STRENGTHENING INTELLECTUAL PROPERTY RIGHTS: EXPERIENCE FROM THE 1986 TAIWANESE PATENT REFORMS

SHIH-TSE LO*

DEPARTMENT OF ECONOMICS

CONCORDIA UNIVERSITY, MONTREAL

Abstract

Intellectual property rights (IPR) have recently moved to the forefront of debates over international policy. As each country establishes its own institutions of IPR, a divergence exists between net producers and net consumers in the returns to providing strong protection. Under pressure from the developed world, many developing countries have begun to strengthen their IPR, particularly as regards patents. These changes in policy provide us with an opportunity to learn more about the effects of intellectual property institutions in developing countries. Whether and to what extent do stronger IPR spur inventive activity in a developing country? What are the factors or characteristics of industries in which strengthening patent rights has the most favorable impact on inventive activity? Will the strengthening of IPR in developing countries induce more foreign direct investment and technology transfer from abroad? In an attempt to answer these questions, this paper uses the 1986 Taiwanese patent reforms to examine the impact of strengthening patent rights in a developing economy. The evidence on the number of patents awarded to Taiwanese inventors as well as that on R&D spending in Taiwan suggests that the reforms stimulated additional inventive activity, especially in industries where patent protection is generally regarded as an effective strategy for extracting returns, and in industries which are more R&D intensive. The reforms also seemed to induce additional foreign direct investment in Taiwan. On the other hand, for industries that chiefly use other mechanisms to extract returns from their innovations, such as secrecy, the strengthening of patent rights had little effect on their inventive activity. Neither investment in R&D nor the number of patents awarded in these industries appeared to be much affected by the strengthening of patent protection.

* I am indebted to Kenneth Sokoloff and Daniel Ackerberg for their continuous encouragement, advice and patience throughout this project. I am grateful to suggestions offered by Hongbin Cai, Dhanoos Sutthiphisal, Richard Scheelings, Richard von Glahn, and seminar participants at UCLA International Institute, IO and Economic History Proseminars. I would also like to thank Taiwanese patent agents Chun-sung Chou and Ying-chou Tu for sharing with me their insights on the Taiwanese patent system and firm practices. Financial supports from the Chiang Ching-kuo Foundation for International Scholarly Exchange are gratefully acknowledged. All errors are mine. Please address comments to shihtlo@alcor.concordia.ca.

Intellectual property rights have recently moved to the forefront of debates on international economic policy. This should not be surprising, given the important role of intellectual property (as embodied in patents, copyrights, or trademarks) in the production of goods and services today, as well as the continued rapid growth in the volumes of international trade and investment. Further accentuating the significance of whether nations cooperate or come into conflict over intellectual property rights, however, are the enormous differences across them in the rates at which they generate new technologies, ideas, and products. Because such inventions and creations can often be easily copied or imitated, and because each country establishes its own institutions of intellectual property, there is an obvious divergence between net producers and net consumers of new technological knowledge in the returns to providing strong intellectual property rights.[1]

The institutions of intellectual property protection of new technologies that countries adopt generally do reflect the significance of this distinction. Traditionally, developing countries have established weaker regimes favoring technological diffusion through imitation and acquisition from abroad. For example, although it rose as a global star in science and technology in the 1980s, Japan was a major source of international counterfeit goods in the 1960s.[2] In contrast, the developed countries have long promoted the idea of stronger intellectual property protection throughout the world so as to improve incentives for private agents to create and advance technology and, not coincidentally, for their own inventors to extract greater returns from their discoveries. A major part of this campaign has been an effort by developed countries to secure harmonization of patent systems across countries through bilateral, regional and international agreements, and they often contend that a strengthening of patent protection would be good even for developing societies, through stimulating more domestic production of inventions as well as by attracting more foreign direct investment to them. Nonetheless, developing countries have been less than enthusiastic in embracing the argument that strong patent protection would have positive

---

[1] Because intellectual property rights, such as patents, are granted on a country-by-country basis, each country establishes her own systems of intellectual property rights. In order to seek patent protection in different countries, inventors and/or firms need to take out patent application in these countries. Therefore, there is no so-called international patent. However, there are a number of international treaties to create a patent system which could be applied to several countries that join the treaties, such as the Patent Cooperation Treaty.

[2] Also, the U.S., a developing country of the 19th century, was regarded by Britain, as the leading intellectual pirate of that era for not providing copyright protection to non-U.S. residents.

long-term effects on the rate of technological change and social welfare. An increase in patent protection in developing countries may raise the prices (and the levels of royalties flowing out of the society) of goods and services produced with technologies developed abroad and decrease the rate of technological diffusion. There is, moreover, little evidence supporting the view that stronger patent rights would stimulate inventive activity. Divisions between developed and developing countries over intellectual property rights have, as a result, widened in recent years.

Under pressure from developed countries and often in conjunction with concessions from them about opening up their domestic product markets to more imports, many developing countries have begun to strengthen their intellectual property systems, particularly as regards patents. These changes in policy provide us with an opportunity to learn more about the effects of intellectual property institutions in developing countries. Whether and to what extent do stronger intellectual property rights spur inventive activity in a developing country? What are the factors or characteristics of industries in which strengthening patent rights may have the most favorable impact on inventive activity? Will the strengthening of IPR in developing countries induce more foreign direct investment and technology transfer from abroad? Most prior empirical work on these issues has been devoted to the experiences in the developed world, and there has been only very limited study of what has happened in developing countries. This paper, therefore, seeks to examine the effect of strengthening patent rights in a developing economy on her inventive activity by investigating the impact of the 1986 Taiwanese patent reforms.

Under considerable pressure from the U.S., which had recently embarked on a campaign to secure better enforcement of intellectual property around the world, Taiwan made important changes to her patent system in 1986 that became effective in January 1987. As this new law imposed much more severe penalties, allowed patent holders to obtain much higher compensation through civil suits for infringement, and permitted Taiwan's judicial system to establish a special court to handle patent litigation, the reforms were mainly centered on improving enforcement of patent rights in Taiwan. This sudden policy shift provides an unusual natural experiment that allows one to study the impact on inventive activity in a developing country of strengthening patent protection.

Following previous scholars, I use both patent statistics as well as information on expenditures of R&D to gauge inventive activity.[3] The use of the two types of measures should help in distinguishing between the effects of stronger patent protection on the propensity to patent an invention and on the investment in inventive activity (a well known issue among those that rely on patent counts). Moreover, because I employ records of U.S. patents as well as of Taiwan patents, awarded to residents of Taiwan, there are even more ways of examining the robustness of findings; the series of U.S. patents offers the advantages of being less likely to be distorted by changes both in the propensity to patent, and of pertaining to inventions that are likely of much higher average market value than those patented in Taiwan.[4] This latter approach of exploiting patent series granted in the U.S. allows me to distinguish between changes in the propensity to patent and in actual changes in inventive output, and seems quite appropriate for this case.[5] As almost half of Taiwan's exports during the 1980s were shipped to the U.S. and the U.S. has been Taiwan's largest trading partner for decades, Taiwanese inventors and companies have long sought patent protection in the U.S. for technologies employed in products that are exported.[6] Furthermore, because no dramatic patent policy shifts took place in the U.S. around the time of the 1986 Taiwanese patent reforms, the propensity of Taiwanese inventors to patent their inventions in the U.S. seems unlikely to have been altered. The record of patenting in the U.S. by residents of Taiwan, therefore, seems to provide a better gauge of their actual record of inventive activity over time than the record of patenting by Taiwanese at home. For this reason, in addition to using patent data from the Taiwanese Intellectual Property Office, I study the record of U.S. patents awarded to Taiwanese so as to better estimate the impact of the 1986 reforms on the country's inventive activity.[7]

The evidence on the number of patents awarded to Taiwanese inventors, as well as that on R&D spending in Taiwan, suggest that the 1986 Taiwanese patent reforms stimulated additional inventive activity, especially in industries where patent protection is

---

[3] See Griliches (1990, 1994) for a detailed discussion on prior work and the issues associated with using patent records to measure inventive activity.

[4] Patenting might be also affected by a change in the quality of patent examination.

[5] Prior studies on investigating inventive activity in countries other than the U.S., such as Trajtenberg (1999) and Qian(2003), often employ U.S. patent records awarded to residents of the countries of interest as a gauge of inventive activity. However, it is unclear why they do so.

[6] As shown in later sections, not only has the Taiwanese export sector intensively sought for patent protection in the U.S., but the domestic-oriented industries have also received a large number of U.S. patents.

[7] I included inventors and assignees who register addresses in Taiwan.

generally regarded as an effective strategy for extracting returns from technological discoveries, and in industries which are more R&D intensive. The reforms also seemed to encourage investment from abroad. On the other hand, for industries that chiefly use other mechanisms to extract returns from their innovations, such as secrecy and lead time advantages, the strengthening of patent rights associated with the 1986 reforms had little effect on their inventive activity. Neither investment in R&D nor the number of patents awarded in these industries were much affected by the strengthening of patent protection.

I organize the rest of the paper as follows. Section 2 outlines the different views towards patent systems and reviews prior empirical work regarding the impact of patent systems on invention. Section 3 explains in detail the hypotheses and how I plan to test them. Section 4 reviews what the Taiwanese patent system was like before the 1986 reforms, as well as the background and substance of the change in patent protection. Section 5 describes the data. The empirical analysis and results are presented in section 6. Finally, I conclude with a discussion of the policy implications to be derived from the findings.

2. Background

The effectiveness of patent systems has long been of concern to economists and policy makers. Indeed, the effects of patent systems were hotly debated and continuously under scrutiny in many European countries during the second half of the 19th century. Even in the U.S., which has historically been the staunchest of proponents, there have been several serious movements for reform. Supporters of stronger patent rights have consistently argued for them on the grounds that stronger patent protection preserves incentives to invent, and thus benefit society as a whole. The opponents of patents, on the other hand, contend that patents are often harmful. They argue that patent rights are often not an effective mechanism for inventors to extract returns from their discoveries, sometimes award property rights for inventions that would have been discovered anyway, and frequently slow the pace of technological diffusion by preventing others from taking advantage of new technological knowledge. Thus, strict patent systems can stifle invention and even technological progress. Perhaps influenced by these latter arguments, the Netherlands, Denmark, and Switzerland are among the countries that did not have any patent system (during the 19th century), and did rather well.

Even though patent systems have come to be widely adopted around the world, the debate has continued. Scholars, such as Levin et al. (1987) and Cohen et al. (2000), have recently sought to address the fundamental issue of whether or not patents are an effective means for inventors to extract returns from their inventions. Working with surveys they conducted of R&D facilities in the U.S. manufacturing sector, they find that firms, in practice, employ not only patents but also a wide range of other mechanisms, such as maintaining secrecy, to secure the income streams generated by their discoveries. Indeed, the strategy of relying on secrecy is widespread across virtually all sectors, while patents are considered effective in only a handful of industries, such as chemicals and pharmaceuticals. In addition to such empirical studies of the effectiveness of patent protection, contemporary theorists (for example, Tandon (1982), Gilbert and Shapiro (1991), Klemperer (1990), Gallini (1992) and Denicolo (1996)) have considered the problem of optimal patent design. They have focused primarily on the interplay between the duration and the breadth of patent grants in providing an inventor appropriate incentives to invent, however, and devoted only limited attention to issues of enforcement or to questions related to harmonizing the patent systems of quite disparate economies.

There have been some attempts to empirically investigate whether the existence of patent systems, or the particular design of a system, influences the rate or direction of inventive activity. But such studies have, thus far, dealt with experiences in developed countries (for example, Kortum and Lerner (1998); Hall and Ziedonis (2001); Sakakibara and Branstetter (2001); Moser (2001)). In general, they have found only small effects on the overall level of invention. One problem with these studies is that the policy shifts in, or variation across, patent systems being exploited by the investigators seem less than exogenous. Moreover, given that the contemporary policy debates center on the advisability of strengthening patent rights in developing countries, another concern is that the changes in the patent systems of developed countries being evaluated, or the circumstances of those economies more generally, may not be representative of conditions in less developed societies. While developing countries may be abundant in labor and/or natural resources, they are in general lacking in capital, human capital and, most importantly, technological knowledge, which are critical elements for invention.[8] The disparity between developing and

[8] See Sutthiphisal (2003) for more details.

developed countries in technological knowledge, in particular, may mean that the response of populations in the former to strengthened patent rights might be very different from the response of populations that are more educated and familiar with the frontiers of technology.

Indeed, in many less-developed countries, the great majority of patents go to foreign inventors from a small number of advanced countries. The stark contrasts in the availability of factors important in inventive activity, as well in the records of invention, surely play a role in explaining why public opinion in less developed countries does not, in general, support stronger intellectual property institutions. The perception that because their nations are poor, they are justified in freely learning and borrowing from the stock of technical knowledge that has been built up, is powerful and pervasive. The popular appeal of this notion, and the not unrelated fact that there is a clear benefit to technology-importing countries of not having to pay royalties to foreign patent holders, could in principle account for developing countries failing to strengthen patent rights even if domestic invention would be boosted by the regime change.

Several authors, such as Lanjouw (1998), Lanjouw and Cockburn (2000), and Qian (2003), have sought to explore the effects of changes in patent systems in developing-country contexts. However, these studies are exclusively focused on the introduction of pharmaceutical patents, and their findings of no significant evidence of causality running from the introduction of new patent laws to domestic invention may not extend to other industries. Given the fact that successful R&D in pharmaceuticals typically requires workforces with highly specialized human capital and substantial investments in resources, very few developing countries would have the capacity and inclination to carry out significant inventive activity in this industry. It is, therefore, not clear that studies that are based on pharmaceutical patent data would yield much general insight into the issue of whether stronger or broader patent protection would spur invention in developing countries. Lerner (2002) has studied all significant patent reforms around the world over a period of 150 years. His analysis is based on snapshots of the patent system in each country every 25 years for the 150-year period. While the study provides some evidence that stronger patent rights are associated with inventive activity, the findings have no clear indication of the causal relationship between invention and patent rights.

Inspired by the contemporary debates on whether stricter enforcement of patent rights would benefit less-developed countries, this paper differs from the previous empirical studies, which typically look at the experience of the developed world, in a number of respects. First, my study focuses on a change in the patent institutions of a developing country, Taiwan, which was induced by sudden and external pressure. Second, given that little empirical work has done on patent enforcement, I pay special attention to the effects of an increase in patent enforcement on inventive activity. Fortunately, the primary thrust of the Taiwanese patent reforms was to improve the enforcement of patent rights. Third, the study employs a variety of alternative measures of inventive activity in a close examination of the record of invention across a broad range of industries, before and after the enactment of the reforms. Given the relatively exogenous and unexpected change in patent regime, there is good reason to believe that any association between the reforms and the changes in inventive activity that followed would stem largely from a causal relationship. My approach should, accordingly, deliver rather direct evidence on the effects of strengthening patent protection in developing countries.

3. Hypothesis

In the view of patent advocates, stronger patent rights tend to deter or delay imitation and help inventors and/or firms realize returns to their investments in inventive activity. The resulting increase in the expected return to investment in inventive activity, in turn, leads to increase in such investment. If this perspective applies in a developing country, such as Taiwan, we should expect the 1986 reform of the patent law to lead to increases in R&D, patent applications, as well as in patent grants on inventions generated in Taiwan. On the other hand, stronger patent rights could in principle discourage potential inventors from working with, and possibly improving upon, already patented inventions. If so, there might actually be less invention after patent rights were strengthened. Another, and perhaps more important reason why the change in patent law might not stimulate an increase in inventive activity is that the conditions in Taiwan were sufficiently unfavorable to boosting effective incentive that the change in the law could not have much of a positive effect.

Of course, one would expect that the effects of strengthening patent protection on inventive activity to vary across industries. There are two different, if not mutually exclusive, reasons why, and to what extent, industries might respond differently to a strengthening of patent protection. First, because patent rights are granted on a country-by-country basis, an increase in patent protection in an economy such as Taiwan may have a stronger impact on an industry that chiefly targets the domestic market than an industry that focuses on foreign markets since the patent policy change applies only within Taiwan. The investments in R&D by firms focusing on foreign markets might be expected to depend more on the ability to secure property rights on new technology in those markets. Because a large amount of Taiwan's exports were shipped to the U.S. in the 1980s and because the U.S. patent system provided strong patent rights, firms that targeted foreign markets should patent the fruits of their R&D investments through the U.S. patent system. If this intuition held, one might expect to observe the biggest impact of the patent reforms on the domestic-oriented industries. Second, a strengthening of patent rights might only affect inventive activity in industries in which patent protection were critical to extract returns from R&D. Given that patents are not the only means to protect inventions and some industries may employ different mechanisms to secure returns from their inventions, a change in the patent system, therefore, might not have the same impact across industries. For example, both Levin et al. (1987) and Cohen et al. (2000) find that while firms in chemical and pharmaceutical sectors consider patents as an effective mechanism to secure the income stream from their inventions, other industries tend to employ other means, such as keeping their improvements in technology secret. As a result, the effects of strengthening patent protection should be more pronounced in industries that are more reliant upon patent protection than industries that chiefly rely on other mechanisms to protect the returns to their inventions.

4. PATENT SYSTEM IN TAIWAN

Patent System before the 1986 Reforms:

Like patent laws in many developing countries, Taiwan's patent system was designed not only to increase the incentive to invest in inventive activity, but also to promote economic development through encouraging technological diffusion within the country and technology acquisition from abroad.[9] The latter goal meant that the early patent laws were

[9] Taiwan enacted a comprehensive patent law to improve industrial property rights in 1949. According to the law, there are three types of patents an inventor might be able to obtain on her invention: an invention patent, a new utility model patent, or a new design patent. An invention patent, which during that time covered a term of 15 years from its issue date, is comparable to an American utility patent, which emphasizes the

not geared for strict enforcement and did not offer broad coverage. For instance, patent protection did not apply to agricultural and extractive industries until a revision to the patent law in 1979.[10] Indeed, the 1949 law defined patentable inventions in such narrow terms that patent protection was only available to manufactured products and manufacturing processes.[11] Despite the fact that revisions to the patent law took place in 1959, 1960 and 1979, patent protection was not provided for chemicals and pharmaceuticals until the 1986 reforms.

Moreover, the generous compulsory licensing provisions of the old Taiwanese patent laws were also viewed by the U.S. and other developed countries as a salient example of lax intellectual property protection in Taiwan. As compulsory licensing provisions enable a government to permit other parties to utilize patented technologies with remuneration, developing countries often employ this mechanism to ensure affordable access to medicines and other products deemed necessities; Taiwan was not exceptional in this regard. According to Taiwan's 1979 patent law[12], a patent holder might be subject to a compulsory license not only in a case of national emergency, but also when she did not actually work her patented invention in Taiwan within three years of the granting of the patent. However, the rapid economic development in Taiwan during 1970s and 1980s led the U.S. to urge the Taiwanese government to weaken the compulsory licensing policies.

Another major deficiency, perhaps the one of greatest concern to the U.S., was the limited attention to enforcement of patent rights. The penalties and liabilities specified for infringement were quite modest. For example, under Taiwan's 1979 patent law[13], a patent holder pursuing civil action for infringement could only recover the amount of damages estimated by the Taiwanese Patent Office, rather than the triple damages generally provided under the systems of developed countries. The criminal provisions of the law also failed to provide much protection. Under the 1979 law, the maximum fine for infringing on a patent right was as little as 40,000 New Taiwan dollars (approximately $1,300).

---

functional and operational characteristics of an invention. A Taiwanese new design patent, similar to the U.S. design patent, protects the shape, pattern, appearance or artistic features of an article. The in-between type known as the new utility model grants protection on the form, structure or fitting. The new design patents under the law expired in 5 years and the new utility model patents had a span of 10 years.

[10] Article 1 of the 1979 Taiwan Patent Law.

[11] Article 1 of the 1949 Taiwan Patent Law.

[12] Article 67-69 of the 1979 Taiwan patent law.

[13] Article 82 of the 1979 Taiwan patent law.

For both of these reasons, before the 1986 reforms, Taiwan's patent system provided quite modest protection to property rights in new technological information.

The Background to The 1986 Taiwanese Patent Reforms:

By the 1980s, many firms in the U.S. (as well as in other developed countries) had become extremely concerned that they were being undercut by competitors who not only benefited from locating production in developing countries with low labor costs, but who were also infringing their intellectual property rights (as embodied in trademarks as well as patents). These firms began to feel that they were suffering substantial losses because of a lack of intellectual property protection abroad. The American general public also grew anxious that the U.S. lead in hi-tech industries would be eroded rapidly if these circumstances continued. In order to maintain their competitive edge, many American companies, together with the U.S. government initiated a campaign to secure reforms of intellectual property right systems (focused particularly on patents) throughout the world. The views of Clayton Yeutter, the U.S. trade representative from 1985 to 1989, are representative:

> The pirating of U.S.-financed research and development discourages innovation, denies markets to American exports, and threatens technological progress. Protection of intellectual property rights preserves America's technological edge, which is a key to our continued international competitiveness.[14]

This atmosphere was certainly reflected in U.S. trade policies. In 1984, the U.S. began to treat inadequate protection of intellectual property rights as an unfair trade practice by other countries. Countries that failed to provide adequate intellectual property protection, thereby damaging U.S. businesses, were to be made subject to U.S. retaliation under Section 301 of the 1974 Trade Act.

Because of Taiwan's deficient intellectual property rights system, piracy was a widespread phenomenon, and many U.S. businesses had been wounded by these imitators.

> When Pfizer Inc. of New York introduced an arthritis drug in Taiwan four years ago, local manufacturers flooded the market with capsules that looked exactly like Pfizer's turquoise-and-maroon Feldeanes. The company says that within a year it had 20 competitors and within two years it held less than a 30% market share. Last year Pfizer's share slipped to 18%.[15]

---

[14] The quotaion is from Alison Butler, "The Trade-Related Aspects of Intellectual Property Rights: What Is at Statke?"

[15] *The Wall Street Journal*, November 13, 1985, p. 37.

Moreover, Taiwanese pirating was not just a domestic matter. Copycat products from Taiwan flooded export markets all over the world during the early 1980s.

> For now, at least, Taiwan is to counterfeiting what Miami is to drug trafficking….The United States International Trade Commission, for example, estimates that fake goods cost American Businesses $6 billion in 1982 and that 60 percent of the bogus products were made in Taiwan….Counterfeiting is a problem common to most developing countries. But Taiwan is distinguished by the wide rage of products it manufactures and by the large amount of the output that it exports.[16]

Consequently, by the 1980s Taiwan was – after Japan in the 1960s and Hong Kong in the 1970s – the counterfeiting and illegal-copying capital of the world.

Taiwan, however, enjoyed a substantial bilateral trade surplus with the U.S. in the 1980s and was U.S. fifth largest trading partner. As a result, Taiwan was one of the first three countries put on the U.S. priority watch for their lack of intellectual property protection.[17]

The 1986 Taiwanese Patent Reforms:

In 1985 and 1986, Taiwan's Ministry of Economic Affairs and the U.S. Trade Representative began a series of talks concerning the protection of intellectual property rights in Taiwan. As a result of these talks, a comprehensive new patent law was submitted to the Yuan (Taiwan's supreme legislature) in December 1986, so as to bring the law into accord with the recommendations of the U.S. Trade Representative. The amended law was finally enacted and promulgated on December 24, 1986, and came into force in January 1987.

Perhaps the most obvious change introduced by the new law was an expansion of patent coverage. Not only did patent protection extend to the pharmaceutical and chemical industries, but new plant varieties and microorganisms could also be patented. However, the crucial feature of the new regime was the emphasis on improved enforcement of patent rights. For example, the new law enforced more stringent requirements before compulsory licensing could be imposed. In addition, because many district courts did not have the proficiency and specialized knowledge appropriate for patent litigation, the new law stipulated the creation of a new court that would exclusively focus on patent infringement.

---

[16] *The New York Times*, May 7, 1985, p. D12.

[17] In October 1986, the U.S. also accused South Korea for her inadequate protection on intellectual property rights while Japan along with Taiwan was charged in November 1986.

The new law also sought to enhance patent protection through increased penalties and expanded liability for patent infringement. According to the new criminal penalty schedule, the maximum fine for infringing an invention patent was raised to 100,000 New Taiwan dollars ($3,300). Most importantly, the reforms substantially increased the compensation that patent holders could realize through civil actions. Before the reforms, the damages of a patentee could only be estimated by the patent office. The new patent system allowed two other ways to determine the damages. Under the new law, the damages could also be estimated as the profits lost by the patent holder, or as the infringer's profits made from the infringed article. Moreover, in case the patent holder suffers damage on her business reputation as a result of the infringement, a separate compensation of up to three times the actual damage would be available. The government also introduced a wide range of administrative measures to curb piracy and counterfeiting, such as withdrawing violators' credits from government-owned banks, and it soon after launched a campaign against infringement. Rapid growth in the number of both patent opposition and anti-counterfeiting cases, as shown in Figure 1, seems to support the view that the reforms substantially strengthened the enforcement of patents due to the largely exogenous pressure from the U.S.[18]

One concern which this study must address is that there are many mechanisms and institutions, other than the design of the patent system, which a government can employ to influence the rate or direction of inventive activity. Such mechanisms and institutions include – but are not limited to – R&D tax subsidies, governmental and semi-governmental research institutes, and support for venture capital institutions. To address this concern, I examined the record of other Taiwanese laws, statutes and Acts concerning R&D, as well as the histories of Taiwan's important research institutes and science-based industrial park. I found no significant change in these policies around the 1986 reforms. Consequently, the sudden shift of patent policy in 1986 provides an unusual natural experiment for the study of the impact of strengthening patent rights in a developing country.

[18] Any person who asserts that a published invention has violated any requirements, stipulated in the patent law, of granting a patent, may, within three months from the publication date, submit a written opposition application. Upon receipt of a written opposition, the patent office shall re-examine the issued patent. (Translated from Chinese to English by the Taiwanese Intellectual Property Office and posted on the page of its website http://www.tipo.gov.tw/eng/laws/laws.asp)

5. THE DATA

Similar to a large volume of prior empirical work on invention and technological progress such as the pioneering work of Schmookler (1966), Pakes and Griliches (1980), Sokoloff (1988) and Hall, Jaffe and Trajtenberg (2003), I employ patent statistics to measure inventive activity. However, a strengthening of patent rights may not only change the level of inventive activity but also affect the willingness of an inventor to obtain a patent. An increase or a decrease in the number of patent applications, and thereby the number of grants after a patent reform, may not be due solely to a change in inventive activity. One must be careful to distinguish between an increase in patenting due to an increase in invention, and an increase that arises from a change in the propensity to patent an invention in the country that has recently reformed her patent institutions.

So as to more effectively deal with this measurement problem, I focus on the patenting of Taiwanese residents in the U.S. Because the export volume to the U.S. market accounted for one half of Taiwan's total exports in the late 1970s and 1980s and still about one fourth today, many Taiwanese have long sought patent protection on their discoveries in the U.S.[19] Because there were no changes in the U.S. system around 1986 and 1987 and because the changes in the counts of Taiwanese patents awarded to her residents might reflect both changes in inventive effort and in propensity to patent, the record of U.S. patents granted to residents of Taiwan seems to provide a better gauge.

Patent Data

Accordingly, I collected patent data for my empirical analysis from two different sources: the U.S. Patent and Trademark Office (USPTO) online patent grant databases and the Taiwan Patent Network (TPN) searchable database on Taiwanese patents.[20] The USPTO database contains all patents granted in the U.S. since 1790, and the TPN patent database also provides a search engine that is comparable to that for the U.S. As the purpose of this paper is to investigate the consequences of the 1986 Taiwanese patent reforms, my U.S. patent data set includes all of the U.S. patents awarded to inventors and assignees in Taiwan from 1983 to 1991. There are a total of 5,983 patents. For each patent,

---

[19] Not only the export but also non-export sectors of Taiwan have patented many of their inventions in the U.S.

[20] The URL address of USPTO is www.uspto.gov and that of TPN is www.twpat.com.

I record its patent number, subject, date of issue, the name and address of the inventor, the assignee at issue and her address, the date of application, the current U.S. classification, the international patent classification, and the number of claims.[21]

As I intend to examine the effect of the reforms not only on overall inventive activity but also on the composition of invention across industries, I categorized these 5,983 patents into 25 different industries by reading their abstracts, claims, and drawings. A close examination is necessary because patent classification is based on the specific function of the invention. For example, under the standard industrial classification (SIC), a sprayer for agricultural use is classified in farm and garden machinery and equipment. An atomizer for medical use is classified into surgical, medical, and dental instruments and supplies. However, under the U.S. patent classification, both of them are categorized into class 239 – fluid sprinkling, spraying, and diffusion. Table 1 summarizes the numbers of granted patents filed by or assigned to Taiwanese residents between 1982 and 1991 across these 25 different industries.

In addition to the U.S. patent data set, I construct another data set from the TPN online database by collecting all the patents issued by the Taiwanese Intellectual Property Office (before 1999 called the National Bureau of Standards) between 1984 and 1991. This dataset consists of 130,268 patents and contains similar bibliographic information on patents to that in the USPTO database. Among these 130,286 patents, 66,537 patents are awarded to residents of Taiwan.

The huge gap between the numbers of patents awarded to Taiwanese residents in the two patent systems might seem peculiar, but a part of the discrepancy is the result of the higher cost for inventors to file a patent application in the U.S. compared to Taiwan. From my interviews with patent agents working in Taiwan, on average it costs about $1,000 to file a Taiwanese patent application through patent agents or attorneys in Taiwan.[22] However, because the requirements for filing a patent application in the U.S. are quite different from those in Taiwan, it is considered a separate task for patent agents to assist an inventor to file the U.S. application. Indeed, some firms even hire different patent agents to apply for

[21] An assignee is a person or an organization to which the rights of a patent have been assigned.
[22] The costs might be higher with the increased complexity of the invention.

patents in the two countries. The cost can be up to $3,000 to $4,000 per U.S. patent application, and even higher if an inventor hires American patent agents.

From these 130,286 patents, I randomly selected a sample of 5,277 patents, 2,725 of which are awarded to Taiwanese inventors. Table 2 reports the distribution of 2,725 granted patents across the 25 industries.

In order to compare the patterns of patents awarded to Taiwanese inventors with the patterns of patents granted to inventors residing in other countries that did not undergo patent reforms (such as Israel and Singapore), I also obtained information on U.S. patents awarded to residents of foreign countries from the technology reports of the USPTO Technology Assessment and Forecast branch.

R&D Data

In addition to the patent records, I obtained Taiwan's estimates of industrial R&D from the yearly Indicators of Science and Technology, 1991-2001, published by the Taiwan National Science Council. Each year since 1983, the National Science Council has conducted the "Survey of National Science and Technology Activity", and their reports contain information on annual spending and manpower by industries.[23] [24]

Other Data

In addition to patent protection, inventive activity might be affected by many other factors such as business cycles and other industrial policies. Hence, it is critical to control for the effects of these factors. From the online economic database provided by Taiwan's Directorate General of Budget Accounting and Statistics, I collected annual series on industrial production from 1981 to 1992, and obtained export figures from the Monthly Statistics of Exports and Imports, published by Taiwan's Ministry of Finance.[25] Information on foreign direct investment is from the Statistical Yearbook on Overseas Chinese &

---

[23] The survey population includes all colleges and universities, all public and private research institutes, all state-owned enterprises and a sample of private corporations in Taiwan. While firms in the Hsinchu science-base industrial park are all included in the sample, other private companies are randomly selected from "The Industrial Statistical Survey" conducted by the Ministry of Economic Affairs.

[24] From the survey questionnaire, figures on R&D spending appear to be net of research and technology import payment, inclusive of technological cooperation, of technology licensing (on patents, trademarks, software, databanks and etc.) and of technology instruction (such as technical training, consulting, and technology assistance).

[25] Export values are F.O.B. (freight on board)

Foreign Investment, Technical Cooperation Outward, Technical Cooperation, Indirect Mainland Investment, Guide of Mainland Industry Technology, 1996, the Republic of China.

Although I classify the 5,983 U.S. patents and the 2,725 Taiwanese patents awarded to residents of Taiwan into 25 industries, annual information on R&D expenditures, exports and production values is not available for all of the 25 industries (simply because the Taiwanese government does not report survey and statistics figures in that type of detail). In order to match the information on R&D and production with my patent data, I removed those patents classified into both the construction and the miscellaneous manufacturing industries categories and grouped the rest into 10 major sectors. The new law took effect in 1987, my period of observation starts in 1984 and ends in 1991. The distributions of patents after removing two industries and grouping the remaining 23 industries into the abovementioned 10 industries are reported in Table 3 and Table 4.

6. Effects of the 1986 Reform on Taiwan's Inventive Activity

In Section 3 I presented several hypotheses regarding the effects of the 1986 patent reforms on Taiwan's domestic inventive activity. In short, if the strengthening of patent rights was expected to help Taiwanese inventors extract greater returns from their inventions, then we should observe increases over the previous trend in expenditures on R&D, in patent applications, as well as in patent grants on inventions generated in Taiwan after the reforms. Moreover, as the effects of strengthening patent protection on inventive activity should vary across industries, we would expect them to be more prominent in those industries where patent protection was technically most feasible (that is, where competitors could not easily invent around the patent or imitate without being detected). Moreover, because the patent reforms applied to the enforcement of Taiwanese patents, the impact of the strengthening of patent protection on inventive activity should be stronger in industries targeting the domestic market than in industries focusing on foreign markets which have their own strong patent systems. In this section, I subject these hypotheses to tests of consistency with the data.

Overall Inventive Activity

If the Taiwanese patent reforms induced greater domestic inventive activity in general, we should observe an increase in R&D efforts in or around the year when the reforms came into force. Figure 2 graphs the total R&D spending of these 10 major sectors around the time of the 1986 patent reforms which took effect in 1987. While the R&D expenditures were rather flat between 1983 and 1986, an abrupt increase took place in 1987 and grew rapidly thereafter. Because inventive activity may simply expand along with production, Figure 3 reveals that the same qualitative pattern holds for R&D spending as a proportion of industrial production. If the effect was only temporary, then the time trend of R&D spending should exhibit a spike in or around 1987. On the other hand, if the effect was long-term, then the time path should instead show a marked increase around 1987 and stay at a high level afterwards. Plots of R&D spending, as shown in Figure 2 and 3, suggest that the reforms might have long-term effects.

While the reforms seem to have encouraged greater investments in R&D, it is not so easy to discern whether the reforms had a major effect on the number of patents awarded to residents of Taiwan, to say nothing of the actual rate at which they generated new technological knowledge. Patenting grew rapidly in the U.S. and in Taiwan both just prior to as well as after 1987. Figure 4 displays the annual counts of patents awarded to Taiwanese inventors in the U.S. and in Taiwan, as reported in the last row, *total*, in Tables 3 and 4 respectively. No obvious increase above trend around 1987 is visible in these aggregate counts. Also, as the reforms only applied within Taiwan, one might expect that the growth rate of the number of patents awarded to Taiwanese residents by the Taiwanese Patent Office should outnumber that granted by USPTO to residents of Taiwan owing to the strengthening of patent rights which would have increased the propensity to patent in Taiwan. With such an expectation, it is puzzling that the number of U.S. patents granted to Taiwanese inventors grew more rapidly than the number of Taiwanese patents going to Taiwanese inventors.

In order to explore the effects of the reforms on patenting in a more systematic and detailed manner, I estimate a series of regressions. In these regressions, I employ two measures of inventive activity – R&D spending and patent counts – as the primary dependent variables.[26] To control for the increase in inventive activity that stems merely from the expansion of production, the annual figures on R&D spending and patent counts

[26] A large body of prior empirical literature on technological progress considers R&D expenditures as a major input of inventive activity while patents are widely regarded as a measure of invention output.

are deflated for each industry by its production value in the respective year, and expressed in a natural log scale.[27] Among the independent variables included in the specifications are: (i) time trend or year dummies; (ii) the export intensity of each industry, measured by the natural log of the ratio of exports to production value; and (iii) a term for the R&D intensity of each industry[28], measured in the same way as exports intensity, lagged one year; (iv) industry dummy variables to control for differences across industries in factors such as the returns to inventive activity and/or the propensity to extract returns from new technology through obtaining patent rights. [29] Most importantly, in order to capture the effect of the reforms, I incorporate a dummy variable, *reform*, or interaction terms between "*reform*" and industry dummies. The dummy variable, *reform*, takes a value of 0 in years before 1987 and 1 afterwards.

I begin with my analysis by examining the effects of the reforms on R&D spending. I applied a fixed effects model across industries while controlling for export intensity and year effects. If the reforms stimulated increased investments in R&D spending relative to the level of production in the respective industry, then the coefficients on the year dummies around 1987 should be positive. The regression results, as reported in Table 5, seem to suggest that the reforms induced additional R&D expenditures. To visualize the effects of the reforms, I plot the time pattern of these estimated year coefficients in Figure 6. If there was only a temporary effect of the reforms, then one would expect only a spike at 1987 or just afterwards. Given that the coefficients remain consistently positive, substantial in magnitude, and generally statistically significant, the effects of the reforms seem more likely to have been long-term.

I then look at the effects of the reforms on the total number of patents. The regressions presented here employ the log of patents (awarded by USPTO and by the Taiwanese Patent Office respectively) awarded by industry over the level of production (production value) as the dependent variable, and add a term for a one-year-lag of R&D intensity to the other covariates used above. As reported in Table 6, the estimated

[27] Actually the measure is equal to log [(patent count + 1)/production] because in some years, some industries did not generate any patented invention.
[28] I compute R&D intensity of each industry as the share of R&D spending over production value.
[29] I use a test proposed by Mackinnon, White, and Davidson (1983) to validate my choice of a log-linear regression model over a linear one. I applied the test to all my regression specifications. As the majority of test statistics tend to reject the use of the linear forms and indeed some of them do reject, the result seems to support my choice of log-linear forms over linear ones.

coefficients are consistently positive and statistically significant for the year-dummies from 1987 on in the regression pertaining to U.S. patents, but – although generally positive – they are smaller and do not quite attain conventional standards of significance except in 1991 for the regression based on patents in Taiwan. The patterns of coefficients on the year-dummy variables are displayed in Figure 7 for the convenience of the reader. Again, the impact of reforms seems to have been much larger when gauged by U.S. patents awarded to Taiwanese residents than by patents granted by the Taiwanese Patent Office.

A possible reason may explain why we observe these conflicting results. Taiwanese residents may be generating increasingly valuable or higher-quality inventions over time, allowing a higher fraction of them to pass the more stringent U.S. patent examination. To evaluate this possibility, Figure 5 plots the proportion of patent applications by Taiwanese residents that are granted. The increase in the success of Taiwanese inventors in obtaining patents, in both regions, over the period seems to support the notion that they were discovering better or higher quality inventions over time. As the total number of U.S. patents granted to residents of Taiwan was much smaller (though of higher quality on average) than those of Taiwanese patents awarded to Taiwanese inventors, an increase in the number of high-quality inventions by Taiwanese inventors would appear more salient in the U.S. patent series than in the Taiwanese series. If the reforms had a disproportionate influence on high-quality inventions, the sort that inventors might want to obtain patent rights for everywhere, and U.S. patents granted to Taiwanese were on average of higher quality or value, then one could indeed explain why the Taiwanese patent counts grew more slowly than the U.S. patent counts.[30]

[30] Another possibility is that along with the 1986 reforms, the Taiwanese Patent Office also adopted a few measures to improve the quality and efficiency of patent examination in 1987 and 1988. In brief, the Patent Office allocated its patent examiners into eight different teams according to their specialties in order to improve the quality of examination as well as to shorten the processing time. Also, given that each patent application is required to be examined twice by different examiners, under the new process of examination, junior examiners are chiefly responsible for the first round of examination and seniors re-examine them. In addition, the Office cooperated with the Chinese National Federation of Industries, a nonprofit industrial organization, to create the first searchable patent records that allow researchers and examiners to search past patent grants by the international patent classification and thereby facilitate patent examination. The more stringent patent examination, posed by the Taiwanese Patent Office around the time when the reform came into effect, might be another reason why the numbers of U.S. patents granted to Taiwanese inventors grew more rapidly than the numbers of Taiwanese patents going to Taiwanese inventors.

Did the Effects of the Reform Vary across Industries and to What Extent?

To further explore whether or not inventors and/or firms in different industries responded differently to the policy change, I consider two possibilities. One is that the effects varied between industries that focused on the international market and those that were more oriented toward the domestic (Taiwan) market. The logic here is that export-oriented industries would be most concerned with whether they could enforce property rights to their technologies in the relevant foreign countries, and thus might not be so affected by changes in Taiwanese intellectual property institutions. Domestic-oriented industries, on the other hand, would in principle be quite sensitive to the change in Taiwan's laws. Table 7 reports the ratios of exports to production values by industry over the period under study. Four industries – food and tobacco, paper and publishing, industrial goods, and transportation equipment – stand out because of their low export intensities. The other six industries exported almost, or more than, half of their output to foreign markets.

In addition to categorizing industries into export- and domestic-oriented industries, one might expect that in general the higher R&D intensive an industry is, the stronger intellectual property systems it demands. Table 8 reports the ratios of R&D expenditures to production values across industries over the period under study. Based on the averages of the ratios, as reported in the last row of Table 8, I categorize wood and furniture as very low R&D intensive. Food and tobacco, leather, textile and apparel, and paper and publishing were low R&D intensive industries. Industrial goods, instruments, and machinery were median R&D intensive industries, while electronic and electric, and transportation equipment sectors are the most R&D intensive industries.

Figures 8 and 9 respectively graph the R&D spending and intensity of the two groups of industries – domestic-oriented and export-oriented. Expenditures on R&D were more volatile in domestic-oriented industries than in industries that mainly targeted foreign markets, perhaps because domestic industries were more vulnerable to business cycles in Taiwan. Nevertheless, the 1987 reforms seemed to have induced greater investment in R&D spending in both sets of industries. I also plot the number of U.S. patents granted in these two groups of industries from 1984 to 1991, as shown in Figure 10. Despite a slight decline in the number of patents in the four domestic-oriented industries awarded to Taiwanese inventors between 1987 and 1988, in general both sets of industries exhibited a marked increase in patenting in the U.S. after the reforms. Eyeballing the trends in the data in this way seems to suggest that there was not much of a difference in how inventive activity responded to the reforms between these two sets of industries. Moreover, as regards patent counts, there was no evident acceleration around 1987 in the rate of growth of U.S. patents in either set of industries.

The other possibility considered here is that a strengthening of patent rights might only affect industries in which patent protection is critical to protect their inventions. Because firms may employ other mechanisms, such as secrecy and/or lead time, to extract returns from their discoveries, the importance of, and reliance on, patent protection may vary across industries. For example, food and tobacco industries are widely known for their intensive use of secrecy to secure their income streams from their inventions. The two industry sectors – textile and apparel, and leather industries, tend to rely more upon trademarks or lead time to protect their creations, while the paper and publishing sectors mainly employ strategies such as complementary sales and secrecy. I therefore distinguish them (food and tobacco, textile and apparel, leather, and paper and publishing) as the set of industries that might not so heavily rely on patent protection, from the other six industries. The low patenting rates of these four industries both in the U.S. and in Taiwan, as reported in Tables 3 and 4, seem to support the notion that these industries were not heavily dependant on patent rights to protect inventions. The other group, therefore, consists of the industrial sectors wood and furniture, industrial goods, transportation equipment, electronic and electric, machinery, and instruments.

I start with examining the time patterns of the total R&D expenditures in these two groups of industries. As shown in Figures 11 and 12, the total R&D spending of non-patent-reliant industries exhibited a surge in 1987, declined significantly in 1988, and then rose again in 1990. The other group of industries that are heavily reliant on patent protection, contrary-wise, had a rather flat level of R&D spending during 1983-1986, and significantly increased their R&D expenditure in later years. Moreover, Figure 13 reveals a stark contrast on patenting trend in the U.S. between these two sets of industries. While there was no significant change in the number of U.S. patents granted to the non-patent-reliant industries, the number of patents received by industries in which patents are frequently used grew rapidly over time. These plots, however, show no clear indication that the reforms had any effect on R&D expenditure and patenting of these two sets of industries.

In order to more systematically examine the responses of inventive activity to the reforms, I undertook a set of regression analyses. In some specifications, I, also include another set of dummy variables as independent variables to control for the difference in R&D intensities across industries. The regressions in Table 9 use patents in the U.S. to gauge inventive activity while those in Table 10 pertain to variation in R&D spending. Panel A in both tables explores the possibility that the impact of the reforms might vary across industries that targeted different geographic markets and Panel B, on the other hand, examines whether or not the responses to the reforms differed in the reliance of industries on patent rights to extract returns from their discoveries.

As reported in Table 9, two basic results stand out from these regression analyses. First, a comparison of the regression results between the domestic- and export-oriented industries seems to suggest that there was little difference between the two sets of industries in the responses to the patent reforms. The regression results between patent-reliant and non-patent-reliant industries also yield similar findings. However, as the coefficients on the dummy variable, *reform*, and most of the interaction terms between *reform* and industry dummies are positive, though not statistically significant, the regressions seem to suggest that the 1986 patent reforms might have some effect, however weak, on overall patenting in the U.S.[31] A closer examination further suggested that the effects were particularly strong in industries that were highly R&D intensive, such as electronic and electric.

To directly investigate the impact of the reform, regressions in Table 10 examine R&D expenditure. The results, as reported in Panel A, seem to suggest that the reforms induced little R&D spending in general. Moreover, domestic- and export-oriented industries did not appear to respond differently to the reform. I then perform Chow tests on these two groups. The tests yield small F statistics which lead me to reject the hypothesis that there exist differences between these two sets of industries in response to the reforms.

[31] Because not all inventions are patentable and, moreover, not all patentable inventions are actually patented (since inventors and/or firms have other mechanisms to protect their inventions), perhaps the insignificant regression results depicted in Table 9 might be attributable to these limitations of patent data.

On the contrary, by categorizing industries by their reliance on patent protection, the regressions show that the policy shift had a positive and statistically significant impact on patent-reliant industries, as reported in the first equation in Panel B. The reforms, however, had little, if not a negative, effect on the set of industries where patent rights were not heavily relied on to extract returns from their inventions.

In addition to the reported regressions, I employ the same specification as the first equation in Panel B to explore the possibilities: (i) inventors might have responded to the strengthening of patent rights prior to the reform or (ii) it might take a longer time for inventors to adjust to the new patent regime. By varying the "year" of *reform* – either pushing back the "assumed" implementation year of the reform from 1987 to 1986 or shifting it forward to 1988 or 1989 – the regressions yield estimated coefficients on the dummy variable, *reform*, in a lesser magnitude which is no longer statistically significant. The results thus support the fundamental assumption that the reform was exogenous. The results also suggest that inventors responded to the new patent policy without a lag.

To examine whether the effects of the reforms varied across industries further, I include in the regression the interaction terms between the R&D intensity dummy variables and *reform*. The results, as reported in the second equation in Panel B, show that the estimated coefficient on the interaction term between *reform* and the high R&D intensity dummy variable is positive and away from zero at the 0.01 significance level, suggesting that the reforms particularly stimulated R&D spending in industries that tend to heavily invest in R&D. A closer look at the third equation in Panel B indicates that the reforms had the most favorable impact on R&D spending in transportation equipment, and electric and electronic industries. In contrast, evidence in the last two columns of Panel B suggests that for industries that chiefly use other mechanisms to extract returns from their inventions, such as secrecy, the strengthening of patent rights had little effect on their inventive activity.

The analyses preformed here imply that the reforms induced additional R&D spending on industries where patent protection is more likely to be relied on. It is especially true in industries that were highly R&D intensive. The policy shift also increased the number of U.S. patents awarded to Taiwanese inventors in the electronic and electric industry. On the other hand, for industries that were not heavily dependent upon patent rights to secure returns from their discoveries, R&D spending and the numbers of patents awarded in these industries changed little from the period before to the period after.

Did the Reform Bring about More Foreign Direct Investment?

In addition to the direct effect on domestic invention, the advocates of stronger patent rights often argue that a strengthening of patent rights might attract more foreign direct investment and technology transfer from abroad. There are several reasons for this conjecture. First, because an enhancement in enforcement of patent rights increases the cost of domestic imitators to infringe patents, it reduces the chance that local competitors free ride on patented technology developed abroad. Second, effective patent protection also reduces transaction costs such as contractual and monitoring expenses.[32] In order to advance our understanding of the effects of strengthening patent rights, I also examine the time pattern of foreign direct investment in Taiwan.

As shown in Figure 14, the time path of foreign direct investment in Taiwan exhibited a surge in 1987 and remained at a relatively high level afterwards, which seems to support the idea that the reform promoted foreign direct investment. Because the total amounts of foreign direct investment reported in Figure 14 are inclusive of investment made in service industries, to examine the impact of the reforms systematically, I look at investment made only in the ten manufacturing industries where I have investigated their patenting and expenditures on R&D earlier in this section. Figure 15 reveals a similar pattern, although in a lesser degree, to Figure 14. The findings imply that the reforms induced more investment from abroad.

International Comparison

The evidence, thus far, shows that the reforms had a strong impact on industries which are not only heavily reliant on patent rights to protect their invention, but also highly R&D intensive, such as the electronic and electric industries. To explore the effects of the reforms further, I then compare the numbers of U.S. patents in some patent-reliant industries awarded to Taiwanese inventors with those awarded to residents of several other countries that had similar levels of technological practice and economic development to Taiwan but did not make significant changes in their patent systems in the 1980s, especially

[32] See the third chapter of Maskus (2002) for details.

in 1986 and 1987. I also include South Korea, which made an equally dramatic change in its patent system in 1986 as a result of U.S. pressure. The countries involved in the comparison are Argentina, Israel, Singapore, South Africa, and South Korea.

Figures 16, 17, and 18 plot the number of U.S. patents granted respectively in the chemical, electric, and mechanical fields by year of patent application. While the number of U.S. patents awarded in these industries to Argentina, Israel, Singapore and South Africa changed little from the early 1980s to early 1990s, patenting in the U.S. by Taiwanese and South Korean residents experienced rapid growth. The evidence suggests that patent reforms did spur domestic inventive activity in Taiwan and South Korea, since the other four countries did not make changes in their patent regimes until much later. Indeed, in recent years, Taiwan has surpassed most OECD countries and has been the fourth largest recipient of U.S. patents, after the U.S., Japan and Germany. South Korea also scores highly in this regard.

7. CONCLUSION

As the GATT and the WTO require member countries to accept and adhere to the 1993 Trade Related Intellectual Property Agreement, in recent years developing countries have been restructuring their patent regimes to bring them more in line with those in industrialized countries. The primary motivation of developed countries, such as the United States, that have pushed for the so-called harmonization of intellectual property regimes has no doubt been in their own interest. However, some proponents of this recent policy trend toward strengthening patent protection argue that regardless of the background to the institutional change, stronger patent protection might actually stimulate domestic inventive activity in developing countries – if not enhance social welfare more generally. The leaders of developing countries have generally reacted skeptically but have not always been able to stand up to the outside pressures.

This paper has sought to improve our understanding of the impact of strengthening patent rights in a developing economy, by examining the effects of a change in the Taiwanese patent system, a change which was to a great extent compelled by pressure from the United States. The empirical evidence supports the idea that the 1986 Taiwanese patent reforms stimulated inventive activity in Taiwan, as gauged both by expenditures on R&D

and by patenting in the U.S. It is especially true in industries that would normally be expected by the nature of their products to be more heavily reliant on patent protection to extract returns from their inventions. Moreover, the more R&D intensive an industry was, the larger the impact of the reforms would be. For industries that are normally considered less dependent on patent rights to realize returns to their new technologies or products, the reforms had little effect on either patenting or R&D expenditures. In addition to the direct effects on domestic invention, there is evidence that the strengthening of patent rights also induced more foreign direct investment in Taiwan.

Several policy implications can be drawn from these findings. First, a stricter patent regime may benefit developing countries by spurring inventive activity and encouraging foreign direct investment. However, the benefits from strengthening patent rights appear to vary across industries. A similar policy change might, therefore, have different effects on countries since each country has its own unique composition of industries. As patent rights are still based on national laws, cooperative efforts to harmonize patent protection around the world by industrialized countries may not be successful unless developing countries can also benefit from strengthening their patent regimes. In order to resolve the conflict between innovative economies and technology net-importing countries, international negotiations and institutions such as the WTO and the World Intellectual Property Organization should perhaps address the ability of developing countries in creating new technical knowledge before persuading them to institute stronger patent regimes.

REFERENCES

1. Cohen, W.M., Nelson, R.R., and Walsh, J.P. "Protecting their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," *NBER Working Paper* (2000).

2. Butler, A. "The Trade-Related Aspects of Intellectual Property Rights: What Is at Statke?" Federal Reserve Bank of St. Louis *Review*, Vol. 72 (1990), pp. 34-46.

3. Denicolo, V. "Patent Races and Optimal Patent Breadth and Length." *Journal of Industrial Economics*, Vol. 44 (1996), pp. 249-265.

4. Gilbert, R. and Shapiro, C. "Optimal Patent Length and Breadth." *Rand Journal of Economics*, Vol. 21 (1990), pp. 106-112.

5. Gallini, N.T. "Patent Policy and Costly Imitation." *Rand Journal of Economics*, Vol. 23 (1992), pp. 52-63.

6. Griliches, Z. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature*, Vol. 28 (1990), pp. 1661-1707.

7. ———, "Productivity, R&D, and the Data Constraint." *American Economic Review*, Vol. 84 (1994), pp. 1-23.

8. Hall, B.H., Jaffe, A. and Trajtenberg, M. "Market Value and Patent Citations," *mimeo* (2003), University of California, Berkeley.

9. Hall, B.H. and Ziedonis, R.H. "The Determinants of Patenting in the U.S. Semiconductor Industry, 1980-1994." *Rand Journal of Economics*, Vol. 32 (2001), pp. 101-128.

10. Klemperer, P. "How Broad should the Scope of Patent Protection Be?" *Rand Journal of Economics*, Vol. 21 (1990), pp. 113-130.

11. Kortum, S. and Lerner, J. "What is Behind the Recent Surge in Patenting?" *Research Policy*, Vol. 28 (1999), pp. 1-22.

12. Lanjouw, J. "The Introduction of Pharmaceutical Product Patents in India: "Heartless Exploitation of the Poor and Suffering"?" *NBER Working Paper* (1998).

13. Lanjouw, J. and Cockburn, I. "Do Patents Matter? Empirical Evidence after GATT." *NBER Working Paper* (2000).

14. Lerner, J. "150 Years of Patent Protection," *American Economic Review Papers and Proceedings*, Vol. 92 (2002), pp. 221-225.

15. Levin, R., Klevorick, A., Nelson, R.R., and Winter, S. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity*, Vol.3 (1987), pp. 783-820.

16. Mackinnon, J., White, H., and Davidson, R. "Tests for Model Specification in the Presence of Alternative Hypothesis; Some Further Results." Journal of Econometrics, Vol. 21 (1983), pp. 53-70.

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

18. Moser, P. "How do Patent Laws Influence Innovation? Evidence from nineteenth-century World Fairs." *mimeo* (2001), University of California, Berkeley.

19. Pakes, A. and Grilliches, Z. "Patents and R&D at the Firm Level: A First Report." *Economics Letters*, Vol. 5 (1980), pp. 377-81.

20. Qian, Y. "Do Additional National Patent Laws Stimulate Domestic Innovation In a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection: 1978-1999." *mimeo* (2003), Harvard University.

21. Sakakibara, M. and Branstetter, L. "Do Stronger Patents Induce More Innovation? Evidence from the 1998 Japanese Patent Law Reforms." *Rand Journal of Economics*, Vol. 32 (2001), pp. 77-100.

22. Schmookler, J. *Inventions and Economic Growth*. Massachusetts, Harvard University Press, 1966.

23. Sokoloff, K.L. "Inventive Activity in Early Industrial America: Evidence From Patent Records, 1790-1846." *Journal of Economic History*, Vol. 48, (1988), pp. 813-850.

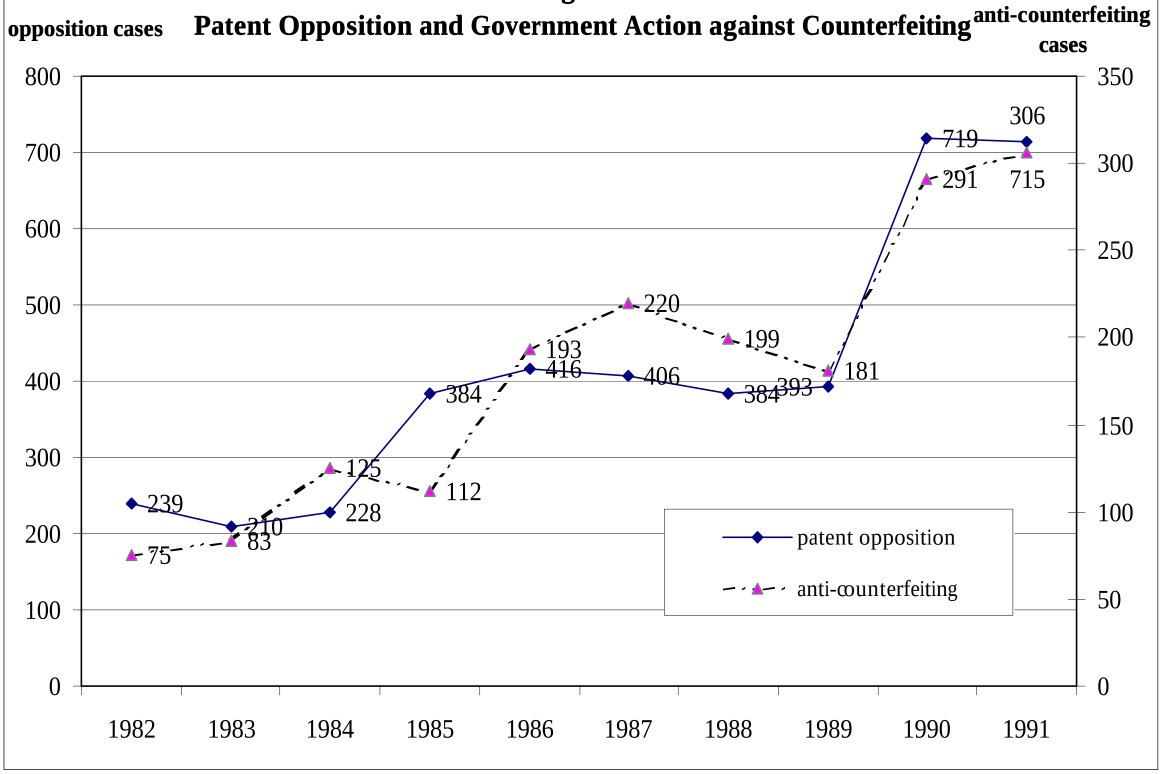
24. Sutthiphisal, D. "The Geography of Invention in High- and Low-Technology Industries: Evidence from the Second Industrial Revolution." *mimeo* (2003), University of California, Los Angeles.

25. Tandon, P. "Optimal Patents with Compulsory Licensing." *Journal of Political Economy*, Vol. 90 (1982), pp. 470-486.

26. Trajtenberg, M. "Innovation in Israel 1968-97: A Comparative Analysis Using Patent Data." *NBER Working Paper* (1999).

Figure 1

Patent Opposition and Government Action against Counterfeiting



Notes: Any person who asserts that a published invention has violated any requirements, stipulated in the patent law, of granting a patent, may, within three months from the publication date, submit a written opposition application. Upon receipt of a written opposition, the patent office shall re-examine the issued patent. (Translated from Chinese to English by the Taiwanese Intellectual Property Office and posted on the page of its website http://www.tipo.gov.tw/eng/laws/laws.asp) Patent opposition cases are reported by year of disposition instead of by year of application. On the other hand, anti-counterfeiting cases are reported by year of disposition.

Sources: *Yearbook of Patents and Trademarks*, 1990 and 1996, Republic of China.

Table 1 U.S. Patents Awarded to residents of Taiwan by Year of Application and Industry

year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
food and tobacco	2			1	1	1	1		2
textile and apparel	3	3	4	4	6	10	9	5	12
leather	2	6	6	8	7	11	6	8	10
paper				7	3	2	1		4
printing and publishing					2	1	1		
wood and furniture	4	6	11	11	19	18	25	28	30
industrial goods	58	73	107	168	230	229	291	430	488
agricultural machinery	1	1	3	2	3		4	3	2
food products machinery				1	3	5	1	4	4
textile machinery		2	1	3	1	2	2	3	3
woodwork machinery	1	1			3	1	1	2	
construction machinery			1	6	2	1	8	2	
engines and turbines	2	2	2	3	1	10		5	8
industrial goods machinery	6	8	9	12	16	21	31	36	18
office machinery	1	1	4	3	2	4	3	6	9
other machinery	7	8	16	22	20	25	23	31	60
paper machinery						1	1	2	2
printing and publishing machinery			1		2		1		3
service machinery			3	2	2	2	1	6	7
construction		3	2	2	3	4	7	8	8
electronic and electrical	34	47	84	111	142	183	265	306	431
transportation equipment	4	9	11	10	21	22	41	49	47
instruments	6	14	14	26	39	44	50	52	65
miscellaneous manufacturing	23	46	58	63	92	115	132	173	179
service				2	1	2	2	1	1
total	154	230	337	467	621	714	907	1160	1393

Notes: This table includes all of the U.S. patents, both utility and design patents, either awarded to Taiwanese residents who filed patent applications between 1983 and 1991, or assigned by inventors to Taiwanese assignees. In many cases, multiple individuals are registered as inventors. The location of patent origin, whether or not from Taiwan, is, therefore, determined by the residence of the first inventor of each patent.

Sources: USPTO online patent grant databases (http://www.uspto.gov).

Table 2 TW Patents Awarded to residents of Taiwan by Year of Application and Industry

year	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
food and tobacco		1	1		1	2		
texile and apparel	3	6	5	2	4	2	6	4
leather	1		2	2	2	5	1	1
paper	2	4	1	2	4		3	2
printing and publishing		1	1		1	2		1
wood and furniture	14	11	9	11	11	19	22	26
industrial goods	64	89	79	94	122	97	140	185
agricultural machinery	4	3	2	3	3	4	2	3
food products machinery	1		3	3	1	3	6	2
textile machinery	3	3	3	4	3	10	4	10
woodwork machinery	1	1	1	3	3	3	1	1
construction machinery			2	4	3	4	4	4
engines and turbines	1							
industrial goods machinery	16	11	9	12	15	23	25	24
office machinery	1	2	1	3	1	2	2	4
other machinery	8	8	9	5	18	14	10	21
paper machinery				1	1	1	1	
printing and publishing machinery	1	1	1			2	2	1
service machinery	1	3	4	4	10	7	3	7
construction	1		2	2	4	1	4	6
electronic and electrical	44	60	63	96	87	99	103	132
transportation equipment	5	10	3	7	15	9	15	17
instruments	9	15	22	20	16	18	16	26
miscellaneous manufacturing	26	34	28	44	48	49	47	40
service								
total	206	263	251	322	373	376	417	517

Notes: This table is based on a random sample of all patents awarded by the Taiwanese Patent Office. The total number of patents in the random sample is 5277. Among them, 2,725 patents are granted to residents of Taiwan. This table is constructed from the 2725 patents. Because in many cases, multiple individuals are registered as inventors, the location of patent origin, whether or not from Taiwan, is determined by the residence of the first inventor of each patent.

Sources: Taiwan Patent Network online patent grant databases (http://www.twpat.com).

Table 3 U.S. Patents Granted to Taiwanese residents by Year of Application and Industry

year	1984	1985	1986	1987	1988	1989	1990	1991
food and tobacco			1	1	1	1		2
textile and apparel	3	4	4	6	10	9	5	12
leather	6	6	8	7	11	6	8	10
paper and publish			7	5	3	2		4
wood and furniture	6	11	11	19	18	25	28	30
industrial goods	73	107	168	230	229	291	430	488
machinery	23	40	54	55	72	76	100	116
electronic and electrical	47	84	111	142	183	265	306	431
transportation equipment	9	11	10	21	22	41	49	47
instruments	14	14	26	39	44	50	52	65
total	181	277	400	525	593	766	978	1205

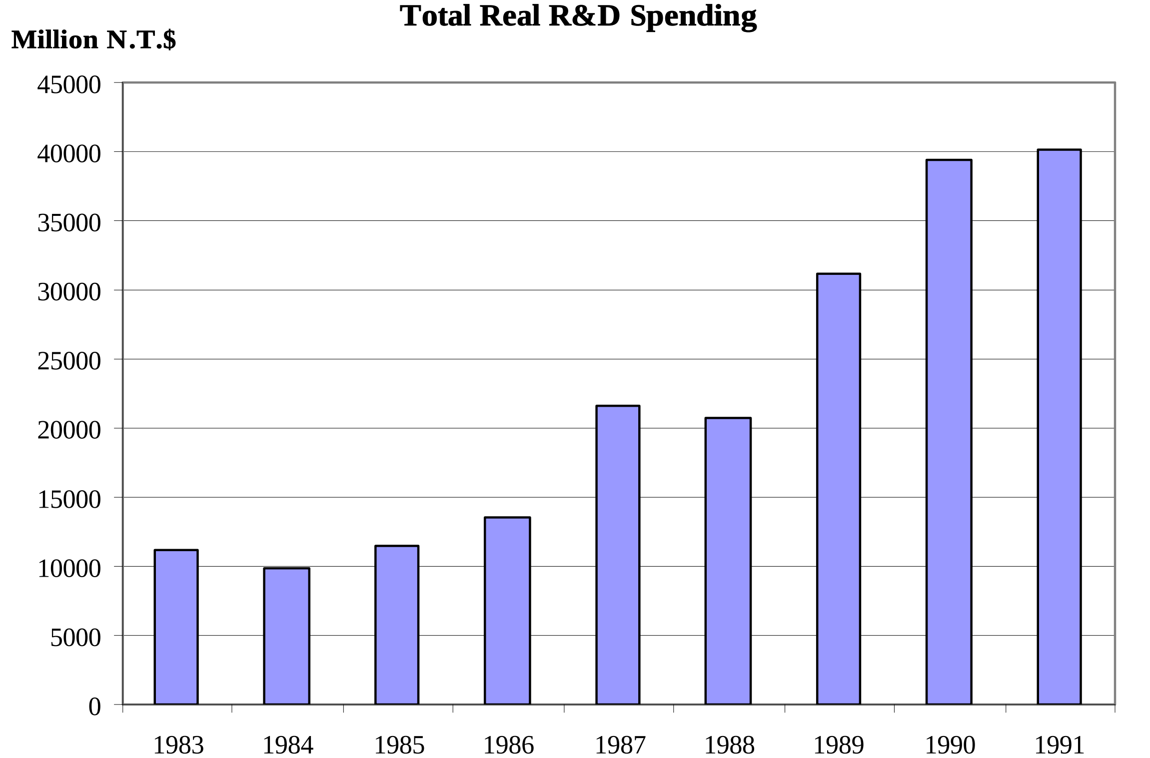
Notes: This table is a consolidation of Table 1. The machinery sector in the table includes engines and turbines, and all of the machinery industries. Also, I removed construction and miscellaneous manufacturing industries because I do not have supplementary data such as exports and R&D on these two industries.

Table 4 TW Patents Granted to Taiwanese residents by Year of Application and Industry

year	1984	1985	1986	1987	1988	1989	1990	1991
food and tobacco		1	1		1	2		
textile and apparel	3	6	5	2	4	2	6	4
leather	1		2	2	2	5	1	1
paper and publish	2	5	2	2	5	2	3	3
wood and furniture	14	11	9	11	11	19	22	26
industrial goods	64	89	79	94	122	97	140	185
machinery	37	32	35	42	58	73	60	77
electronic and electrical	44	60	63	96	87	99	103	132
transportation equipment	5	10	3	7	15	9	15	17
instruments	9	15	22	20	16	18	16	26
total	179	229	221	276	321	326	366	471

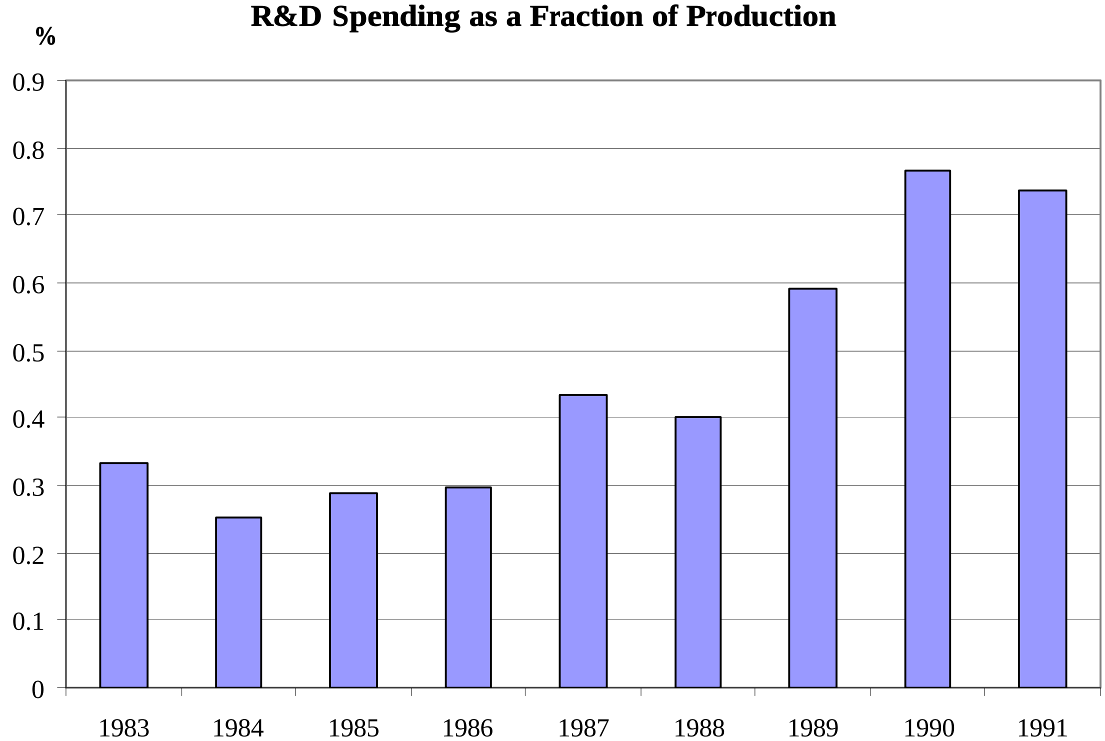
Notes: See Table 3.

Figure 2
Total Real R&D Spending



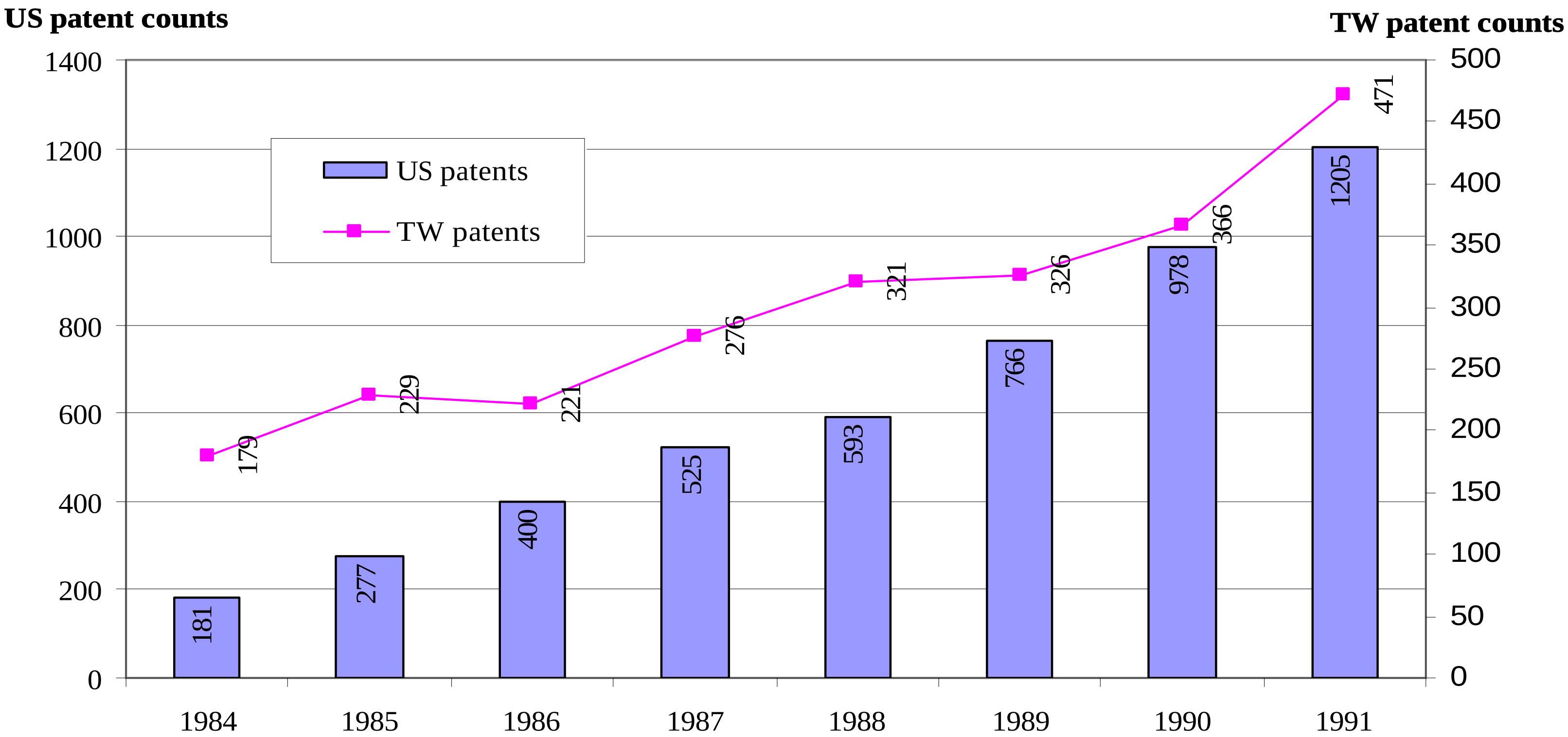
Notes: In this table, I summed up the R&D spending of the ten industries reported in Table 3 and 4 and then derived the real R&D spending, by using GDP deflators. The GDP deflators were calculated from Taiwanese GDP data. The reference year is 1996.
Sources: Information on R&D spending is from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council. GDP data are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics (http://www.dgbas.gov.tw/dgbas03/bs8/dbase/data.htm).

Figure 3
R&D Spending as a Fraction of Production

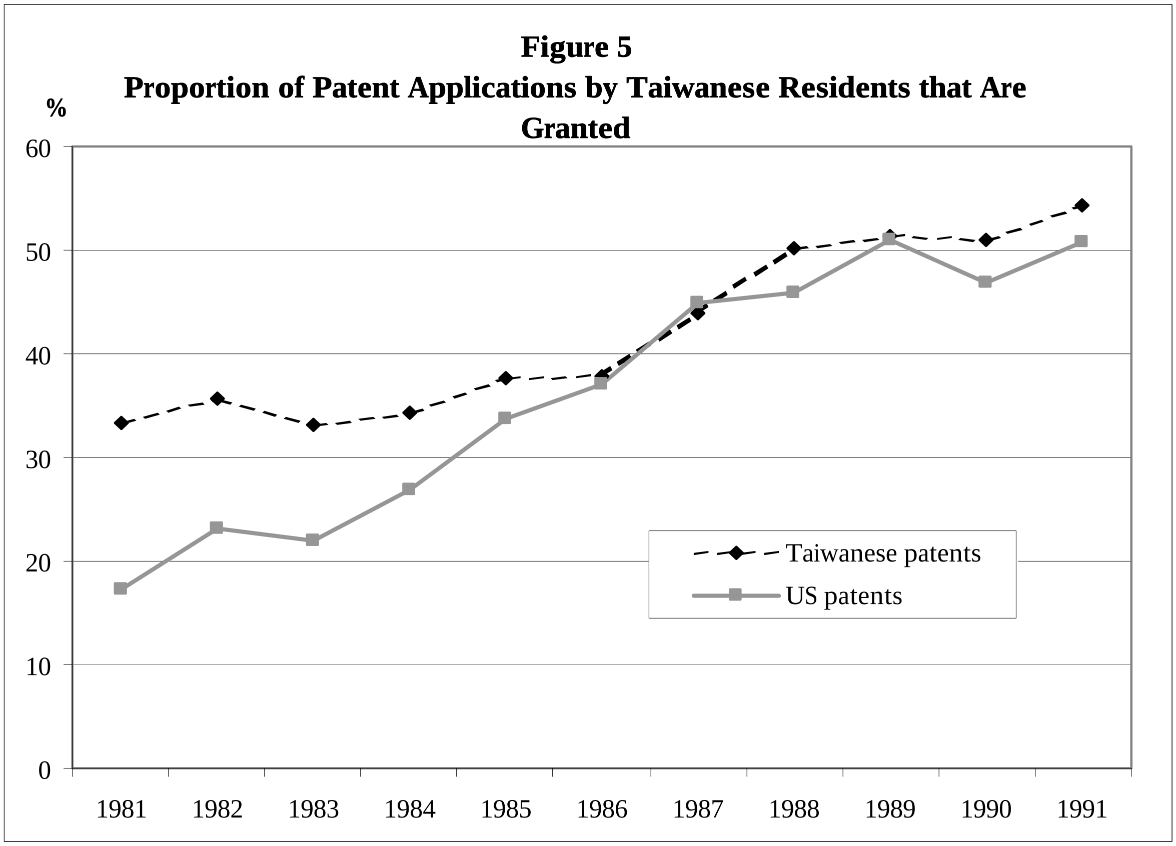


Notes: I summed up both the R&D spending and the production values of the ten industries reported in Table 3 and 4 each year between 1983 and 1991 and then derived the fractions by dividing them.
Sources: See Figure 2.

Figure 4
Patents Awarded to Taiwanese Residents by Year of Patent Application



Source: Table 3 and 4.



Notes: The U.S. series are derived by only using utility patent applications and grants that were filed by and awarded to Taiwanese residents. On the other hand, the Taiwanese patent series include all the three kinds of patents – invention, new utility model, and new design – issued by the Taiwanese Patent Office.

Sources: Data on Taiwanese patent applications filed by residents of Taiwan are from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council. The numbers of Taiwanese patent grants going to Taiwanese residents are from the online patent database provided by Taiwan Patent Network. Data on the US utility patent applications applied by Taiwanese inventors are from the report – *Number of Utility Patent Applications Filed in the United States By Country of Origin, Calendar Years 1965 to Present* – 2001, USPTO Technology Assessment and Forecast branch while the numbers of US utility patent grants awarded to Taiwanese inventors are collected from USPTO online patent grant database.

Table 5 The Effect of Patent Reform on R&D spending, Using Year Dummies

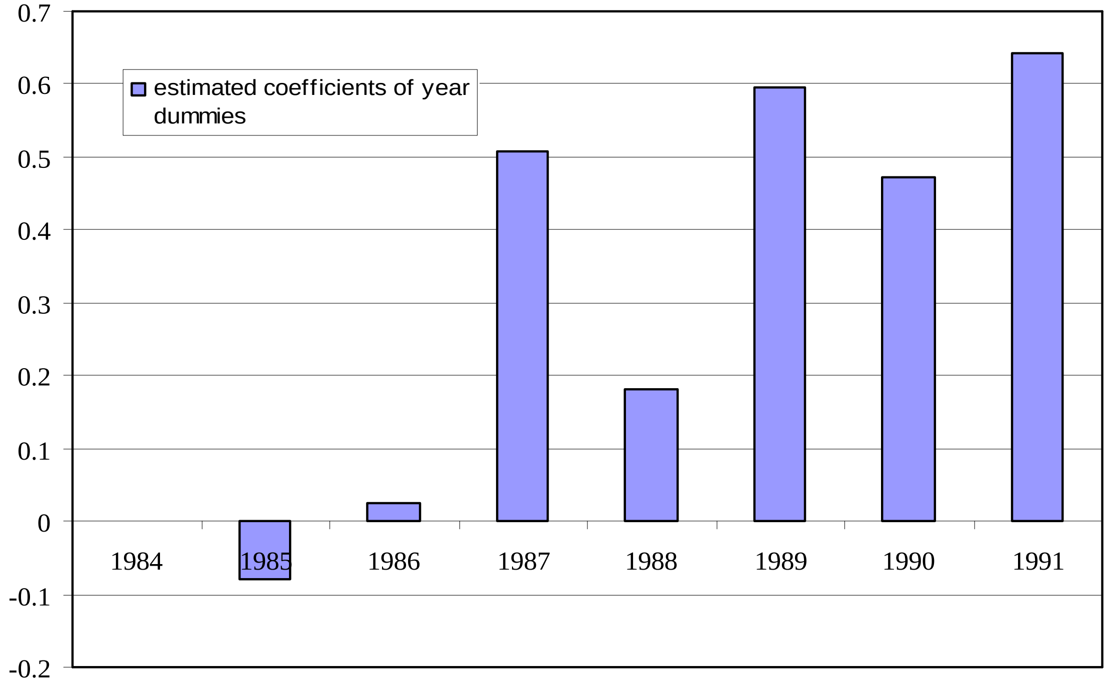
	log(R&D spending / production value)
1984 (reference year)	
1985	-0.08
	(0.234)
1986	0.024
	(0.238)
1987	0.509
	(0.239)*
1988	0.181
	(0.238)
1989	0.596
	(0.235)*
1990	0.473
	(0.235)*
1991	0.642
	(0.238)**
log(exports / production)	0.117
	(0.501)
Constant	-6.231
	(0.580)**
R^2	0.26
N	80

* denotes significance at the 0.05 level, ** the 0.01 level. The reference year is 1984.

Notes: The regression was estimated over a panel data using a fixed effects model. In addition to the variables listed in the table, the independent variables include industry dummy variables to control for differences across industries in technology opportunities. The estimated coefficients on these industry dummy variables are not reported. "Production" indicates production value of each industry.

Sources: R&D spending of each industry is from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council. Production values across industries are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics. Export volumes are collected from the *Monthly Statistics of Exports and Imports*, June 1993, Ministry of Finance, Republic of China.

Figure 6
Time Trend of R&D Spending



Notes: This figure plots the estimated coefficients of year dummy variables in Table 5. The reference year is 1984.

Table 6 The Effect of Patent Reform on Patenting, Using Year Dummies

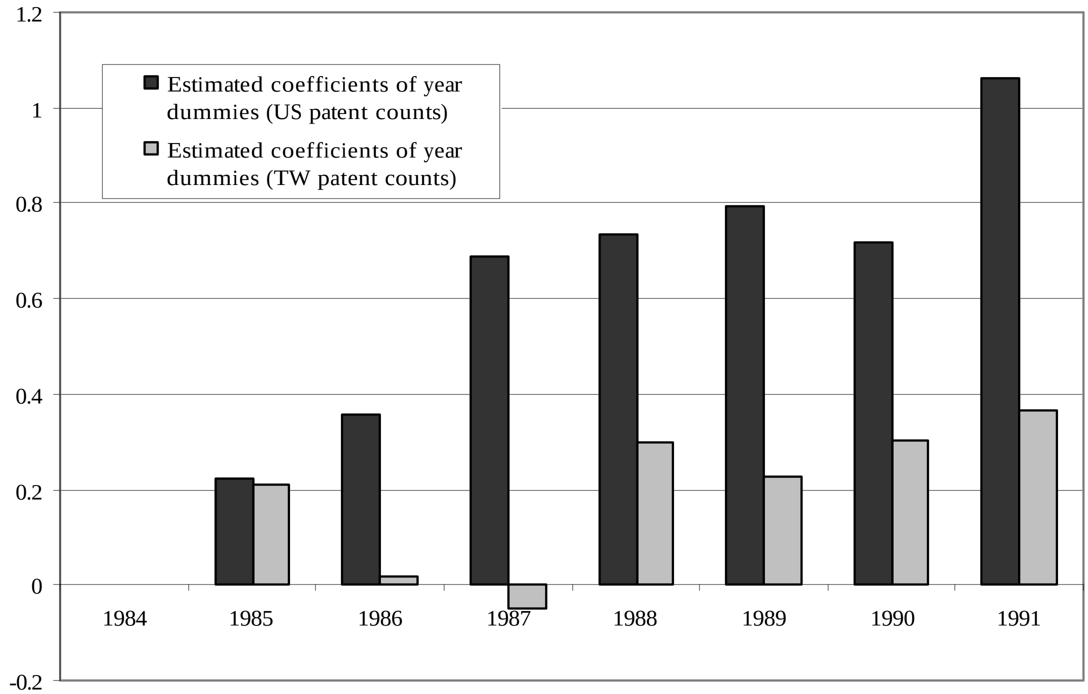
	log(US patents / production)	log(TW patents / production)
1984 (reference year)		
1985	0.225	0.212
	(0.196)	(0.149)
1986	0.358	0.017
	(0.200)	(0.152)
1987	0.687	-0.048
	(0.200)**	(0.152)
1988	0.736	0.299
	(0.204)**	(0.155)
1989	0.792	0.227
	(0.196)**	(0.149)
1990	0.72	0.301
	(0.203)**	(0.155)
1991	1.063	0.364
	(0.203)**	(0.154)*
log(exports / production)	-0.484	-0.189
	(0.418)	(0.317)
log(RD_{-1} / $production_{-1}$)	0.037	-0.199
	(0.120)	(0.091)*
Constant	-10.524	-11.673
	(0.883)**	(0.671)**
R^2	0.420	0.190
N	80	80

* denotes significance at the 0.05 level, ** the 0.01 level. The reference year is 1984.

Notes: The regression was estimated over a panel data using a fixed effects model. In addition to the variables listed in the table, the independent variables include industry dummy variables to control for differences across industries in technology opportunities. The estimated coefficients on these industry dummy variables are not reported. "Production" indicates production value of each industry. Because several industries did not generate any patents in some years, the measure of log (patents / production) is, in fact, calculated by log [(patent count + 1) / production].

Sources: R&D spending of each industry is from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council. Production values across industries are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics. Export volumes are collected from the *Monthly Statistics of Exports and Imports*, June 1993, Ministry of Finance, Republic of China. Patent counts are from Table 3 and 4.

Figure 7
Time Trend of Patenting

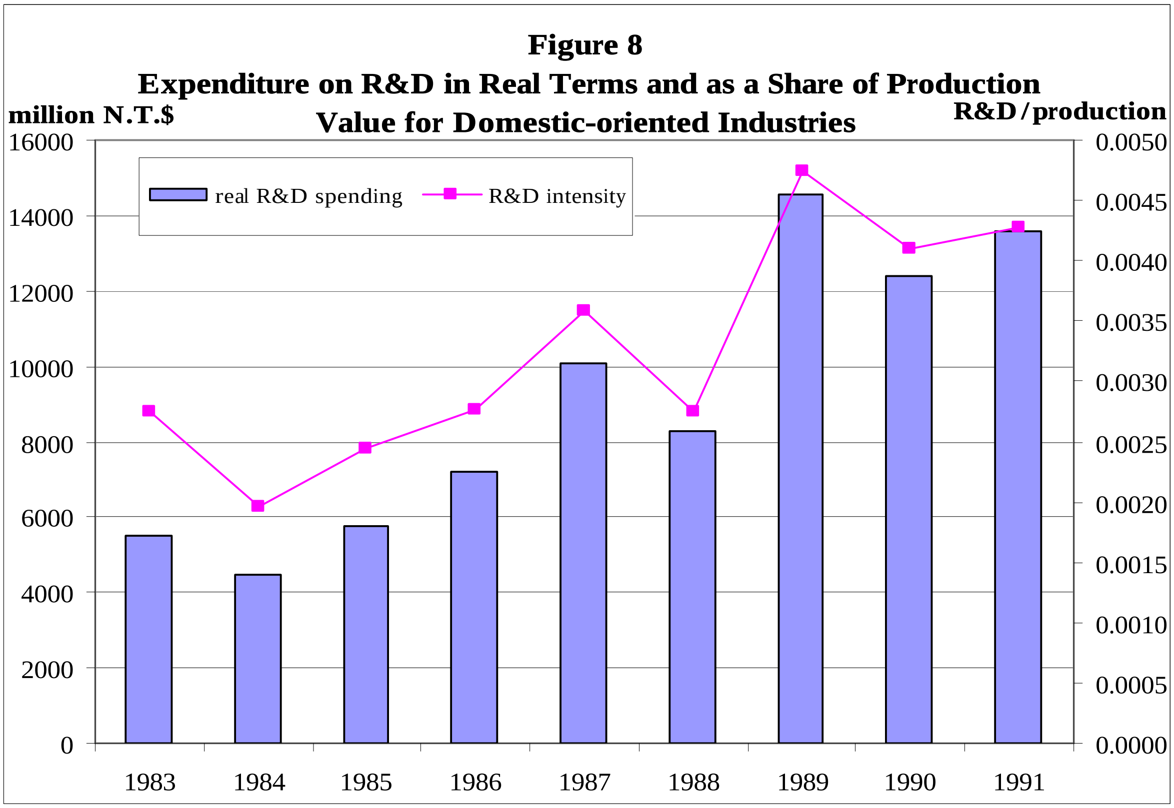


Notes: This figure plots the estimated coefficients of year dummy variables in Table 5. The reference year is 1984.

Table 7 Export Volume as a Fraction of Production Value (%)

year	food and tobacco	paper and publish	industrial goods	transportation equipment	leather	wood and furniture	machinery	textile and apparel	electronic and electrical	instruments
1984	12.255	4.418	28.844	28.543	57.987	56.296	49.337	48.452	58.684	73.901
1985	12.462	5.241	28.660	31.352	56.968	54.041	49.329	49.198	58.953	63.635
1986	16.256	6.488	28.882	32.760	61.929	52.243	47.890	49.486	60.892	76.672
1987	17.129	6.170	29.534	29.298	66.771	49.034	49.278	49.155	64.404	82.091
1988	14.562	7.590	27.756	26.384	69.460	43.959	50.593	50.648	62.701	82.171
1989	13.302	7.506	25.918	24.504	66.329	40.091	53.365	52.276	59.042	83.560
1990	12.926	9.305	24.990	27.312	51.584	39.846	54.255	54.069	57.059	82.043
1991	14.878	10.364	25.192	28.239	47.710	37.884	55.759	57.369	57.922	90.671

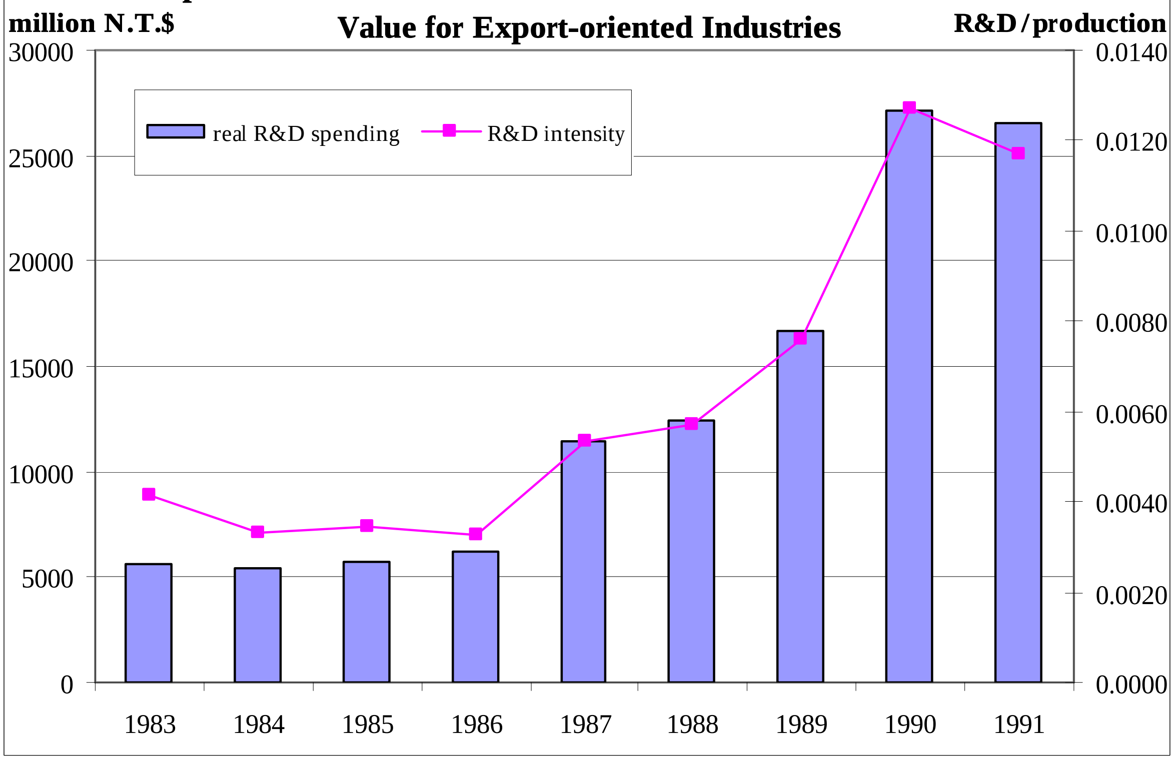
Sources: Production values across industries are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics. Export volumes are collected from the *Monthly Statistics of Exports and Imports*, June 1993, Ministry of Finance, Republic of China.



Notes: I summed up R&D spending and production values of the four domestic-oriented industries – food and tobacco, paper and publish, industrial goods, and transportation equipment. I then computed the shares of R&D spending to production values. I also calculated R&D spending in real terms by using GDP deflators. The GDP deflators were derived from Taiwanese GDP data. The reference year is 1996.

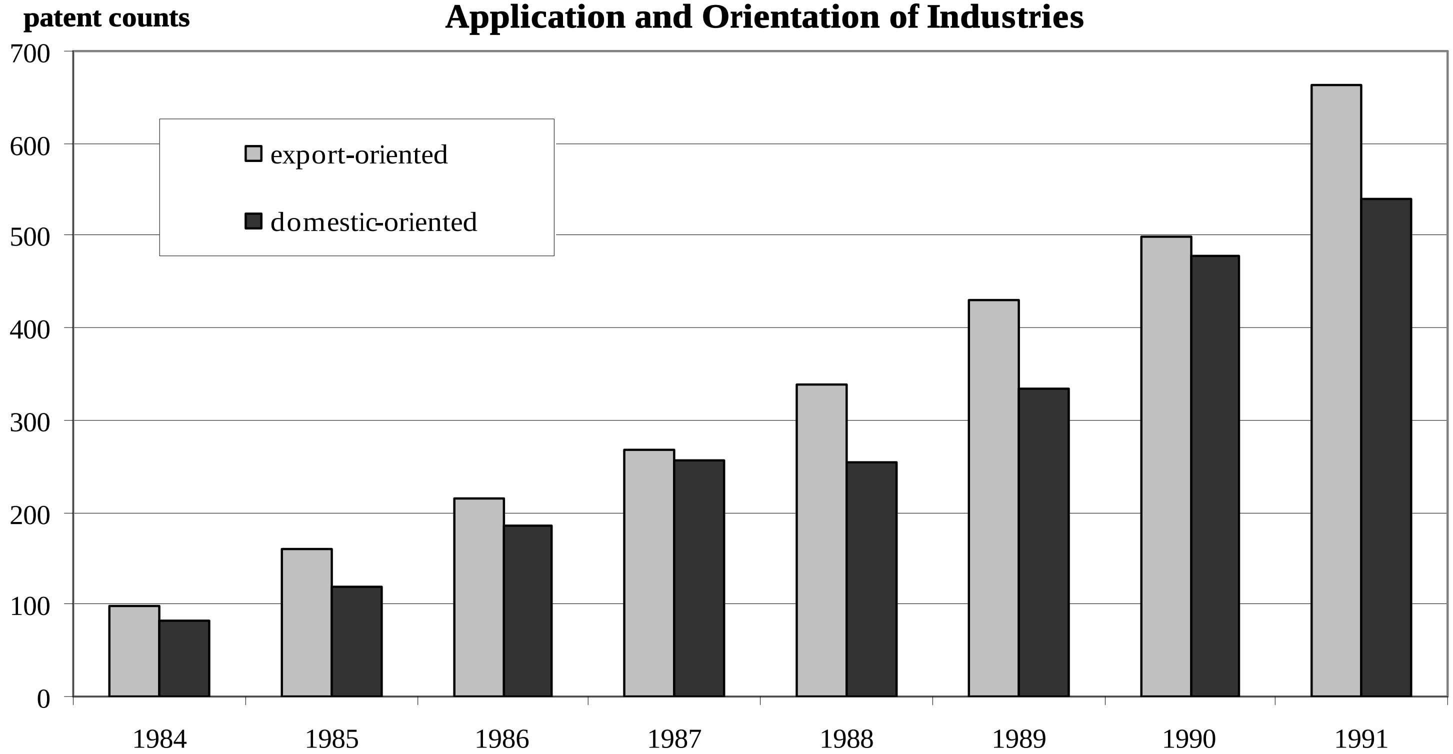
Sources: Information on R&D spending is from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council. Data on industrial production are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics.

Figure 9
Expenditure on R&D in Real Terms and as a Share of Production Value for Export-oriented Industries



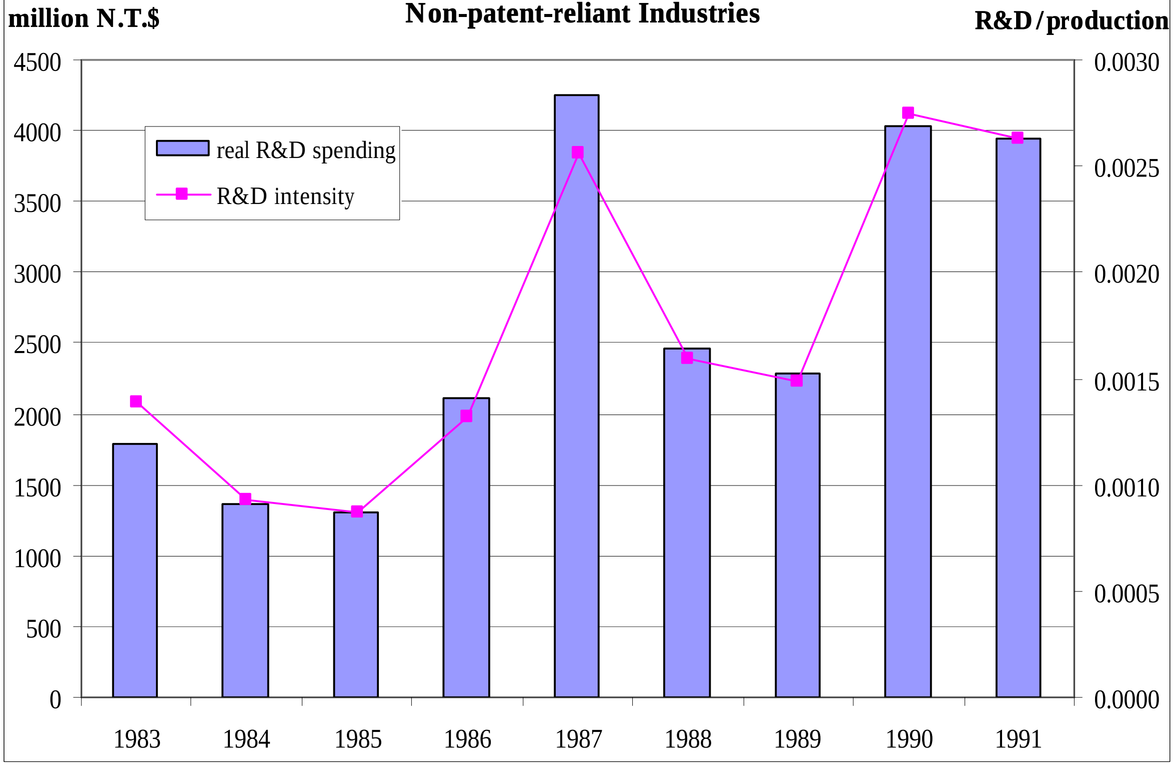
Notes: I summed up R&D spending and production values of the six export-oriented industries. I then computed the shares of R&D spending to production values. I also calculated R&D spending in real terms by using GDP deflators. The GDP deflators were derived from Taiwanese GDP data. The reference year is 1996.
Sources: See Figure 8.

Figure 10
Number of US Patents Awarded to Taiwanese Residents by Year of Application and Orientation of Industries



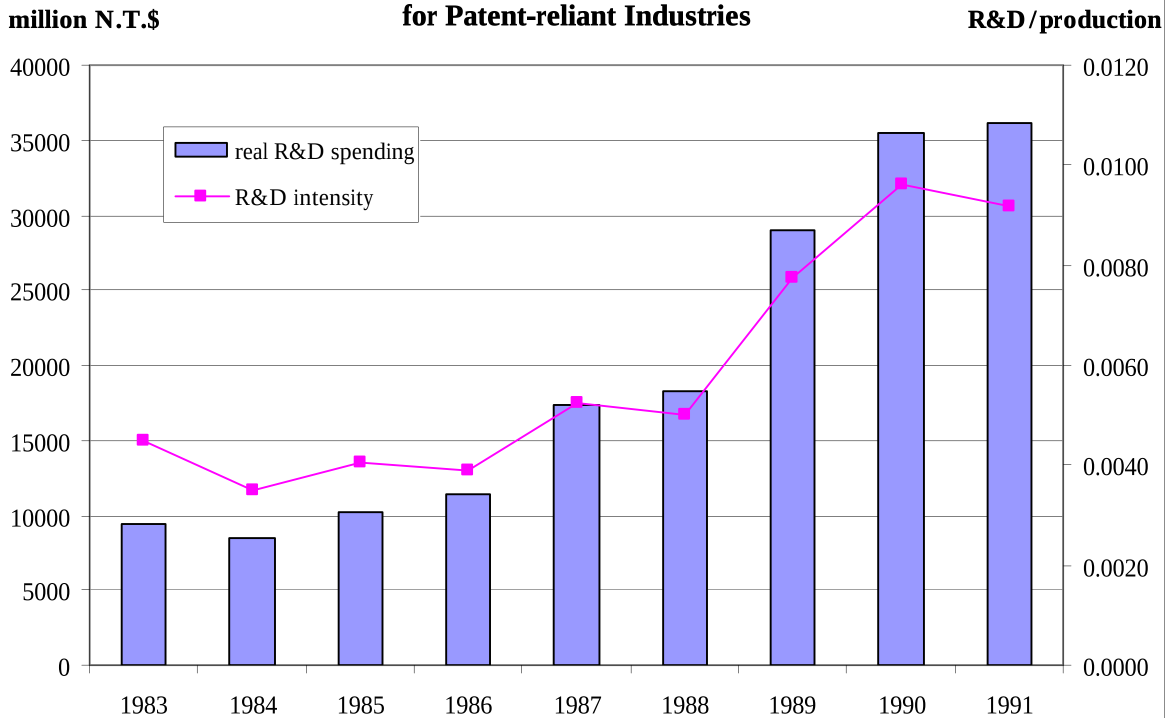
Notes: The export-oriented industries comprise of textile and apparel, leather, wood and furniture, machinery, electronic and electric, and instruments industries. The domestic-oriented industries, on the other hand, are food and tobacco, paper and publish, industrial goods, and transportation equipment sectors.
Sources: see Table 3.

Figure 11
Expenditure on R&D in Real Terms and as a Share of Production Value for Non-patent-reliant Industries



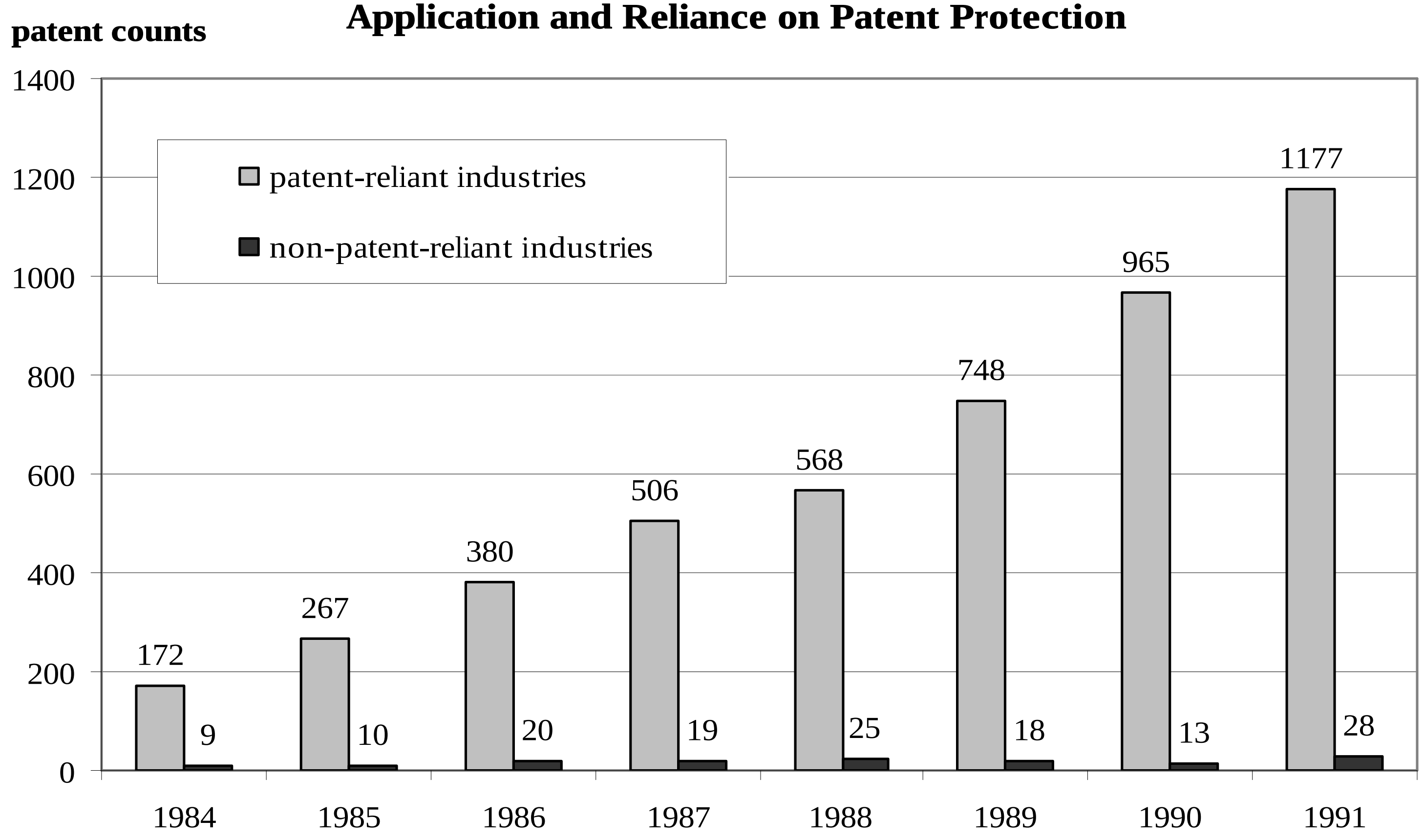
Notes: I summed up R&D spending and production values of the four non-patent-oriented industries – food and tobacco, paper and publish, textile and apparel, and leather. I then computed the shares of R&D spending to production values. I also calculated R&D spending in real terms by using GDP deflators. The GDP deflators were derived from Taiwanese GDP data. The reference year is 1996.
Sources: See Figure 8.

Figure 12
Expenditure on R&D in Real Terms and as a Share of Production Value for Patent-reliant Industries



Notes: I summed up R&D spending and production values of the six patent-reliant industries. I then computed the shares of R&D spending to production values. I also calculated R&D spending in real terms by using GDP deflators. The GDP deflators were derived from Taiwanese GDP data. The reference year is 1996.
Sources: See Figure 8.

Figure 13
Number of US Patents Awarded to Taiwanese Residents by Year of Application and Reliance on Patent Protection



Notes: The non-patent-reliant industries comprise of food and tobacco, textile and apparel, leather, paper and publish industries. The patent-reliant industries, on the other hand, are wood and furniture, industrial goods, machinery, electronic and electric, transportation equipment, and instruments sectors.
Sources: see Table 3.

Table 8 Expenditure on R&D as a Fraction of Production Value

year	wood and furniture	leather	food and tobacco	paper and publish	textile and apparel	industrial goods	instruments	machinery	transportation equipment	electronic and electrical
1984	0.000432	0.000506	0.000800	0.001650	0.000914	0.002233	0.004027	0.004199	0.003532	0.006762
1985	0.000318	0.000348	0.000646	0.000639	0.001203	0.002568	0.001932	0.007857	0.007948	0.006332
1986	0.000275	0.001857	0.001501	0.000913	0.001197	0.003319	0.002247	0.002316	0.003526	0.006535
1987	0.001068	0.000562	0.002089	0.001670	0.003460	0.003850	0.007022	0.004135	0.006092	0.008712
1988	0.000403	0.000184	0.001863	0.001111	0.001716	0.002629	0.008542	0.004482	0.005967	0.010082
1989	0.000537	0.004111	0.001898	0.001479	0.000901	0.004657	0.003621	0.006627	0.011124	0.013979
1990	0.000292	0.000526	0.002455	0.001737	0.003735	0.003712	0.003404	0.004120	0.009458	0.023533
1991	0.000183	0.004127	0.001626	0.001718	0.003678	0.004343	0.005616	0.004553	0.008963	0.020722
Average	0.000438	0.001528	0.001610	0.001365	0.002100	0.003414	0.004551	0.004786	0.007076	0.012082

Sources: Production values across industries are from the online economic database provided by the Taiwanese Directorate General of Budget Accounting and Statistics. Information on R&D spending is from the *Yearly Indicators of Science and Technology*, 1991-2001, published by the Taiwanese National Science Council.

Table 9 The Effect of Patent Reform on Patenting in the U.S. across Industries

	Panel A: Export-Oriented Industries VS Domestic-Oriented Industries						**Panel B: Patent-Reliant Industries VS Non-Patent-Reliant Industries**				
	dependent variable: log(US patents / production)						dependent variable: log(US patents / production)				
	export-oriented industries (ref=cloth)			domestic-oriented industries (ref=food)			patent-reliant industries (ref=wood)			non-patent-reliant (ref=food)	
year	0.097	0.101	0.098	0.137	0.124	0.125	0.119	0.124	0.126	0.025	0.019
	(0.047)*	(0.043)*	(0.042)*	(0.076)	(0.083)	(0.083)	(0.046)*	(0.045)**	(0.042)**	(0.073)	(0.075)
reform	0.259			0.196			0.261			0.232	
	(0.223)			(0.326)			(0.205)			(0.351)	
Log(exports / production)	-0.123	0.199	-0.138	-0.36	-0.125	0.177	-0.315	-0.202	-0.921	0.204	0.504
	(0.616)	(0.075)	(0.743)	(0.570)	(0.7360	(0.830)	(0.621)	(0.787)	(0.909)	(0.618)	(0.755)
$\log(RD_{-1} / production_{-1})$	0.119	0.103	0.084	-0.495	-0.419	-0.506	0.143	0.104	-0.002	-0.042	-0.028
	(0.112)	(0.104)	(0.102)	(0.297)	(0.339)	(0.358)	(0.148)	(0.148)	(0.143)	(0.172)	(0.181)
high-RD-intensive*reform		1.013			0.246			0.523			
		(0.314)**			(0.496)			(0.253)*			
median-RD-intensive*reform		0.081			0.422			0.115			
		(0.278)			(0.480)			(0.243)			
low-RD-intensive*reform		-0.028			0.063						
		(0.260)			(0.411)						
very-low-RD-intensive*reform		0.322						0.129			
		(0.342)						(0.357)			
food*reform						0.293					0.236
						(0.502)					(0.499)
paper*reform						-0.206					-0.105
						(0.531)					(0.540)
indgoods*reform						0.465			0.232		
						(0.487)			(0.292)		
transport*reform						0.299			0.041		
						(0.504)			(0.301)		
cloth*reform			0.296								0.604
			(0.313)								(0.475)
leather*reform			-0.277								0.094
			(0.306)								(0.483)
wood*reform			0.254						-0.043		
			(0.333)						(0.350)		
machine*reform			-0.109						-0.189		
			(0.313)						(0.320)		
electric*reform			1.041						0.979		
			(0.305)**						(0.295)**		
instrument*reform			0.383						0.425		
			(0.341)						(0.346)		
Constant	-11.277	-8.772	-11.536	-17.423	-13.959	-16.459	-8.659	-8.803	-9.976	-11.42	-10.849
	(0.900)**	(0.831)**	(0.941)**	(2.355)**	(2.836)**	(3.208)**	(1.023)**	(1.075)**	(1.120)**	(1.645)**	(1.814)**
R^2	0.510	0.630	0.670	0.340	0.360	0.380	0.620	0.650	0.730	0.140	0.200
N	48	48	48	32	32	32	48	48	48	32	32

* denotes significance at the 0.05 level, ** the 0.01 level. The reference year is 1984.

Notes: The regression was estimated over a panel data using a fixed effects model. In addition to the variables listed in the table, the independent variables include industry dummy variables to control for differences across industries in technology opportunities. The estimated coefficients on these industry dummy variables are not reported. Production indicates production value of each industry. Because several industries did not generate any patents in some years, the measure of log (patents / production) is, in fact, calculated by log [(patent count + 1) / production].

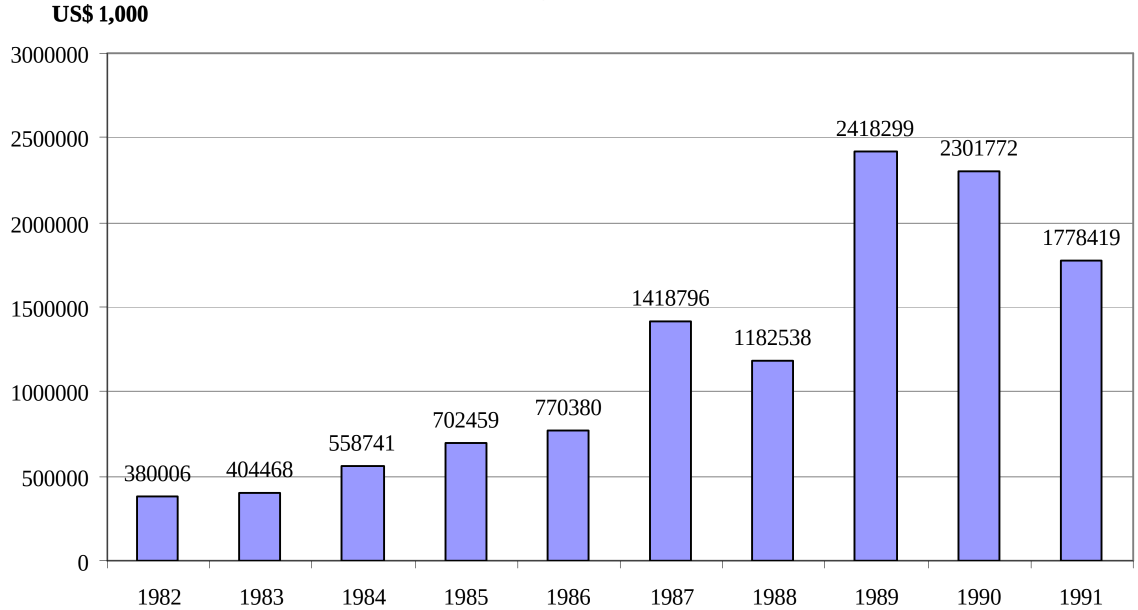
Table 10   The Effect of Patent Reform on R&D across Industries

	Panel A: Export-Oriented Industries VS Domestic-Oriented Industries						Panel B: Patent-Reliant Industries VS Non-Patent-Reliant Industries				
	dependent variable: log(R&D spending/production)						dependent variable: log(R&D spending/production)				
	export-oriented industries (ref=cloth)			domestic-oriented industries (ref=food)			patent-reliant industries (ref=wood)			non-patent-reliant (ref=food)	
year	0.052	0.05	0.046	0.056	0.061	0.057	-0.018	-0.015	-0.015	0.178	0.18
	(0.076)	(0.080)	(0.081)	(0.043)	(0.044)	(0.045)	(0.046)	(0.046)	(0.048)	(0.095)	(0.101)
reform	0.275			0.31			0.556			-0.032	
	(0.362)			(0.200)			(0.217)*			(0.446)	
Log(exports/production)	0.464	0.337	0.01	-0.115	-0.35	-0.162	0.869	1.215	1.17	-0.698	-0.834
	(0.997)	(1.374)	(1.427)	(0.351)	(0.431)	(0.499)	(0.659)	(0.843)	(1.071)	(0.809)	(1.015)
high-RD-intensive*reform		0.577			0.266			0.8			
		(0.579)			(0.292)			(0.271)**			
median-RD-intensive*reform		0.166			0.072			0.38			
		(0.518)			(0.286)			(0.258)			
low-RD-intensive*reform		0.347			0.436						
		(0.478)			(0.237)						
very-low-RD-intensive*reform		0.097						0.581			
		(0.636)						(0.381)			
food*reform						0.545					0.096
						(0.278)					(0.636)
paper*reform						0.274					0.058
						(0.320)					(0.720)
indgoods*reform						0.105			0.497		
						(0.291)			(0.344)		
transport*reform						0.309			0.769		
						(0.300)			(0.354)*		
cloth*reform			0.583								0.105
			(0.606)								(0.636)
leather*reform			0.172								-0.354
			(0.587)								(0.640)
wood*reform			0.031						0.571		
			(0.647)						(0.411)		
machine*reform			-0.082						0.078		
			(0.607)						(0.364)		
electric*reform			0.598						0.83		
			(0.587)						(0.347)*		
instrument*reform			0.526						0.579		
			(0.658)						(0.408)		
Constant	-6.21	-6.282	-6.464	-6.571	-7.009	-6.658	-5.272	-5.01	-5.044	-8.257	-8.471
	(0.582)**	(0.787)**	(0.816)**	(0.660)**	(0.809)**	(0.935)**	(0.510)**	(0.647)**	(0.818)**	(1.282)**	(1.604)**
^{2}	0.16	0.17	0.2	0.51	0.54	0.55	0.31	0.35	0.38	0.28	0.3
N	48	48	48	32	32	32	48	48	48	32	32

* denotes significance at the 0.05 level, ** the 0.01 level. The reference year is 1984.

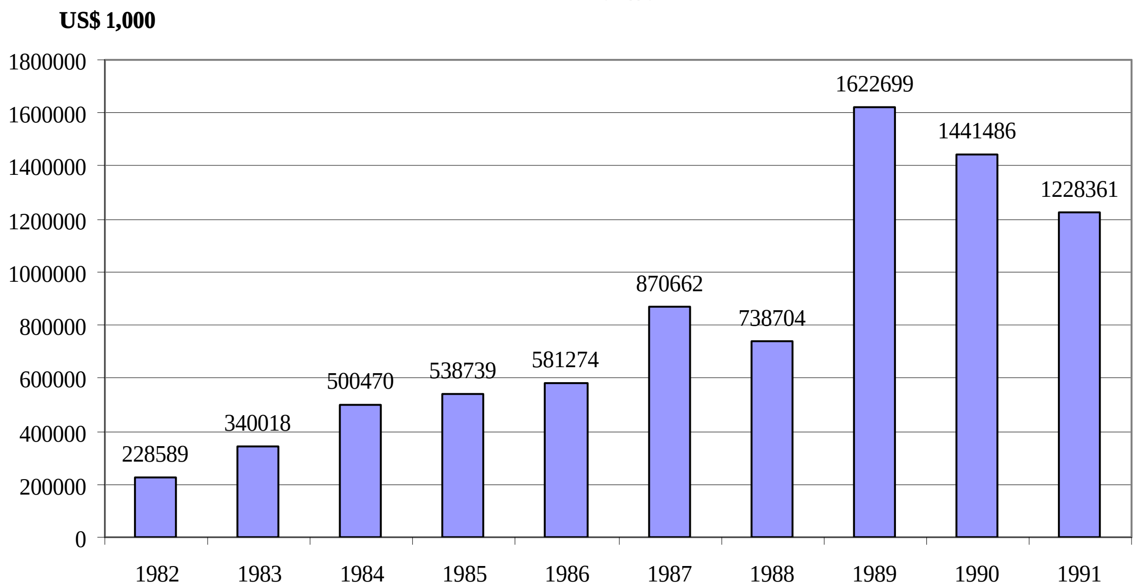
Notes: The regression was estimated over a panel data using a fixed effects model. In addition to the variables listed in the table, the independent variables include industry dummy variables to control for differences across industries in technology opportunities. The estimated coefficients on these industry dummy variables are not reported. Production indicates production value of each industry.

Figure 14
Overseas Chinese and Foreign Direct Investment in Taiwan by Year



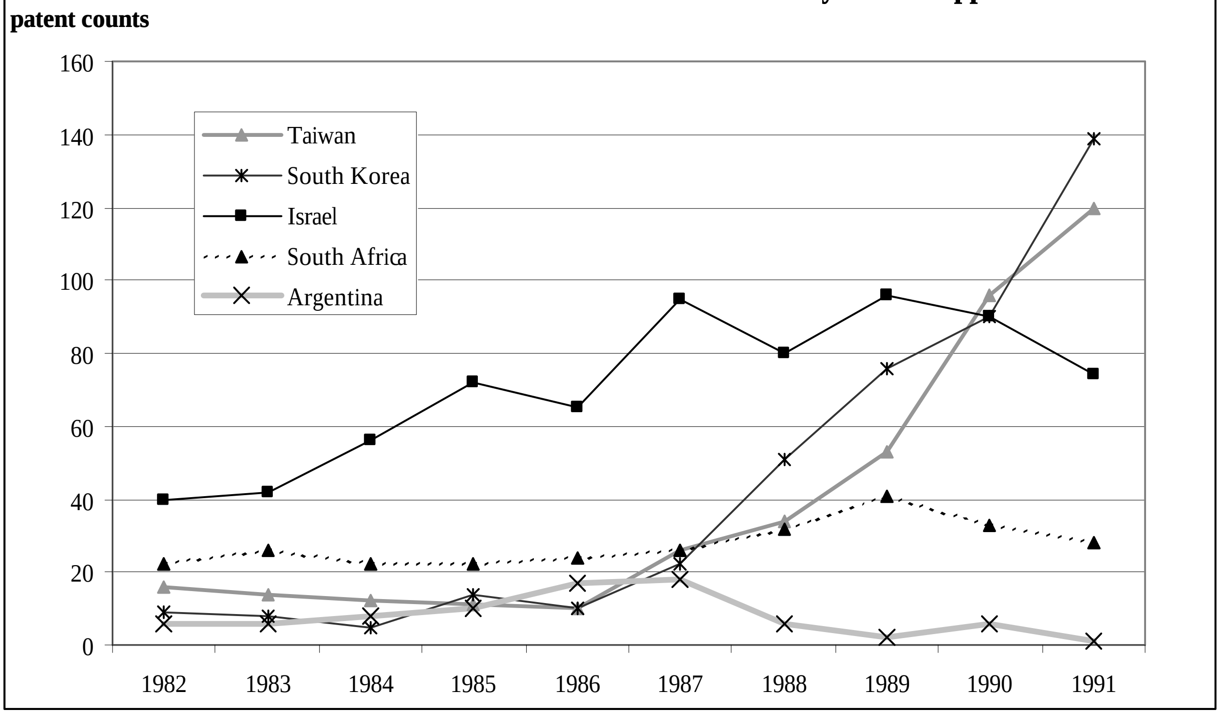
Notes: The figures reported in the graph are inclusive of all investment made in Taiwan.
Sources: *Statistical Yearbook on Overseas Chinese & Foreign Investment, Technical Cooperation Outward, Technical Cooperation, Indirect Mainland Investment, Guide of Mainland Industry Technology*, 1996, the Republic of China.

Figure 15
Overseas Chinese and Foreign Direct Investment in Manufacturing Sectors in Taiwan



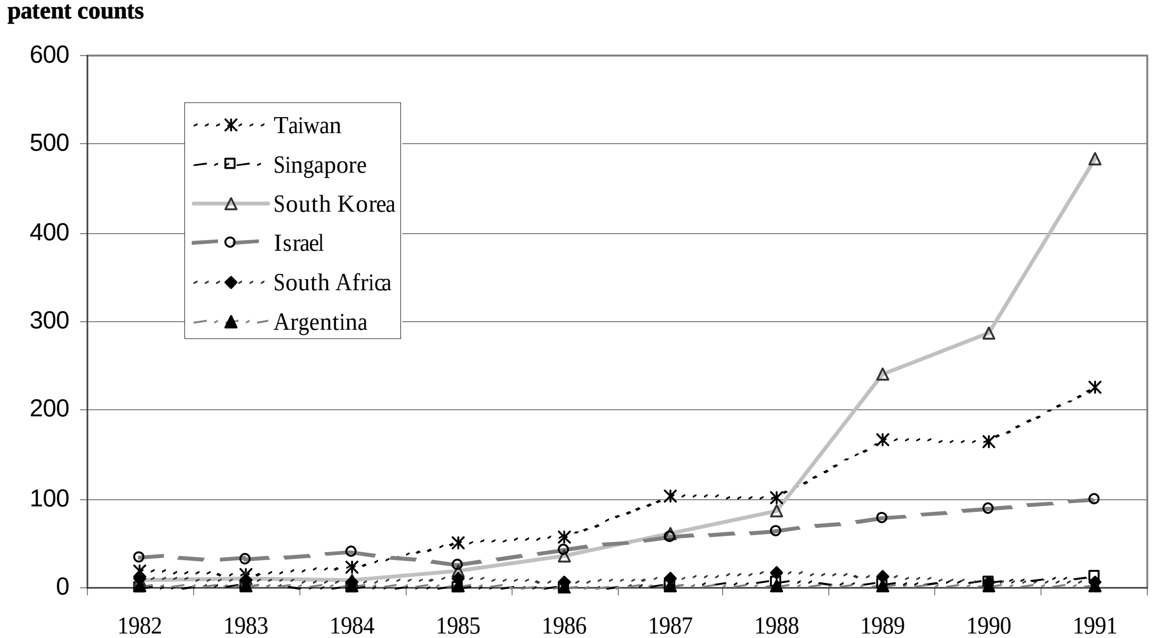
Notes: The figures reported in the graph are the sum of investment made in the ten major manufacturing sectors. *Sources*: *Statistical Yearbook on Overseas Chinese & Foreign Investment, Technical Cooperation Outward, Technical Cooperation, Indirect Mainland Investment, Guide of Mainland Industry Technology*, 1996, the Republic of China.

Figure 16
Numbers of US Patents Granted in Chemical Classes by Year of Application



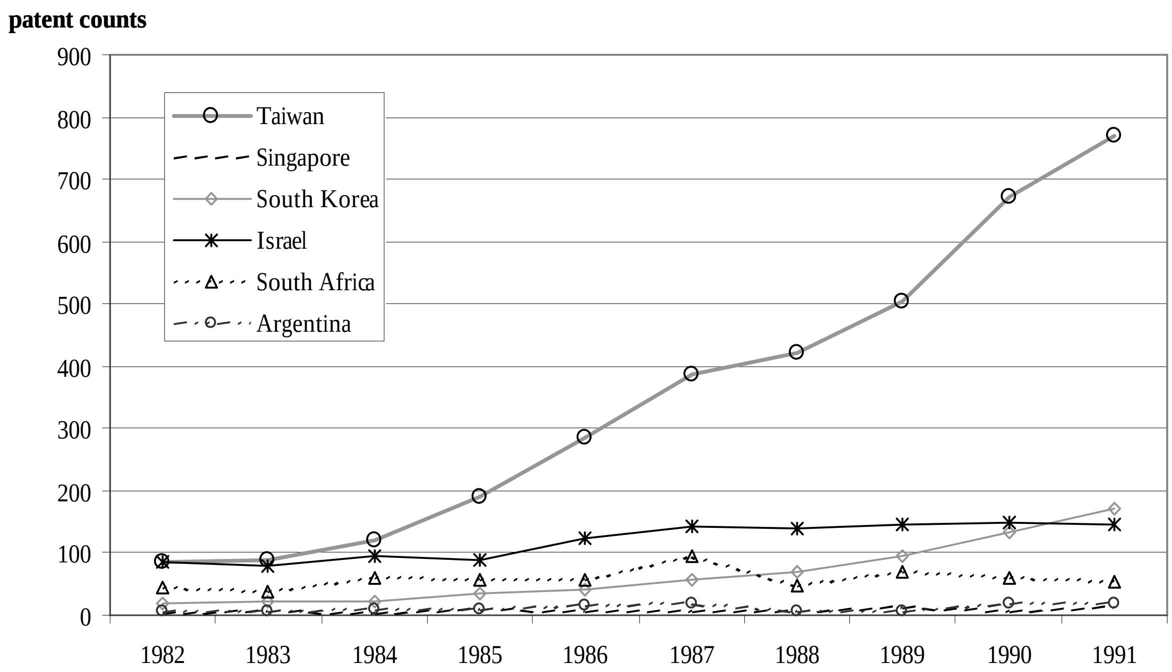
Notes: Chemical classes denote chemical discipline classes within the U.S. Patent Classification System.
Sources: *Technology Access and Forecast Report, Chemical Classes*, 1995 and 2003, USPTO Technology Assessment and Forecast branch.

Figure 17
Numbers of Patents Granted in Electrical Clases by Year of Application



Notes: Electrical classes denote electrical discipline classes within the U.S. Patent Classification System.
Sources: *Technology Access and Forecast Report*, *Electrical Classes*, 1995 and 2003, USPTO Technology Assessment and Forecast branch.

Figure 18
Numbers of Patents Granted in Mechanical Classes by Year of Application



Notes: Mechanical classes denote mechanical discipline classes within the U.S. Patent Classification System.
Sources: *Technology Access and Forecast Report, Mechanical Classes*, 1995 and 2003, USPTO Technology Assessment and Forecast branch.