What is Behind the Recent Surge in Patenting in China?

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Abstract

By identifying the features of patent applications filed by 22 countries at the Chinese Patent Office from 1996 to 2003, this study finds that the main factors accounting for the recent patent boom in China can be attributed to the second revision of the Chinese patent law in 2000, the intensification of R&D expenditure both in China and the rest of the world, and the increasing foreign direct investment flowing into China.

JEL classification: O30; O32; O34

Keywords: Patent Applications, R&D, FDI, Revision of Patent Law, China

1. Introduction

When China started its economic reform in 1979, whether to establish a patent system became a controversial issue. Some people were worried that the adoption of a patent system would further weaken the Chinese domestic industries since China was weak in technology at that time. However, the establishment of a patent system is one of the most important institutional innovations necessary for effective technology borrowing, and as Hayami and Godo (2005) assert, "effective borrowing of technologies developed in advanced economies is the key for late starters of industrialization to catch up with early starters". More than two decades' economic growth in China since then has strongly proved the farsightedness of those who supported establishing the Chinese patent system at the beginning.

Since the Chinese Patent Law was implemented on April 1, 1985, the number of patent applications filed at the Chinese Patent Office by both Chinese and foreign entities have increased tremendously, especially over the last 5 years. Since 2000, the average annual growth rate of patent applications has been more than 20%. A question naturally arises as to what is behind the recent explosion of patent applications in China.

Studying the patent applications in China is important for several reasons. First, patents have long been used as an indicator of innovative activity and technological change in both micro- and macro-economic studies, as reviewed by Griliches (1990). Eaton and Kortum (1997) argue that the relative constancy of US domestic patenting prior to the late 1980s is consistent with the behavior of other indicators of technological change, in particular, constant productivity growth and increasing research efforts. Does China have the same consistency? Second, if the increase in patenting is due to legal changes, for example, a substantially broadened patent protection scope, it is necessary to analyze how the legal changes affect patent applications and social welfare. Third, an increase in foreign patenting in China may reflect an increase in innovative activities in foreign countries that spill over into China. Does the increasing foreign direct investment account for this rapid rise in patent applications? Fourth, identifying the determinants for both foreign and domestic patenting may suggest whether further reforms of the Chinese patent system are needed.

By identifying the features of patent applications filed at the Chinese Patent Office, this study finds that the main factors accounting for the recent patent boom in China can be attributed to the latest revision of the Chinese patent law in 2000, the intensification of R&D expenditure both in China and the rest of the world, and the increasing foreign direct investment flowing into China.

The paper is organized as follows. Section 2 reviews the relevant literature, while the current situation in China and the hypotheses will be introduced in Section 3. The methodology is explained in Section 4, followed by the estimation results and interpretation in Section 5. Finally, Section 6 summarizes the major findings and discusses the policy implications.

2. Literature Review

There are only a few research papers dealing with the determinants of patent applications. Bound et al. (1982) use firm-level data in the United States and find that R&D spending explains a great deal of the cross-sectional variation in patents, indicating that R&D is a very important determinant of patenting. The same study also finds that estimates of the elasticity of patenting with respect to R&D expenditure vary from 0.35 to 2, depending on the choice of specification from log linear, Poisson, negative binomial, or non-linear least squares. This difference is greatly attenuated when the firms are divided into two groups: those with R&D budgets larger than two million dollars and those with smaller R&D budgets.

Kortum and Lerner (1997) consider a function explaining the determinants of patenting. They assume that the level of patenting by the source country *i* in the destination country *n* depends upon three factors: (1) α_{it}, the rate at which the source country generates patentable inventions in year t; (2) ε_{ni}, the probability that an invention developed in the source country is applicable in the destination country; and (3) f_{nt}, the propensity to patent, which means the fraction of inventions applicable in the destination country that source country entities choose to patent in the destination country in year *t*. Therefore, the number of patent applications from country *i* for protection in country *n* in year t, or P_{nit}, is:

$$P_{nit}=\alpha_{it}\varepsilon_{ni}f_{nt}. \quad (1)$$

Kortum and Lerner's study provides an innovative analysis of patenting patterns into and out of the United States. Following them, the Canadian experience is analyzed by Rafiquzzaman and Whewell (1998), who perform an analysis similar to Kortum and Lerner to examine the impact of policy changes that occurred over the past decade. Based on Equation (1) Rafiquzzaman and Whewell assume that the rate at which a country produces patentable inventions, α_{it}, depends upon the number of researchers in a source country, R_{it}. Technology diffusion, the probability that an invention from country *i* will be adopted in country *n*, or ε_{ni}, depends on: (1) whether *n* and *i* are the same country or not, or $DUMMY_{ni} = 1$ if $n = i$, $DUMMY_{ni} = 0$ otherwise, since ideas flow more freely within than between countries (Eaton and Kortum 1996); (2) the distance between *n* and *i*, or $DIST_{ni}$, reflecting possible geographical impediments to the flow of ideas and technology transfer; (3) the level of human capital in n, or HK_{nt}, because a country's level of human capital increases its ability to absorb ideas either from domestic or foreign sources (Benhabib and Speigel 1994); and (4) the level of country *n*'s imports from country *i* relative to country *n*'s gross domestic product (GDP), or IM_{nit}, to the extent that imported goods are a vehicle for the diffusion of technology (Coe and Helpman 1995). Rafiquzzaman and Whewell also assume that the propensity to patent, f_{nt}, depends upon (1) the cost of patenting in country *n* by country *i* in year *t*, or C_{nit}, (2) the destination country's market size, which is measured by GDP of the destination country in year *t*, or M_{nt} in the model, and (3) the strength of intellectual property protection provided by the destination country in year *t*, or IP_{nt}. They establish the following model:

$$\begin{aligned}\ln(P_{nit}/L_i) = {} & \ln\alpha_0 + \alpha_1\ln(R_i/L_i) + \alpha_2 C_{nit} + \alpha_3 IP_{nt} + \alpha_4 \ln M_{nt} \\ & + \delta_1 DUMMY_{ni} + \delta_2 DIST_{ni} + \delta_3 DIST^2_{ni} + \delta_4 \ln HK_{nt} + \delta_5 IM_{nit} \\ & + \delta_6 (DUMMY_{ni} * HK_{nt}) + \delta_7 (C_{nit} * IP_{nt}) + \mu_{nit}, \quad (2)\end{aligned}$$

where (P_{nit}/L_i) is the ratio of patent applications from country *i* for protection in country *n* to the number of workers in country *i*, and (R_i/L_i) is country *i*'s research intensity, which is measured by the proportion of research workers to the total work force. Rafiquzzaman and Whewell find that the coefficients on $\ln(R_i/L_i)$, IP_{nt}, $\ln M_{nt}$, $DUMMY_{ni}$, $DIST_{ni}$, $\ln HK_{nt}$, and the dummy interaction variables $(DUMMY_{ni} * HK_{nt})$ and $(C_{nit} * IP_{nt})$ are statistically significant, indicating that these explanatory variables have some impact on patenting. However, they find that the estimated effects of IM_{nit} and C_{nit} are not significant, implying that imports are not an important vehicle for technology diffusion and that patenting cost in the destination country does not matter.

Hall, Griliches and Hausman (1984) investigate the lag structure of the relationship between R&D and patenting. Using both non-linear least squares and Poisson type models, they try to discern the lag structure of this relationship in greater detail. Since only short time series are available, two different approaches are pursued in trying to solve the lag truncation problem. In the first, the influence of the unseen past is assumed to decline geometrically, while in the second, the unobserved past series are assumed to have followed a low order autoregression. While neither approach yields strong evidence for a long lag, both approaches reconfirm, however, a significant effect of R&D on patenting. Moreover, they find a rather strong contemporaneous relationship between R&D expenditures and patenting, which does not disappear even when they control for the size of the firm, its permanent patenting policy, or even the effects of its R&D history. There is very little direct evidence of anything but the contemporaneous effect in the year-to-year movement of patents and R&D.

Few empirical studies have examined the determinants of patenting in China. To my knowledge, the only work is a recent study by Cheung and Lin (2004), who are actually more interested in analyzing the spillover effects of FDI on innovation in China. They use provincial data from 1995 to 2000 and find positive effects of FDI on the number of domestic patent applications in China. In their model, they also find that R&D input is the most important element in determining patenting. They use the following model to estimate the spillover effects of FDI on innovation in China:

$$\ln Patent_{it} = \beta_0 + \beta_1 \ln FDI_{it-1} + \beta_2 \ln S\&Tper_{it} + \beta_3 \ln S\&Texp_{it} + \beta_4 \ln Fexport_{it} + \beta_5 \ln PGDP_{it} + \mu_{nit}, \quad (3)$$

where all the variables are in logarithm and subscript *i* and *t* denote province and time period, respectively. They use the number of patent applications ($Patent_{it}$) as a measure of R&D output. FDI_{it-1} refers to the realized value of FDI in province *i* in year *t-1*. They assume, without explanation, that the lag effect of FDI on patenting is one year, even though the best lag structure of FDI on patenting is unknown. They also include the number of personnel for science and technical development ($S\&Tper_{it}$) and expenditures on science and technical development ($S\&Texp_{it}$), which turned out to be highly correlated with each other. In addition, they also include the proportion of foreign funded enterprises' export to its gross output ($Fexport_{it}$) and the level of per capita GDP ($PGDP_{it}$) in their estimation.

They find that a 1% increase in FDI can lead to a 0.12% increase in the number of applications for invention patents. They also find that the effects of S&T personnel and S&T expenditures are positive and significant, with the estimated coefficient of S&T personnel being around 0.70 for invention patents. For the export-output share of FDI firms, they do not find significant effects on domestic innovation. However, for the effect of per capita GDP, they find significantly positive effects, reflecting that the level of economic development is a major determinant of innovation activities across provinces in China. They also check the effects of these explanatory variables for the other two types of patents in China, namely utility model and design patents.

Cheung and Lin (2004) set out to find the spillover effects of FDI on innovation and check the determinants of domestic patent applications in China. On the other hand, I am going to explore the determinants of both domestic and foreign patent applications filed in China.

3. The Situation in China and Hypotheses

The previous studies inspire me to find the determinants of the recent boom in patent applications in China. First, let's look at the situation in China and search for the factors behind this recent surge in patenting in China. Figure 1 shows the general picture of this increasing trend for the three types of patents filed in China, namely invention, utility model, and design patents. We can see that, since the establishment of the patent institution in China in 1985, patent applications in China have increased continuously and tremendously, especially over the last 5 years. What are the possible factors behind this rapid growth? First, China amended its patent law by expanding the scope of patent protection, introducing new mechanisms to enforce patent rights and revising provisions not in line with international standards respectively in 1992 and 2000. Second, the growing number of researchers and the increasing R&D expenditure both in China and the rest of the world also made it possible to create more patentable inventions. The third possible factor influencing patent applications in China is foreign direct investment. As foreign invested firms expand their manufacturing activities in China, with some established R&D operations, the need to protect their innovations might also be expected to rise. Moreover, the use of patents by foreign firms as legal weapons might also be demonstrating to Chinese firms the strategic importance of patent rights.

Based on the above overview, I postulate the following hypotheses:

H_1: The pro-patent amendments to the Chinese Patent Law played a significant role in raising patent applications in China. While the patent law was amended in 1992 and 2000, the limited availability of data allows me to examine the effect of only the amendment in 2000 but not that in 1992.

H_2: The intensification of R&D channels more resources into innovation activities that led to an increase in patentable technologies flowing into China;

H_3: International economic integration, particularly the vast inflow of foreign direct investment, raises the stakes for protecting intellectual property rights in China for foreign firms and hence increases foreign patent applications in China.

4. Methodology

4.1 Data and Source

Data on the annual invention patent applications originating from 22 countries including China and filed in China from 1996 to 2003 are collected from the Yearbooks of the State Intellectual Property Office of China. Those countries are Japan, the United States, Germany, the United Kingdom, France, Korea, Netherlands, Canada, Australia, Italy, Russia, Singapore, Austria, Belgium, Denmark, Spain, Finland, Israel, Norway, Sweden, Thailand, and China.

According to the Chinese Patent Law, there are three types of patents, namely invention, utility model, and design patents. "Invention" in the Chinese Patent Law means any new technical solution relating to a product, a process or improvement thereof. "Utility model" in the Chinese Patent Law means any new technical solution relating to the shape, the structure, or their combination of a product, which is fit for practical use. "Design" in the Chinese Patent Law means any new design of the shape, the pattern or their combination of the color with shape or pattern, of a product, which creates an aesthetic feeling and is fit for industrial application. The differences among invention, utility model and design patents mainly are reflected by the different protection subject matter, examination procedures, and protection terms. However, in most countries, patents only refer to the invention patents in the sense of the Chinese Patent Law. For example, the United States does not have a utility model system in this sense, and its utility patents are virtually equivalent to invention patents in the Chinese Patent Law. Some other countries do not treat utility models and designs as patents but rather as independent types of intellectual property rights. To avoid confusion, I focus on the data of invention patents because Chinese domestic filings on utility models and designs have relatively low technical requirements compared with invention patents and have little to do with the level of R&D in a source country. The comparisons between domestic and foreign patent applications of the three types are shown in Figure 2, 3, and 4. From these figures, we can see that the domestic and foreign applications for invention patents are almost the same, while the numbers of foreign applications for utility model and design patents are only a few hundred in total, far below those of domestic applications.

The data on annual R&D expenditure intensity (% of GDP) and GDP of the source countries including China from 1996 to 2003 are collected from the World Development Indicators 2005. The data on annual R&D expenditure then can be calculated, which equals its annual GDP times its annual R&D expenditure intensity (% of GDP) and divided by 100. Some part of the data on R&D expenditure intensity (% of GDP) in 2003 is collected from OECD data sources.

The data on the annual foreign direct investment (FDI) from a source country to China from 1996 to 2003 are collected from China's Statistical Year Book from 1998 to 2005, which is measured in nominal US$.

The distance between a source country to China is calculated by using a proxy of the distance between the capital of the source country to Beijing, the capital of China, in thousands of kilometers.

4.2 Model Specification

In terms of the Kortum-Lerner and Rafiquzzaman-Whewell approaches, i.e., Equations (1) and (2), China is considered here as the only destination country (*n*) and also as one of the 22 major source countries (*i*). I assume that the rate at which a country produces patentable inventions, α_{it}, depends upon its annual R&D expenditure, RDE_{it}. As perceived in the previous studies, such as Rafiquzzaman and Whewell (1998) and Cheung and Lin (2004), either R&D expenditure or personnel can be identified as the determinant on the rate of generating patentable inventions because frequently R&D expenditure and personnel are highly correlated with each other. Technology diffusion, the probability that an invention from country *i* will be adopted in China in year *t*, or ε_{nit}, and the propensity to patent, f_{nt}, – together depend on whether (1) China is the source country, $n=i$, (2) the distance between *n* and *i*, (3) the annual amount of foreign direct investment from country *i* into China, and (4) China's overall economic growth and prospectus, which is approximately reflected by the annual GDP of China. Thus:

$$\ln P_{nit} = \beta_0 + \beta_1 Y + \beta_2 \ln RDE_{it} + \beta_3 \ln FDI_{nit} + \beta_4 D_{ni} + \beta_5 DIST_{ni} + \beta_6 \ln GDP_{nt} + \mu_{nit}, \quad (4)$$

where $\ln P_{nit}$ is the natural log of patent applications from a source country to China in year *t*; Y is a dummy variable that equals to 1 if year *t* is between 2000 and 2003, and 0 if it is between 1996 and 1999; $\ln RDE_{it}$ is the natural log of the R&D expenditure of a source country in year *t*; $\ln FDI_{nit}$ is the natural log of the foreign direct investment from country *i* into China in year *t*; D is the other dummy variable that equals to 1 if the source country is China, and 0 otherwise; $DIST_{ni}$ is the distance in thousands of kilometers from Beijing, to the other capital city of a source country *i*; $\ln GDP_{nt}$ is the natural log of the real GDP in constant US$ in 2000 of China in year t; and μ_{nit} is an error term. Equation (4) is qualitatively consistent with Rafiquzzaman-Whewell's approach in building up the model, but I add the Y dummy to check whether the pro-patent amendments to the Chinese Patent Law in 2000 played a significant role in raising patent applications in China.

Among the independent variables, I observe very high correlation between $\ln RDE_{it}$ and $\ln GPD_{nt}$. To avoid multicolinearity problem, I further change my model to:

$$\ln P_{nit} = \beta_0 + \beta_1 Y + \beta_2 \ln RDE_{it} + \beta_3 \ln FDI_{nit} + \beta_4 D_{ni} + \beta_5 DIST_{ni} + \mu_{nit}. \quad (5)$$

Moreover, according to Hall, Griliches and Hausman (1984), R&D and patents are mostly dominated by a contemporaneous relationship, rather than leads or lags. I add the following equations to test whether this conclusion is consistent with my model:

$$\ln P_{nit} = \beta_0 + \beta_1 Y + \beta_2 \ln RDE_{it-1} + \beta_3 \ln FDI_{nit-1} + \beta_4 D_{ni} + \beta_5 DIST_{ni} + \mu_{nit}, \quad (6)$$

$$\ln P_{nit} = \beta_0 + \beta_1 Y + \beta_2 \ln RDE_{it-2} + \beta_3 \ln FDI_{nit-2} + \beta_4 D_{ni} + \beta_5 DIST_{ni} + \mu_{nit}, \quad (7)$$

and

$$\ln P_{nit} = \beta_0 + \beta_1 Y + \beta_2 \ln RDE_{it-3} + \beta_3 \ln FDI_{nit-3} + \beta_4 D_{ni} + \beta_5 DIST_{ni} + \mu_{nit}, \quad (8)$$

where the subscripts *t-1*, *t-2*, and *t-3* are denoted to the 1st, 2nd, and 3rd lagged year respectively. I run regressions on each equation from Equation (5) to (8) and the results are reported in Table 1.

5. Results

From Table 1 we can see that the results of the four equations show a strong robustness, reinforcing the finding that R&D, FDI, and patents appear to be dominated by a contemporaneous or long-run relationship. The estimated coefficient of the Y dummy in each regression is positive and statistically significant, which is consistent with Hypothesis 1 that the revision of the Chinese Patent Law in 2000 did enhance the growth of patent applications in China.

The estimated coefficient of lnRDE in each regression is almost the same, and is also positive and highly significant, indicating that a 1 percent increase in the annual growth rate of R&D expenditure in a source country will lead to a 1 percent increase in the annual growth rate of the patent applications from the source country to China on average, holding other factors constant. This finding proves Hypothesis 2 that the intensification of R&D channels more resources into innovation activities that led to an increase in patentable technologies flowing into China.

The estimated coefficient of lnFDI in each regression is also very similar, positive and significant, implying that if the annual foreign direct investment from a source country into China increases by 1 percent, the annual growth rate of the patent applications from the source country to China will increase by about 0.12 percent on average, holding other factors constant, which is coincidentally consistent with the finding of Cheung and Lin (2004). This finding verifies Hypothesis 3 that the vast inflow of foreign direct investment raises the stakes for protecting intellectual property rights in China for foreign firms and hence increases foreign patent applications in China.

In addition, the estimated coefficient of the D dummy in each regression is positive and highly significant, indicating that the growth rate of domestic patent applications is higher than that of foreign ones, a result that is consistent with that of Rafiquzzaman and Whewell (1998). The highly significant negative coefficient on DIST indicates that technological diffusion from a source country to China falls as the distance between them increases. An increase of 1000 kilometers between the capital of a country to Beijing will decrease its growth rate of patent applications to China by 0.1 percent on average, holding other variables constant. This indicates that geographic proximity is an important factor in making patenting decisions to China. If the source country is close to China, the source country inventors tend to file more patent applications in China – although the effect is comparatively weak, which is also consistent with the findings of Rafiquzzaman and Whewell (1998).

6. Conclusion

The cross-country regression on patent applications in China discussed above suggests that the annual growth rate of patent applications from a source country to China, on average, is determined by the R&D expenditure in the source country and the foreign direct investment from the source country to China, and also depends on whether China is the source country, how far the source country is from China, and whether China changes its patent law or not.

The results have several policy implications. First, R&D does appear to be a very important determinant of patenting. The estimated elasticity of patents with respect to R&D expenditure is about unity, indicating that nowadays R&D expenditure is more and more patent-oriented. It implies that in general, patents have become an increasingly important legal weapon in securing returns from the large amount of R&D investment. As China's level of R&D intensity (% of GDP) has just risen beyond one percent, policies in favor of further encouraging R&D in China are desirable.

Second, foreign direct investment is an important transmission channel of technology spillovers. Thus, policies in favor of attracting foreign direct investment are desirable. It is worth mentioning that although this study and that of Cheung and Lin (2004) both find that a 1% increase of FDI will lead to a 0.12% increase of invention patent applications, their interpretations are different. Cheung and Lin (2004) use Chinese provincial data to show the dominant positive spillover effect of FDI over the crowding out effect at the provincial level. According to Cheung and Lin (2004), because purchasing technologies from abroad (e.g., by setting up joint ventures with foreign investors) is a substitute for innovating on one's own, this substitute is more attractive when conducting one's own R&D is risky, or when the technology concerned is of high standard. However, they find the estimated coefficients of FDI on domestic patent applications are all positive and significant, suggesting a positive spillover effect of FDI at the provincial level in China. However, this paper examines the effect of FDI from a source country on its patenting to China. In the research by Cheung and Lin (2004), the increasing FDI at the provincial level has a spillover effect on domestic local R&D, with the result of increased domestic applications filed and owned by Chinese entities within provinces. In this study, the effect of the increasing FDI from a source country to China is reflected in the increased patent applications filed and owned by entities of the source country. These two findings show that the vast inflow of foreign direct investment raises the stakes for protecting intellectual property rights in China for foreign firms. It has also raised the stakes for domestic Chinese firms who can use patents as a strategic tool to compete with firms with foreign funds and technologies. Since the Chinese patent law (similar to patent laws in other countries) requires the publication of inventions, in this sense, those foreign applications induced by the increasing FDI from their original countries and filed in China also have a technology spillover effect for the disclosure of their inventions in China. The promotion of FDI is an important and effective policy to attract foreign advanced technologies and to catch up with advanced economies. With more and more foreign companies establishing their R&D centers in China, the spillover effect of technologies also contributes to China's own economic growth.

Third, an appropriate legal institution is important to attract foreign advanced technologies, such as a strengthened intellectual property system. Before China acceded to WTO in 2001, major intellectual property laws such as the patent law, the trademark law, and the copyright law had been revised to be in line with the international standard. This study shows that the revision of the Chinese Patent Law in 2000 did contribute to the growth of patent applications in China.

However, this study is limited in the sense that it shows the effect of R&D, FDI, and other variables on patent applications only in China. It cannot reflect the general relationship among those independent variables and the dependent variable in other countries or at an international level. A more general international comparison is necessary to examine the impact of R&D and other important factors on patenting in the future.

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Table 1. Comparison of Regression Results of Equation5, 6, 7 and 8

Explanatory Variable	Eqn5	Eqn6	Eqn7	Eqn8
Y	0.36** (2.90)	0.33** (2.59)	0.40** (2.71)	0.46* (2.39)
$\ln RDE_{it}$	1.05*** (16.62)			
$\ln FDI_{it}$	0.11* (2.41)			
$\ln RDE_{it-1}$		1.04*** (15.98)		
$\ln FDI_{it-1}$		0.12* (2.56)		
$\ln RDE_{it-2}$			1.00*** (14.42)	
$\ln FDI_{it-2}$			0.12* (2.51)	
$\ln RDE_{it-3}$				0.98*** (13.12)
$\ln FDI_{it-3}$				0.12* (2.37)
D_{ni}	1.38*** (3.73)	1.43*** (3.74)	1.54*** (3.74)	1.65*** (3.69)
$DIST_{ni}$	-0.11*** (-4.11)	-0.12*** (-4.02)	-0.12*** (-3.81)	-0.12*** (-3.63)
_cons	-19.91*** (-18.17)	-19.64*** (-17.46)	-18.93*** (-15.65)	-18.37*** (-14.01)
Observations	168	147	126	104
R-squared	0.83	0.84	0.84	0.84

Numbers in parenthesis are t statistics.

Legend: * p<0.05; ** p<0.01; *** p<0.001

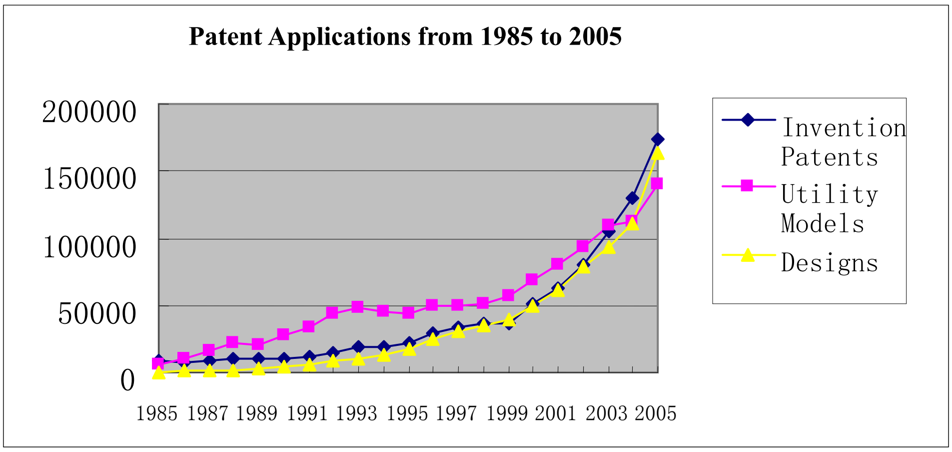

Figure 1.

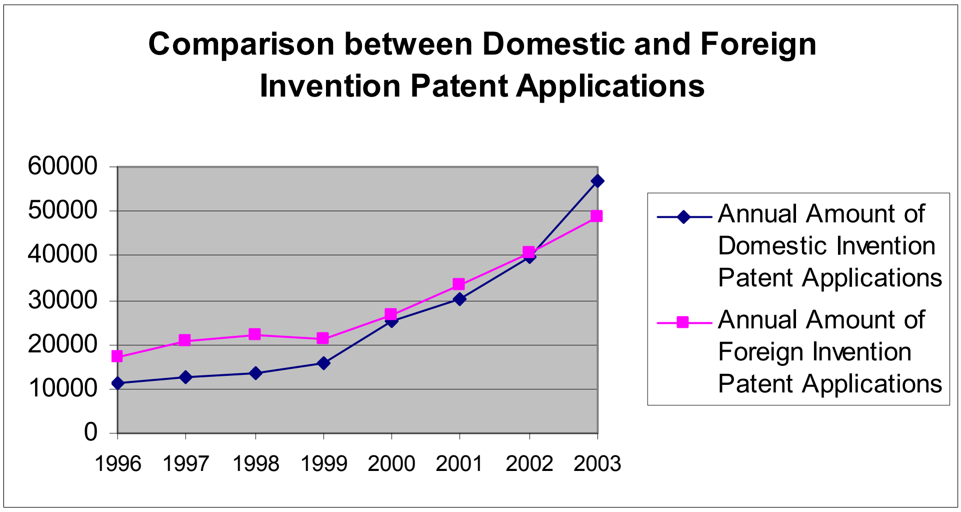

Figure 2.

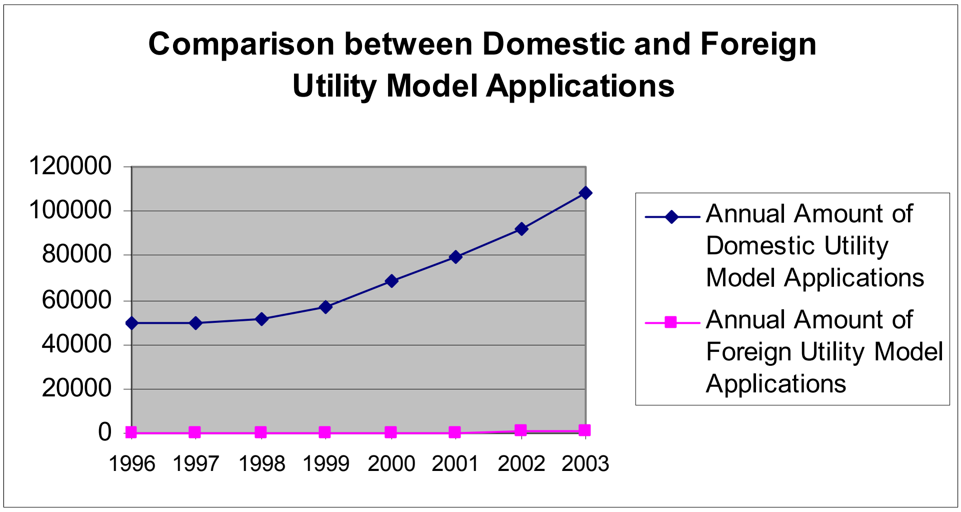

Figure 3.

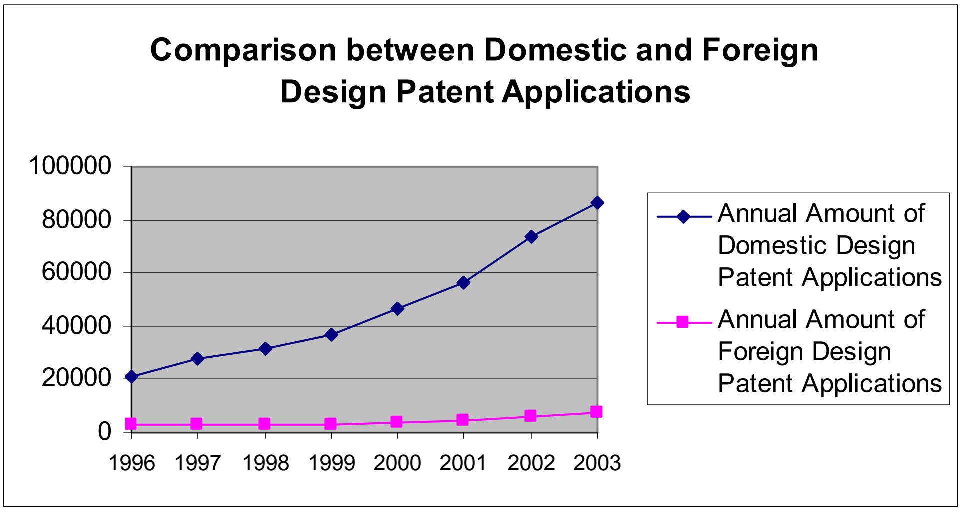

Figure 4.