter G. Park, "Appropriate Intellectual Property Protection and Economic Growth in Countries at Different Levels of Development", 3*d Annual Conference of the EPIP Association*, Bern, Switzerland, October 3-4, 2008.

Lederman, Daniel, and Laura Saenz, "Innovation and Development around the World, 1960-2000", World Bank Policy Research Working Paper 3774, November 2005.

Lerner, Joshua, "Patent policy shifts and innovation over 150 years", *American Economic Review: Papers and Proceedings of the American Economic Association*, Vol. 92 No. 2, May 2002, 221–5.

Lerner, Josh, "The Empirical Impact of Intellectual Property Rigts on Innovation: Puzzles and Clues", *American Economic Review: Papers and Proceedings of the American Economic Association*, Vol. 99 No. 2, May 2009, 343–8.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter, "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity*, 1987, pp. 783–820.

McCalman, Phillip, "Reaping What You Sow: An Empirical Analysis of International Patent Harmonization", *Journal of International Economics*, Vol. 55, 2001, 161-186.

Martinez, Catalina, and Dominique Guellec, "Overview of Recent Changes and Comparison of Patent Regimes in the United States, Japan and Europe", Chapter 7 in *Patents, Innovation and Economic Performance*, Paris, France: OECD Publishing, 2004.

Maskus, Keith, *Intellectual Property Rights in the Global Economy*, Institute for International Economics, Washington, DC, 2000.

Mookherjee, Dilip, and I.P.L. Png, "Marginal Deterrence in Enforcement of Law", *Journal of Political Economy*, Vol. 102 No. 5, 1992, 1039-1066.

Moser, Petra, "How do patent laws influence innovation? Evidence from nineteenth-century world fairs", *American Economic Review*, Vol. 95 No. 4, September 2005, 1214–36.

Nicita, Alessandro, and Marcelo Olarreaga, "Trade, Production and Protection 1976-2004", *World Bank Economic Review*, Vol 21 No. 1, 2007, 165-171.

Nordhaus, William D., *Invention, growth and welfare: A theoretical treatment of technological change*, Cambridge, MA: MIT Press, 1969.

Park, Walter, and Juan Carlos Ginarte, "Intellectual Property Rights and Economic Growth", *Contemporary Economic Policy*, Vol.15 No. 3, July 1997, 51-61.

Park, Walter, "International Patent Protection: 1960-2005", *Research Policy*, Vol. 37 No. 4, May 2008, 761-766.

Park, Walter G., "Do Intellectual Property Rights Stimulate R&D and Productivity Growth? Evidence from Cross-National and Manufacturing Industry Data", in Jon Putnam, ed., *Intellectual Property Rights and Innovation in the Knowledge-Based Economy*, Calgary: University of Calgary Press, 2003.

Rajan, Raghuram G., and Luigi Zingales, "Financial Dependence and Growth", *American Economic Review*, Vol. 88 No. 3, June 1998, 559-86.

Rodriguez, Francisco and Dani Rodrik, "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence", In Ben Bernanke and Kenneth Rogoff, eds., *NBER Macroeconomics Annual* 2000, Cambridge, MA: MIT Press.

Qian, Yi, "Do Additional National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment: A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978–2002", *Review of Economics and Statistics*, Vol. 89, No. 3, August 2007, 436-453.

Sachs, Jeffrey D and Andrew Warner, "Economic Reform and the Process of Global Integration", *Brookings Papers on Economic Activity*, Vol 1, 1995, 1-118.

Sakakibara, Mariko, and Lee Branstetter, "Do stronger patents induce more innovation? Evidence from the 1988 Japanese patent law reforms", *RAND Journal of Economics*, Vol. 32, 2001, 77–100.

San Francisco Chronicle, "Thailand business climate still uncertain: Potential drug patent changes among concerns", March 29, 2007.

Scherer, F. M., "Nordhaus' Theory of Optimal Patent Life: A Geometric Reinterpretation", *American Economic Review*, Vol 62, 1972, 422-427.

Taipei Times, "Thousands protest latest Thailand-US free-trade talks", January 10, 2006, 12.

Vichyanond, Jade, “Intellectual Property Protection and Patterns of Trade”, Department of Economics, Princeton University, November 2009.

Wacziarg, Romain, and Karen Horn Welch, “Trade Liberalization and Growth: New Evidence”, *World Bank Economic Review*, Vol 22, No. 2, 2008, 187-231.

Yamada, Tetsuo, “Relevance and Applicability of the UNIDO Industrial Statistics Database for Research Purposes”, UNIDO ESA/STAT/AC.105/21, Vienna, 2005.

Figure 1. Fraser Index vs. Ginarte Park Index

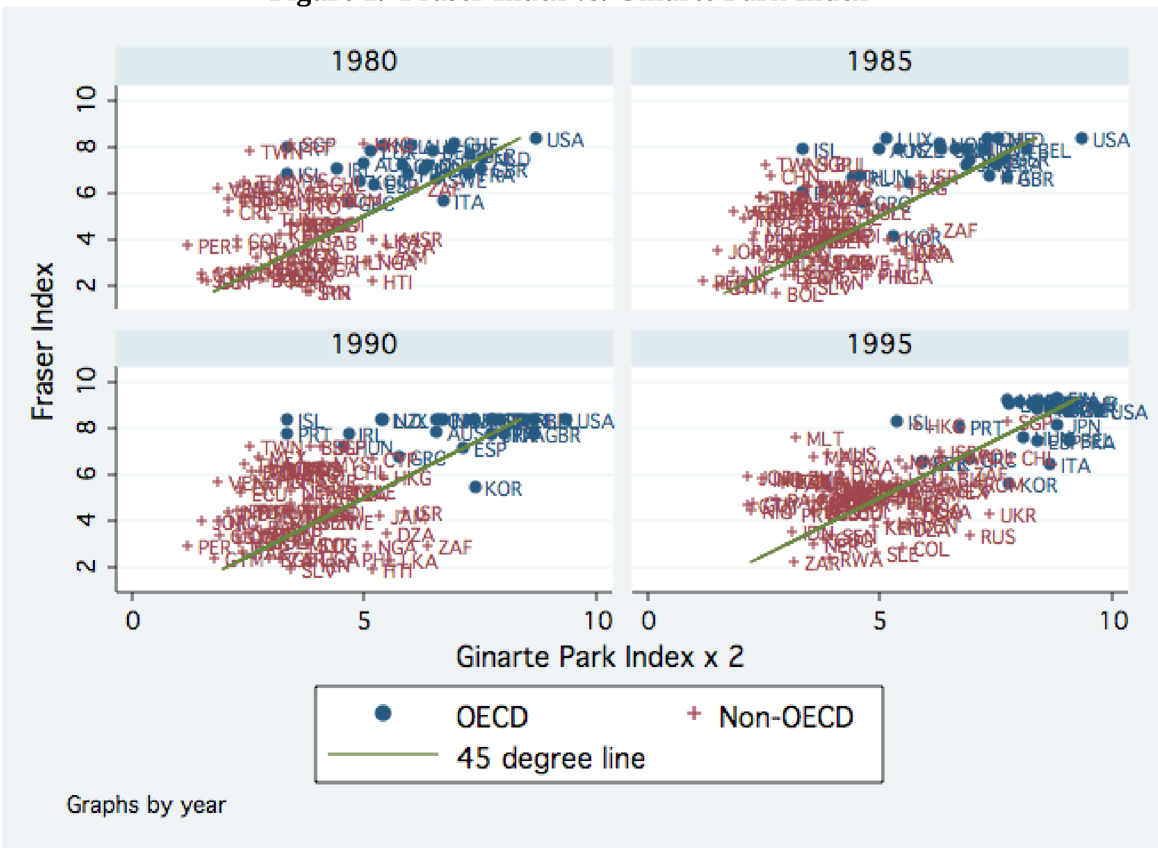


Figure 2. Box plot of patent rights index

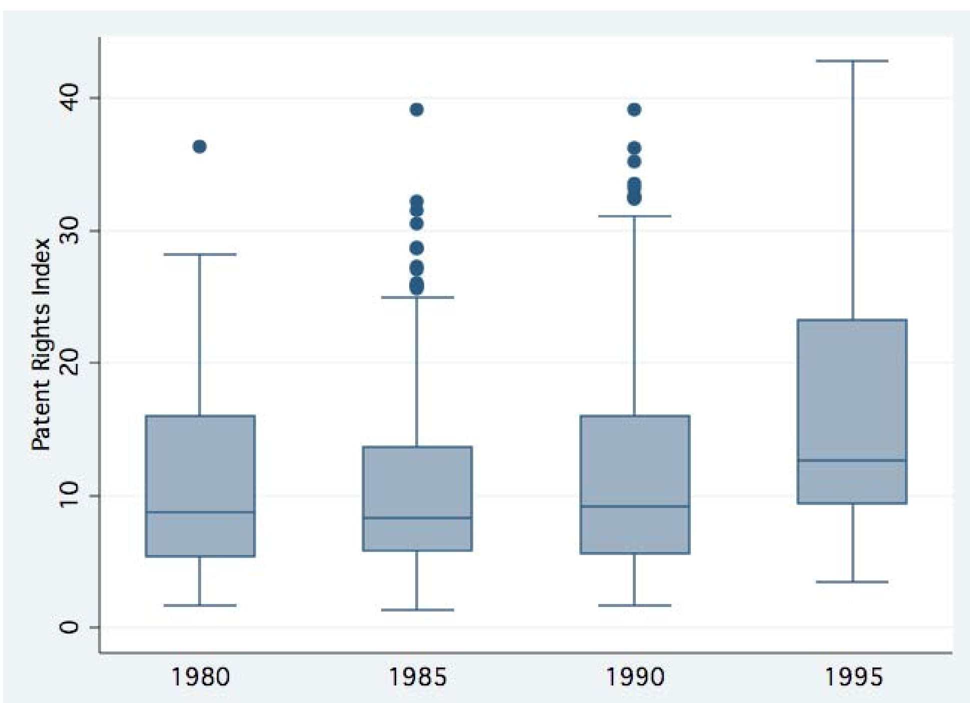


Figure 3. Patent rights index: Variance decomposition

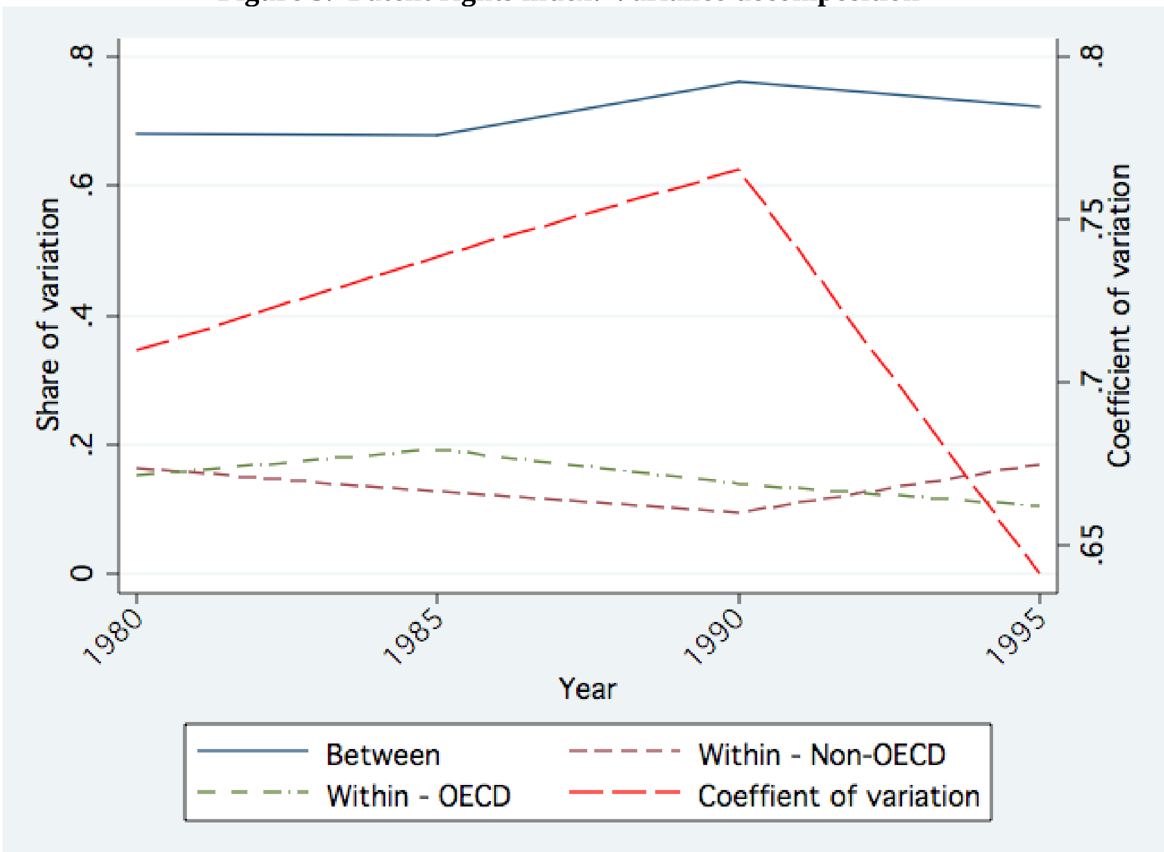


Figure 4. Patent intensity, by industry

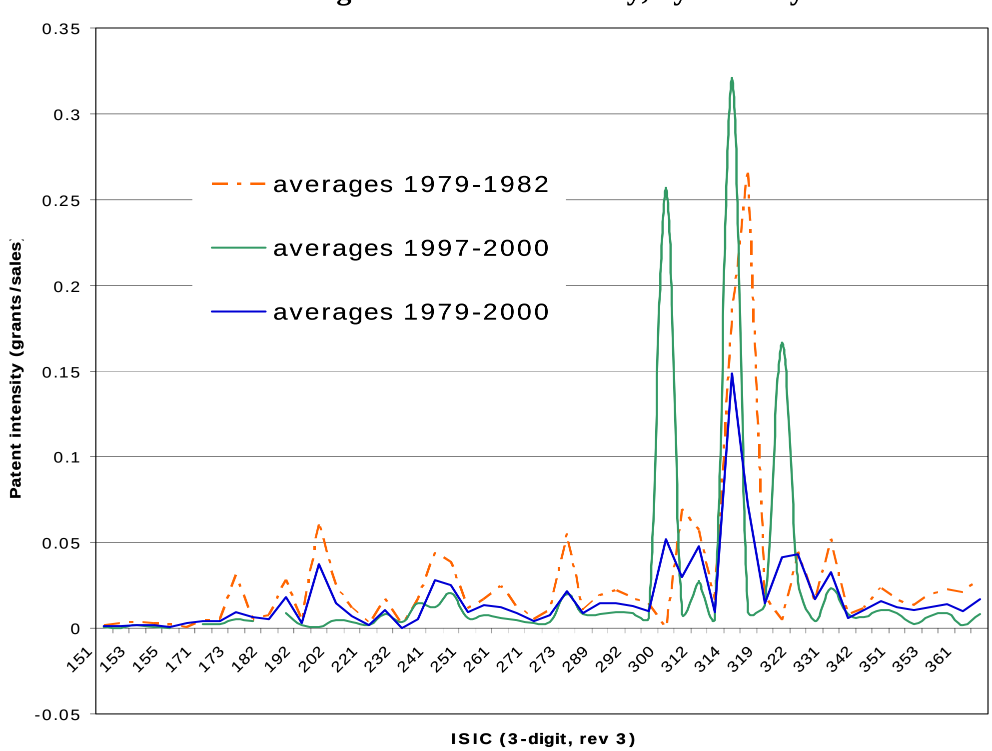
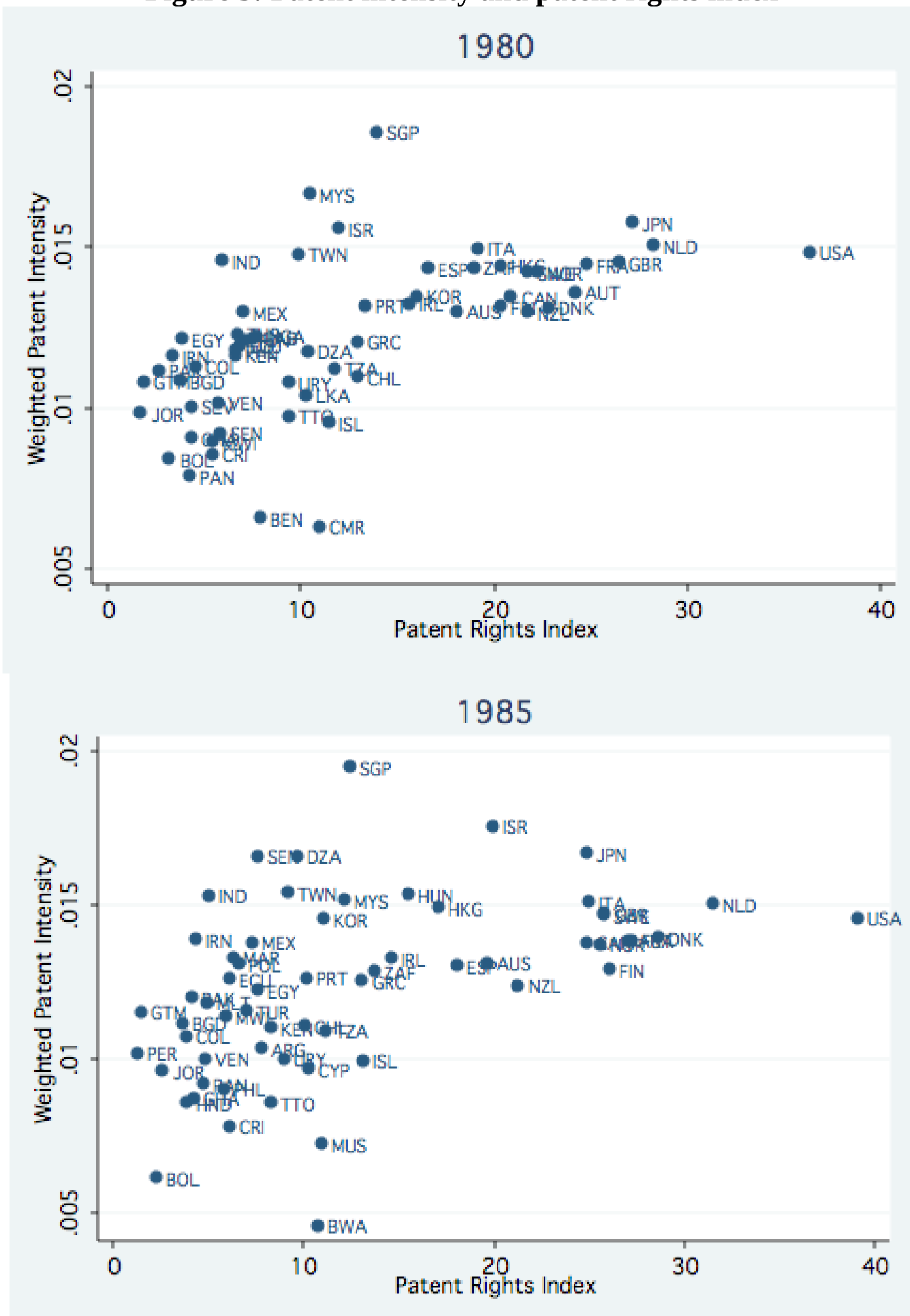
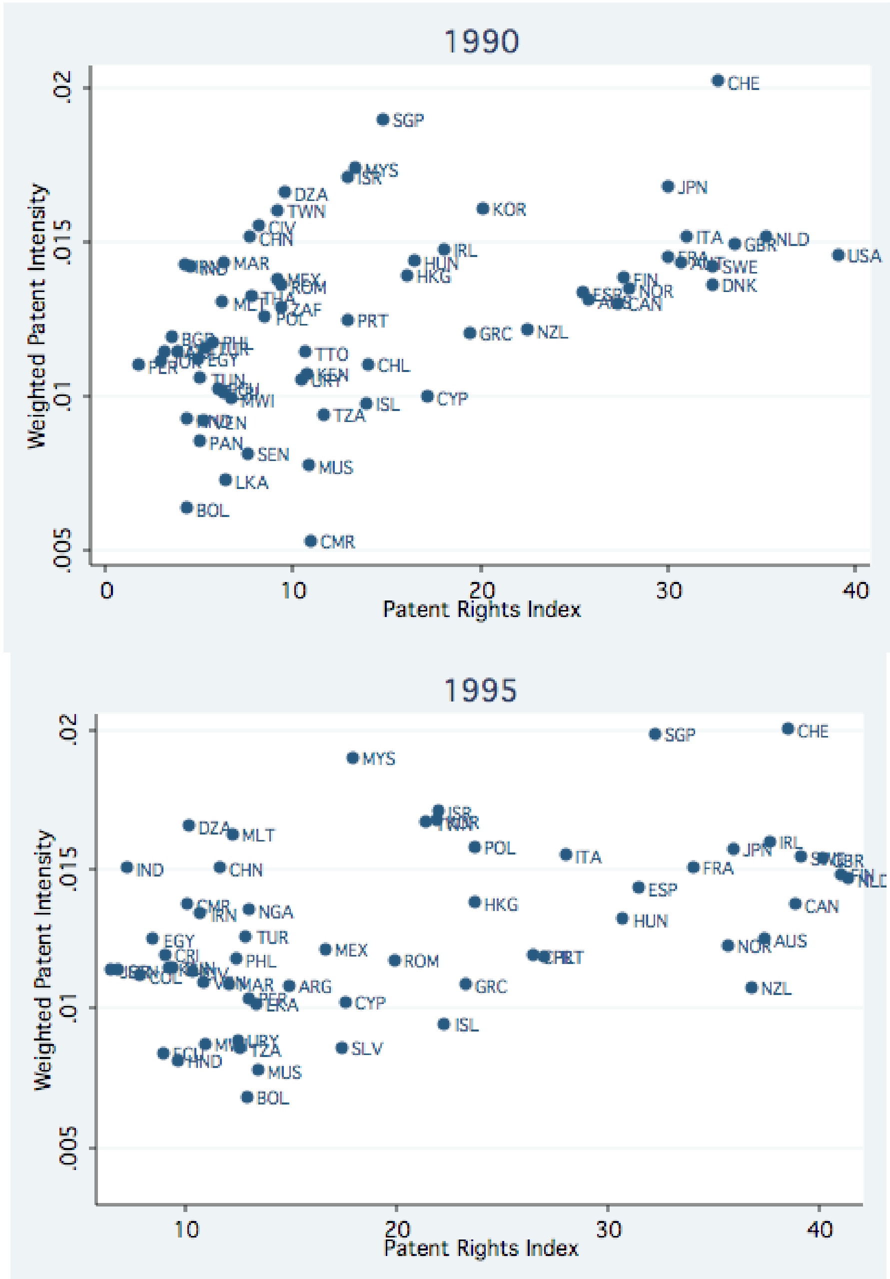


Figure 5: Patent intensity and patent rights index





Notes:

1. Horizontal axis is country patent rights index for the year indicated.
2. Vertical axis is country's weighted average of industry patent intensity, weighted by the industry's share of the country's total value added.
3. Marker is country code.

Table 1. Patent rights index, top and bottom countries, 1980-95

1980		1985		1990		1995	
Top countries							
U.S.A.	39.30	U.S.A.	39.06	U.S.A.	39.06	U.S.A.	42.75
Netherlands	28.20	Belgium	32.23	Belgium	36.22	Netherlands	41.36
Switzerland	28.12	Netherlands	31.47	Netherlands	35.22	Denmark	41.26
Germany	28.01	Switzerland	30.55	U.K.	33.57	Finland	41.01
Japan	27.14	Germany	28.73	Germany	33.14	U.K.	40.15
Bottom countries							
Nicaragua	2.38	Nicaragua	2.38	Guyana	3.17	Niger	5.38
Peru	2.22	Bolivia	2.30	Pakistan	3.17	Guatemala	5.10
Guatemala	1.90	Guyana	1.69	Jordan	2.95	Nicaragua	5.00
Guyana	1.78	Guatemala	1.50	Guatemala	2.15	Rwanda	4.64
Jordan	1.72	Peru	1.31	Peru	1.73	Zaire	3.51

Table 2. Descriptive statistics

VA growth	Fraser Index	GP index	Patent rights index	Patent rights index (alternative)	Patent intensity 79-82	Patent intensity 79-00	R&D/ Sales 79-00	Capital ($ mill.)	Labor
					1981-85				
-0.007	5.371	2.077	12.06	4.762	0.027	0.018	0.023	2,633	23,425
0.137	1.931	0.890	8.09	1.621	0.043	0.022	0.023	40,536	64,846
					1986-90				
0.122	5.430	2.095	12.48	4.810	0.027	0.018	0.023	1,385	33,613
0.187	1.840	0.941	8.85	1.680	0.043	0.022	0.023	5,947	113,843
					1991-95				
0.037	5.703	2.184	13.50	5.035	0.027	0.018	0.023	1,998	38,060
0.184	1.883	1.013	9.71	1.711	0.043	0.022	0.023	5,885	153,453
					1996-2000				
-0.009	6.428	2.990	20.41	6.205	0.027	0.018	0.023	3,191	42,633
0.182	1.658	1.038	11.36	1.708	0.043	0.022	0.023	8,902	166,376

Notes: each panel reports means in the first row and standard deviations in the second row.

Table 3. Growth of industry value added

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0154***	-0.0512***	-0.0290**	-0.0132**
	(0.00436)	(0.00677)	(0.0138)	(0.00622)
Patent rights x patent intensity	0.0141**	0.0114*	0.0397***	0.0221**
	(0.00644)	(0.00659)	(0.0121)	(0.00969)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Growth of industry value added, alternative patent rights index

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0155***	-0.0512***	-0.0292**	-0.0132**
	(0.00437)	(0.00679)	(0.0138)	(0.00622)
Patent rights x patent intensity	0.0835**	0.0540	0.263***	0.144**
	(0.0358)	(0.0360)	(0.0711)	(0.0702)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 5. Growth of industry value added, Fraser index

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0156***	-0.0512***	-0.0290**	-0.0135**
	(0.00436)	(0.00680)	(0.0139)	(0.00620)
Patent rights x patent intensity	0.0804**	0.0454	0.224**	0.197**
	(0.0349)	(0.0362)	(0.0882)	(0.0940)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Growth of industry value added, GP index

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0151***	-0.0511***	-0.0289**	-0.0127**
	(0.00435)	(0.00675)	(0.0137)	(0.00623)
Patent rights x patent intensity	0.0823	0.0871	0.367***	0.132
	(0.0568)	(0.0638)	(0.0831)	(0.0850)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Growth of industry value added, 1979-82 patent intensity

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0149***	-0.0510***	-0.0282**	-0.0128**
	(0.00431)	(0.00672)	(0.0137)	(0.00618)
Patent rights x patent intensity	0.00339	0.00314	0.0129***	0.00922**
	(0.00356)	(0.00303)	(0.00482)	(0.00423)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.358	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Growth of industry value added, patent intensity calculated by applications

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0155***	-0.0513***	-0.0296**	-0.0135**
	(0.00441)	(0.00681)	(0.0139)	(0.00624)
Patent rights x patent intensity	0.0167**	0.0118	0.0544***	0.0258**
	(0.00747)	(0.00808)	(0.0146)	(0.0108)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Growth of industry value added, R&D intensity

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0160***	-0.0516***	-0.0303**	-0.0138**
	(0.00450)	(0.00688)	(0.0141)	(0.00626)
Patent rights x R&D intensity	0.0178**	0.0140	0.0577***	0.0255**
	(0.00823)	(0.00954)	(0.0163)	(0.0111)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.360	0.527

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 10. Growth of industry value added, total factor productivity

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Change in log of capital services	0.0587	0.190***	0.247***	0.276***
	(0.0510)	(0.0582)	(0.0739)	(0.0804)
Change in log of labor	0.900***	0.792***	0.745***	0.923***
	(0.0544)	(0.102)	(0.137)	(0.0614)
Patent rights x patent intensity	0.0102**	-0.00725	-0.00106	0.0402**
	(0.00475)	(0.00550)	(0.00832)	(0.0171)
Observations	1652	1910	1694	1471
R-squared	0.821	0.652	0.322	0.792

Delta=0.1, gamma=0.05
Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 11. Growth of industry value added, financial development

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0138***	-0.0326***	-0.0261	-0.00401
	(0.00479)	(0.00933)	(0.0204)	(0.00551)
Patent rights x patent intensity	0.0243***	-0.00388	0.0207*	0.0283***
	(0.00579)	(0.00736)	(0.0122)	(0.00863)
Financial devt x patent intensity	-0.671***	-0.0113	0.822*	-0.101
	(0.210)	(0.285)	(0.488)	(0.199)
Observations	1538	2173	2227	2408
R-squared	0.714	0.509	0.376	0.506

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 12. Growth of industry valued added, trade openness

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0153***	-0.0512***	-0.0290**	-0.0137**
	(0.00438)	(0.00678)	(0.0138)	(0.00623)
Patent rights x patent intensity	0.0167*	0.00231	0.0367***	0.0354***
	(0.00926)	(0.00870)	(0.0102)	(0.00978)
Trade openness x patent intensity	-0.0656	0.397*	0.243	-1.333***
	(0.186)	(0.238)	(0.507)	(0.483)
Observations	3006	3235	3288	2840
R-squared	0.530	0.574	0.359	0.528

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table 13. Growth of industry value added, human capital

VARIABLES	(1) 1981-1985	(2) 1986-1990	(3) 1991-1995	(4) 1996-2000
Initial value added	-0.0121***	-0.0495***	-0.0254***	-0.0157**
	(0.00438)	(0.00692)	(0.00917)	(0.00707)
Patent rights x patent intensity	0.0243**	0.00730	0.0263	0.0252**
	(0.0112)	(0.00993)	(0.0168)	(0.0109)
Human capital x patent intensity	-0.0853	0.0250	0.0777	-0.0323
	(0.0697)	(0.0747)	(0.171)	(0.125)
Observations	2850	3114	2994	2578
R-squared	0.538	0.535	0.380	0.522

Robust standard errors in parentheses
All regressions included country and industry fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Appendix

Table A.1. Patent intensity, by industry

Industry (ISIC3 rev 3)	1979-2000 average
Food and beverages (15)	0.0014
Tobacco (16)	0.0029
Textiles (17)	0.0058
Apparel (18)	0.0059
Leather (19)	0.0107
Wood products (20)	0.0258
Paper products (21)	0.0073
Printing	0.0065
Coke and petroleum products (23)	0.0027
Basic chemicals (241)	0.0279
Other chemicals (242) (incl. pharmaceuticals)	0.0249
Rubber and plastics (25)	0.0113
Other non-metal (26)	0.0108
Basic metals (27)	0.0111
Fabricated metals (28)	0.0116
Other machinery (29)	0.0125
Office, accounting, computing machinery (30)	0.0516
Electric motors, generators, transformers (311)	0.0300
Electricity distribn and control apparatus (312)	0.0477
Insulated wire and cable (313)	0.0096
Accumulators, cells and batteries (314)	0.1485
Electric lamps and lighting equipment (315)	0.0725
Electronic valves, tubes (321)	0.0415
TV and radio transmitters (322)	0.0430
TV and radio receivers (323)	0.0169
Medical appliances (331)	0.0329
Motor vehicles (34)	0.0107
Other transport equipment (35)	0.0125
Furniture and other manufactures (36)	0.0134

Note: For industries with low ratios of patents to sales, we aggregated the 3-digit industries to the 2-digit level. We exhibited more of the 3-digit industries with high ratios of patents to sales and/or of particular interest, e.g., 242 includes pharmaceuticals.