Effect of China's Domestic Patents on Total Factor Productivity：1988-2009

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Abstract: Using panel data of Chinese different provinces in 1988-2009, we do the empirical study about the effect of China's domestic patents on total factor productivity. We get main conclusions as followed: (1) Different kinds of China's domestic patents both have positive impact on total factor productivity from 1988 to 2009, and the effect of invention patents is much higher than utility model patents and design patents for higher quality, which is different from former studies' conclusions. (2) Invention patents have positive effect on total factor productivity of both coastal China and inner China. However, utility model patents and design patents just have significant impact on the total factor productivity of inner China, and the effect of utility model patents and design patents is lower than invention patents. (3) Invention patents don't have significant impact on total factor productivity before 1999, whereas the impact of invention patents is much larger than other two kinds of patents in 1999-2009. Lastly, the paper discusses the reasons about the empirical results and also gives some policy implications for China and developing countries.

Key Words: Patent; Total Factor Productivity; Panel Data Model
JEL Classification: O31, O34

1. Introduction

China's economy has grown fast and continuously since the policy of reformation and opening started in 1978. However, many studies show that capital input and labor input are the main factors driving China's fast economic growth, the contribution of TFP (total factor productivity) is relative limited (e.g. Madisson, 1998; Chow and Li, 2002; Zheng et al., 2009).The economic growth mode of China have obvious feature of "extensive", and the extensive economic growth mode is widely thought to be difficult to keep continuous growth (Krugman, 1994). Moreover, some recent studies indicate that the contribution of TFP to China's economic growth after mid-1990s is lower than that during the period 1978 to mid-1990s (Zheng and Hu, 2006; Zheng et al., 2009). Therefore, China should transform the extensive economy growth mode to maintain economy growth continuously in the future.

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

As Figure 1 shows: the number of China's total domestic patents has enhanced rapidly since 1999. The amount of total patent applications increased from 14401 in 1999 to 218040 in 2009, and the average annual growth rate reached 23.86% during this period, indicating that China's national innovation capacity has increased very fast since 1999. However, the proportion of China's domestic invention patents which are thought to have much higher quality and potential economic value than utility model patents and design patents was always less than 30%[1], and the share of foreign-resident's invention patents in china mainly owned by OECD countries was 86% during the period 1988-2009. This phenomenon suggests that though China's total domestic patents enhance sharply recently, the quality of which is still not high.

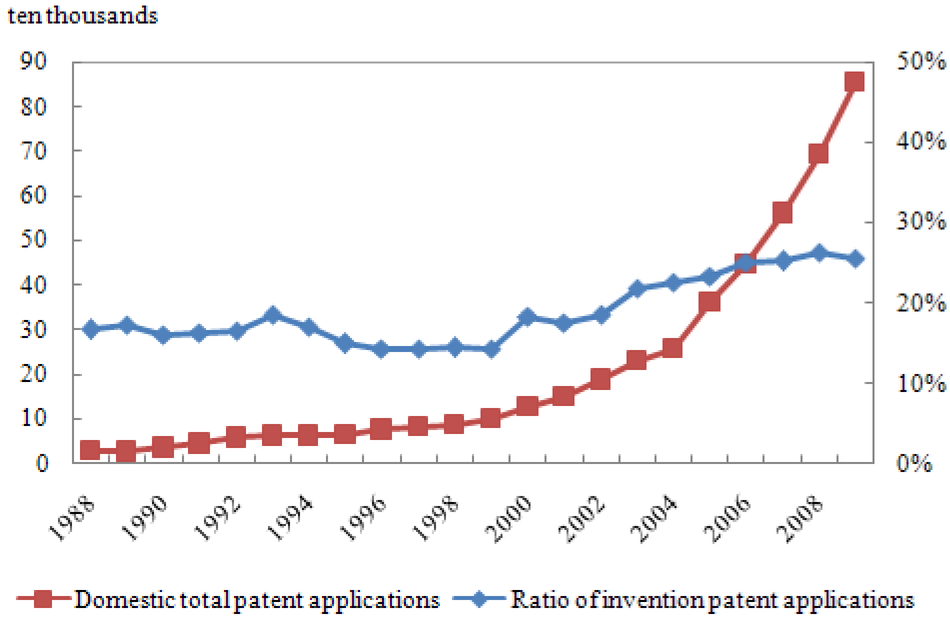

Figure 1 China's domestic patents and share of invention patents

As we know, there exists obvious gap of economic development and industrialization level between coastal China and inner China[2]. The population ratio of coastal China in 2009 was 39.52%, but these 11 provinces owned 58% of the GDP in China. In fact, the innovation diversity between these two regions is also very significant. We can find that coastal China has possessed 60%~80% of China's domestic patents during 1988~2008 from Figure 2, indicating that patent activity of China highly clusters in coastal regions. These data descriptions suggest that coastal China and inner China are at different development stage.

Based on the feature of China's domestic patents and economy development

[1]There are three types of patents in china: invention patent, utility model patent and design patent. The invention patent is regarded as original innovation, and its legal protection duration is 20 years. However, the legal protection duration of utility model patent and design patent is both 10 years.

[2]In this paper, we just consider provinces of mainland China, not including Taiwan, Hong Kong and Macao. To be consistent with the classification of China science and technology statistical yearbook, Coastal China in this paper includes 11 provinces of Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shangdong, Guangdong and Hainan. Inner China refers to 20 provinces of Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Hunan, Hubei, Henan, Inner Mongolia, Guangxi, Chongqing, Guizhou, Sichuan, Yunnan, Tibet, Shaanxi, Gansu, Qinhai, Ningxia and Xinjiang.

discussed above, the issues we concentrate on are as followed: How do Chinese domestic patents affect TFP? How do different kinds of Chinese domestic patents affect TFP? Is the effect of Chinese domestic patents various between coastal China and inner China? Does patents' effect differ in various development stage of China?

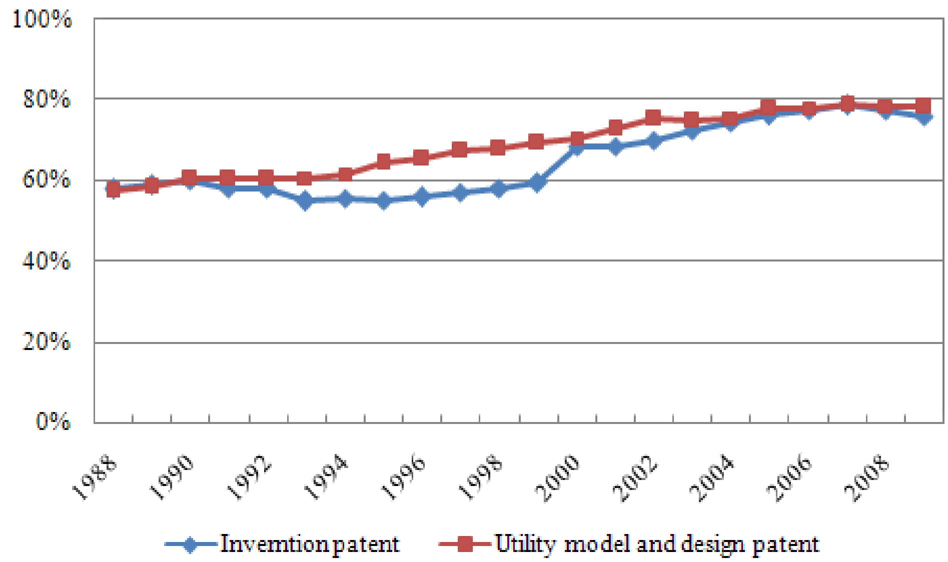

Figure 2 Share of the patents of coastal China

2. Relative Literatures Review

Former studies mainly examine the economic effect of patents by doing the empirical studies about the impact of patents on productivity or other economic output variables. Crépon et al. (1998) use CDM model to study the links between productivity, innovation and research investment at the firm level, and they find labor productivity of French firms is positively correlated with the patent accounts. Ernst (2001) utilizes the panel date of 50 German machine tool manufacturers from 1984 to 1992 to compare the effect of German patent applications and European patent applications on sales increases, he finds the effect of European patents is larger than German patents, and the maximum lagged effect of patents is 3 years. Lach (1995) compares the effect of R&D stock and patent stock on TFP growth rate of US manufacturing sectors, and the study shows the elasticity coefficient of patent stock is around 0.30 which is 3 to 4 times larger than R&D stock. The study of Kim et al. (2009) indicates that Korean domestic patents and foreign patents both have positive effect on the TFP growth of Korean manufacturing. Groshby (2000) uses VAR model to do empirical study about patents' contribution to real GDP and labor productivity of Australia from 1901 to 1907. He finds the positive effect of patent is statistical significant, whereas the effect of domestic patents and foreign patents differs. At the same time, patents' effect also varies in different periods. The research of Yang (2006) indicates that patents play very important role on the miracle of Taiwan's postwar economic growth. Jalle (2010) proves that patents have positive effect on economy and TFP growth using the data of 73 countries from 1980 to 2005. These studies have investigated the economic effect of patents at the firm, industry and country (region) level, and almost all the studies proved the positive effect of patents.

Among the studies about the effect of Chinese patents, most focus on the total domestic patents and few researches take different types of patents into consideration. Liu (2002) does the correlation analysis between number of patent grants and GDP based on the cross-section data of 31 provinces of China during the periods from 1997 to 2000, she finds the correlation coefficient between GDP and utility model patent grants, design patent grants and invention patent grants are respectively biggest, second and smallest. Sui et al.(2005) consider invention patents, utility model patents and design patents separately as original innovation and imitation innovation, and their ridge regression analysis shows that imitation innovation rather than original innovation promotes the development of provincial high-tech industry of China in 2000~2002. Using the provincial penal date from 1997 to 2004, Huang and Yu (2007) also get the conclusion that invention patents' effect is the smallest among three types of patents.

It is necessary to take the effect of various kinds of Chinese patents into consideration. This is because if we just investigate the gross patents' effect, some important information may not be excavated. As Ernst (2001)'s study shows, the effect of European patents on sales growth of firm is larger than German patents for higher quality. However, the studies of Liu (2002), Sui et al. (2005), Huang and Yu (2007) all indicate that the effect of invention patents is the smallest among three kinds of Chinese patents, which seems to mean that the economic effect of Chinese patents is not consistent with the quality. We believe their studies have some spaces to improve: Firstly, the observations of Liu (2002) and Sui et al.(2005)'s empirical researches are relative limited, so their empirical results are not very convincing. Secondly, Ernst (2001)'s study indicates patents have lagged impact on sales growth, but these studies all neglect this effect. Thirdly, these studies ignore the effect of some important control variables. Finally, these studies have not deeply discussed the reason why the economic effect of invention patents was smallest. Meanwhile, few studies investigate Chinese patents' effect from the perspective of region differences and time evolution.

In a word, this paper will use penal data model to capture various kinds of patents' contribution on the TFP of China. In our empirical research, we will take the lagged effect of patents into consideration and also add some key control variables (human capital, industry structure, openness degree, private economy degree) affecting China's TFP. Moreover, we also attempt to explore Chinese patents' effect in different regions and periods.

3. Model, Data and Measurement of TFP

3.1 Model

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

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha} , \qquad 0 < \alpha < 1 \tag{1}$$

Where Y is gross economic output; K is capital stock; A is TFP; L is labor input; i denotes region; t denotes time. Following the research of Solow (1957), we can express A_{it} as equation (2):

$$A_{it} = A_{i0} e^{\lambda t} \tag{2}$$

By corresponding mathematics transformations, we can easily get equation (3):

$$Ln(Y_{it} / L_{it}) = LnA_{i0} + \lambda t + \alpha * Ln(K_{it} / L_{it}) \tag{3}$$

We can utilize penal data model to estimate capital output elasticity coefficient α in equation (4) based on the date of 29 provinces in China from 1988 to 2009, and then calculate TFP of each province by equation (1):

$$Ln(Y_{it} / L_{it}) = LnA_{i0} + \lambda t + \alpha * Ln(K_{it} / L_{it}) + \varepsilon_{it} \tag{4}$$

As TFP is influenced by many factors such as technology innovation, management innovation and system transition, it is different for us to consider all the affecting factors. Considering the reality of China's economy, we select human capital, industry structure, openness degree, private economy degree as the key control variables. We can get the empirical model as equation (5):

$$TFP_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 S_{it} + \beta_3 P_{it} + \beta_4 O_{it} + \beta_5 I_{it} + \beta_6 UD_{it} \quad (5)$$

Where *H* is human capital; *S* is industry structure; *P* is private economy degree; *O* is openness degree; *I* is the number of invention patent applications; *UD* is the sum of the amount of utility model patent applications and design patent applications[3]. As patents have lagged effect on TFP, it may be more reasonable to use stock form of patents in empirical research. However, the patent data of stock form is not available. Meanwhile, it is different for us to estimate patent stock accurately by perpetual inventory method in selecting depreciation ratio for great quality discrepancy among three kinds of Chinese patents. Therefore, we still use flow form of annual data in empirical research, but we seek to capture the lagged effect of patents on TFP by adding lag structure of patents in equation (5). As the maximum lagged effect of patents many scholars consider is 4 years (Ernst, 2001), we examine the impact of China's domestic patents on TFP from 0~4 years lagged from the year of priority.

3.2 Data

The sample in our empirical study includes 29 provinces in Mainland China expect Tibet, Taiwan, Hong Kong and Macao, this is because the statistical data of these regions is missed too much or difficult to get. Because Chongqing estimated in 1997 for separating from Sichuan, we combine the statistical data of these two regions. As patent system of China just set up in 1985, and some provinces didn't have patent applications before 1988, the data period we select is 1988 to 2008. The gross regional economic output and capital stock both adjusted in constant price of the base price in 1978. The statistical data of all indicates are illustrated as followed:

Gross economic output. We use real gross domestic product of each province to measure.

Labor input. As the provincial data of employees' real woke time is not available, we use number of employed persons to replace. Meanwhile, considering the statistical

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[3]The reason why we make the sum of the number of utility model patent applications and design patent applications into empirical model are as followed: On the one hand, as the amount of three kinds of patent applications are highly correlated, if we put the amount of utility model patent applications and design patent applications into empirical model simultaneously, the VIF of variables will be greater than 10, suggesting that we may meet the danger of multicollinearity seriously. On the other hand, the quality and potential economic value of utility model patents and design patents are viewed to be at the similar level, so it should be relative reasonable to plus the amount of these two types of patents in empirical model.

data from China statistical yearbook fluctuates severely, we obtain the data from the statistical yearbook of each province instead.

Physical capital stock. The physical capital stock data of each province is not available from official department, so we use the data estimated from Zhang et al.(2004) by perpetual inventory method[4]. We directly cite the data during the period 1988 to 2000 from Zhang et al.(2004), and estimate the data after 2000 with the same method.

Human capital. We use average years of schooling to embody human capital[5]. As the data about schooling years of population structure is incomplete before 1995 published by official channel, we directly quote the data from 1988 to 2004 by Chen and Lu (2004)'s estimation, and also enlarge the data after 2004 using the same approach.

Industry structure. We use proportion of the added value of secondary industry and tertiary industry to GDP measuring industry structure.

Private economy degree. Strictly speaking, it may be more rational to use **"**ratio of non- state-owned enterprises' total industrial output value" to measure private economy degree. However, considering the statistical criterion has changed since 1998, we use "share of non-state-owned enterprises' investment in fixed assets" to replace.

Openness degree. We use share of imports value and exports value to GDP to measure openness degree of economy, and we also transformed dollar into RMB by reference exchange rate of RMB.

Patent. The statistical data of invention patent, utility model patent and design patent applications (grants) are annual.

The statistical data of all variables in this paper are from China statistical yearbook, statistical yearbook of each province, China science and technology statistical yearbook and China patent statistical yearbook. Table A in Appendix reports the measurement method and date resource of each variable.

3.3Measurement of TFP

Considering that the estimation of penal data model is prone to be affected by

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[4]The formulation is: $K_{it}= I_t+(1-9.6\%)*K_{it-1.}$

[5] The measurement method of average schooling years is: H= (number of no schooling population*0+number of primary schooling population*6+number of junior secondary schooling population*9+number of senior secondary schooling population*12+collage and higher level schooling population*16) / gross population of each province.

autocorrelation and herteroscedasticity of residual, we use commander “xtscc” in STATA 10.1 to estimate parameters for fixed effect model (Hoechle, 2007). As for random effect model, we estimate the parameters by the method of feasible generalized least squares. The estimation result of equation (4) is reported in Table 1 :

As Table 1 shows, the capital output elasticity coefficient of China we estimate from 1988 to 2009 is 0.5014 which is very close to 0.526 OECD(2005) estimates. Therefore, we can calculate TFP of each province as followed: $TFP_{it} = Y_{it} / (K_{it}^{0.5014} L_{it}^{0.4986})$.

Table 1 Estimation result of production function

Variables	Coefficient
Ln(K/L)	0.5014(14.44)***
t	0.0377(12.04)***
C	-1.1437(-24.01)***
Hausman	22.42***
F Value	2469.11***
Obs	638

(1) T value in parenthesis.

(2) *significant at the 1% level;**significant at the 5% level;*** significant at the 10% level.

4. Empirical Study

4.1 Empirical study of entire sample

In order to capture the effect of different kinds of Chinese patents on TFP since the foundation of Chinese patent system, we estimate parameters during the period 1988-2009. As Table 2 shows: invention patents, utility model patents and design patents both have positive effect on the TFP of China, and the lagged effect is also statistical significant, which demonstrates the promotion effect of China’s domestic innovation output on TFP. Meanwhile, we can clearly find that the affecting coefficient of invention patents is much larger than the other two patents at both current and lagged time, which is absolutely different from the conclusions of Liu(2002), Sui et al.(2005) and Huang and Yu(2007). Besides patents, human capital, industry structure, private economy degree and openness degree all have positive effect on TFP.

Table 2 Result of domestic patents' effect on TFP of China (1988 to 2009)

Variables	Current	Lag 1 year	Lag 2 years	Lag 3 years	Lag 4 years
I	0.0471 (3.48)***				
UD	0.0119 (2.99)***				
L.I		0.0587 (3.97)***			
L.UD		0.0131 (2.97)***			
L2.I			0.0729 (3.48)***		
L2.UD			0.0173 (2.82)***		
L3.I				0.0268 (1.01)	
L3.UD				0.0362 (4.26)***	
L4.I					0.1685 (4.29)***
L4.UD					0.0161 (1.40)
H	0.0237 (8.18)***	0.0229 (7.71)***	0.0216 (7.65)***	0.0214 (7.52)***	0.0748 (6.57)***
S	0.4324 (11.03)***	0.4560 (11.29)***	0.5075 (13.12)***	0.5285 (12.60)***	-0.0267 (-0.42)
P	0.1379 (8.29)***	0.1395 (8.15)***	0.1507 (9.04)***	0.1433 (8.38)***	0.2476 (6.71)***
O	0.0207 (2.11)**	0.0292 (2.81)***	0.0355 (2.90)***	0.0522 (3.67)***	0.2069 (9.97)***
C	-0.1148 (-3.44)***	-0.1301 (-3.73)***	-0.1653 (-3.90)***	-0.1805 (-5.08)***	-0.1762 (-3.89)***
Hausman	0.59	8.52	4.81	4.32	13.65***
Wald	674.44***	664.47***	708.14***	673.26***	
F					1147.88***
Obs	638	609	580	551	522

(1) T value and Z value in parenthesis.

(2) *significant at the 1% level; **significant at the 5% level; *** significant at the 10% level

4.2 Empirical study of various regions

The estimation results of different regions are reported in Table 3. The invention patents have significant effect on TFP both in coastal China and inner China robustly during the period 1988 to 2009. However, the utility model patents and design patents don't have significant effect on the TFP of coastal China, which indicate that 60%~80% of china's domestic utility model patents and design patents don't have positive effect on China's economy. However, utility model patents and design patents have significant effect on the TFP of inner China, but the effect of which is much lower than invention patents. As shown in Figure 3, the share of High-tech industry value added to GDP in coastal regions is always much higher than that of inner China from 1995 to 2007. We believe the possible reason why utility model patents and design patents just take significant impact on the TFP of inner China is that the industrialization level and industry structure of inner China are much lower-end than those of coastal China, and the utility model patents and design patents regarded as imitation innovation with low quality may be more suitable with the industry development of inner China than that of coastal China.

Table3 Result of domestic patents' effect on TFP in different regions of China (1988 to 2009)

	Sample of coastal China					Sample of inner China				
Variables	Current	Lag 1 year	Lag 2 years	Lag 3years	Lag 4 years	Current	Lag 1 year	Lag 2 years	Lag 3 years	Lag 4 years
I	0.0412 (2.65)***					0.0557 (2.18)**				
UD	0.0130 (0.68)					0.0495 (4.73)***				
L.I		0.0493 (3.12)***					0.1059 (3.37)***			
L.UD		0.0039 (0.83)					0.0583 (4.50)***			
L2.I			0.0399 (1. 80)*					0.2467 (5.13)***		
L2.UD			0.0104 (1.55)					0.0428 (2.75)***		
L3.I				0.0069 (0.24)					0.1634 (3.46)***	
L3.UD				0.0225 (2.38)**					0.0845 (4.28)***	
L4.I					0.1259 (2.24)**					0.2546 (4.10)***
L4.UD					-0.0027 (-0.19)					0.0848 (4.19)***
H	0.0237 (3.95)***	0.0216 (3.63)***	0.0252 (3.81)***	0.0253 (3.69)***	0.0208 (3.06)***	0.0205 (7.18)***	0.0211 (7.12)***	0.0201 (7.67)***	0.0189 (6.85)***	0.0154 (5.29)***
S	0.9889 (10.39)***	1.0806 (11.05)***	1.0649 (10.37)***	1.1046 (9.81)***	1.2858 (8.73)***	0.2669 (7.03)***	0.2717 (6.96)***	0.3344 (9.22)***	0.3505 (8.99)***	0.3342 (7.62)***
P	0.1717 (5.79)***	0.1672 (5.58)***	0.1823 (5.80)***	0.1880 (5.78)***	0.1976 (5.94)***	0.1087 (6.26)***	0.1169 (6.50)***	0.1136 (6.72)***	0.1099 (6.28)***	0.1356 (7.28)***
O	0.0126 (0.95)	0.0210 (1.55)	0.0305 (1.92)*	0.0246 (1.54)	0.0349 (2.05)**	-0.0019 (-0.18)	-0.0002 (-0.02)	-0.0142 (-1.02)	0.0648 (1.98)*	0.0539 (1.44)
C	-0.4957 (-6.39)***	-0.5654 (-6.99)***	-0.5941 (-6.98)***	-0.6253 (-6.83)***	-0.7455 (-6.25)***	0.0039 (0.12)	-0.0096 (-0.29)	-0.0423 (-1.41)	-0.0531 (-1.62)	-0.0207 (-0.56)
Hausman	2.90	2.70	1.93	1.65	1.44	1.25	1.92	2.87	4.59	5.71
Wald	388.18***	410.34***	371.84***	338.49***	290.09***	418.89***	489.47***	603.58***	506.37***	531.51***
F	242	231	220	209	198	396	378	360	342	324

(1) Z value in parenthesis.

(2) *significant at the 1% level; **significant at the 5% level; *** significant at the 10% level

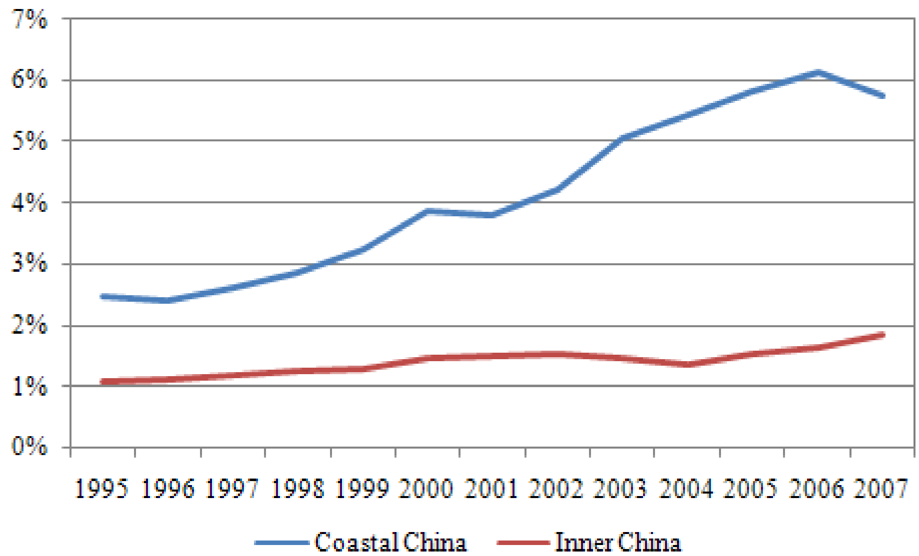

Figure 3 Comparison about High-tech industry development between coastal and inner China

Moreover, human capital, industry structure and private economy degree all have positive effect on TFP both in coastal China and inner China, but the effect of openness degree is not very robust. However, openness degree has significant effect on the TFP of coastal China at the significant level of 0.15, but the effect is still not significant in inner China. We think the main reason is the openness degree of inner China is much lower than coastal China for the location disadvantage. Meanwhile, the human capital of inner China is relative low, which is not beneficial to technology "spillover" from other countries (Borensztein et al.,1998).

4.3 Empirical study of different periods

4.3.1 Estimation of different periods

In this part, we will attempt to make the year 1998 of the breakpoint to examine patent's effect in various periods. The reasons why we select 1998 as the break point are as followed. On the one hand, the feature of China's economy has greatly changed for continuous reformations of economic and scientific system and mechanism, and it is interesting to explore the effect of innovation output on TFP in different economic development stages of China. On the other hand, as we discussed in the part of introduction, the amount of patents has improved fast since 1999, we are also interested in capturing China's domestic patents' effect on the TFP in different period of patents' development. We respectively do the empirical research about the effect of patents on TFP during the period 1988 to 1998 and 1999 to 2009, and the estimation results are shown in Table 4.

Table 4 Result of domestic patents' effect on TFP of China during various periods

	During the period 1988-1998					During the period 1999-2009				
Variables	Current	Lag 1 year	Lag 2 years	Lag 3years	Lag 4 years	Current	Lag 1 year	Lag 2 years	Lag 3 years	Lag 4 years
I	0.2183 (1.11)					0.0480 (4.62)***				
UD	0.1398 (4.42)***					0.0049 (2.27)**				
L.I		0.2730 (1.32)					0.0697 (5.19)***			
L.UD		0.1666 (4.88)***					0.0049 (1.56)			
L2.I			0.3469 (1.33)					0.0883 (4.15)***		
L2.UD			0.1416 (3.28)***					0.0083 (1.52)		
L3.I				0.0591 (0.73)					0.0176 (0.72)	
L3.UD				0.1496 (4.79)***					0.0299 (3.89)***	
L4.I					0.3609 (2.09)**					0.1483 (2.81)***
L4.UD					0.1548 (3.25)***					0.0100 (0.74)
H	0.0441 (10.88)***	0.0482 (11.64)***	0.0620 (6.19)***	0.0804 (13.61)***	0.0664 (13.73)***	0.0619 (2.55)**	0.0064 (2.07)**	0.0097 (2.44)**	0.0161 (3.23)***	0.0153 (2.70)***
S	0.3997 (9.22)***	0.4034 (8.95)***	0.5529 (11.30)***	0.5414 (7.78)***	0.4615 (4.39)***	0.5899 (2.81)***	0.6196 (7.75)***	0.6430 (7.38)***	0.6761 (6.95)***	0.7263 (6.87)***
P	0.0951 (4.24)***	0.0735 (3.13)***	0.2279 (3.53)***	0.1665 (3.53)***	0.1452 (3.29)***	0.1287 (3.04)***	0.2062 (8.18)***	0.1929 (7.01)***	0.1968 (6.01)***	0.2145 (5.87)***
O	0.0030 (0.27)	0.0047 (0.40)	0.0720 (4.60)***	0.0887 (3.67)***	0.0923 (5.53)***	0.0480 (2.65)**	0.0891 (5.58)***	0.1089 (5.21)***	0.0766 (3.60)***	0.0875 (3.30)***
C	-0.2462 (-6.44)***	-0.2741 (-6.89)***	-0.5334 (-11.20)***	-0.6192 (-13.14)***	-0.4594 (-3.97)***	-0.5006 (-2.62)**	-0.1394 (-2.08)**	-0.1776 (-2.34)**	-0.2457 (-2.87)***	-0.2975 (-3.02)***
Hausman	9.38	4.51	16.75**	17.04**	10.65*	10.74*	2.17	3.90	4.02	6.20
Wald	550.52***	604.15***					668.92***	466.57***	342.64***	275.18***
F			8993.60***	1885.42***	230001***	3513.74***				
Obs	319	290	261	232	203	319	290	261	232	203

(1) T value and Z value in parenthesis.

(2) *significant at the 1% level; **significant at the 5% level; *** significant at the 10% level

We can clearly find that not the invention patents but the utility model patents and design patents have significant positive effect on TFP during the period 1988-1998, indicating that the original invention is not important to the economy development of China in this period. Moreover, human capital, industry structure and private economy degree all have robust positive effect on TFP, but the effect of openness degree is not very robust. We think the main reason is also the relative low openness degree and human capital of China during this period. During the period 1999 to 2009, different types of patents both have positive effect on TFP, whereas the effect of invention patent is much higher than utility model patents and design patents, indicating that the original invention plays more important role in the economy development of current stage of China. Meanwhile, human capital, industry structure, private economy degree and openness degree all have significant effect on TFP.

4.3.2 Discussion about the reasons for estimation result

Why do invention patents not have significant effect on the TFP of China during the period 1988 to 1998 but have larger effect than utility model patents and design patents from 1999 to 2009? We can mainly explain this phenomenon from the perspective of industry development, promotion of enterprise's status in technology innovation and innovation policy enforced by the government.

As Figure 4 shows, the proportion of value add of high-tech industries to GDP was less than 2.3% before 1999, but it enhanced very fast after 1999 and reached to 4.46% in 2007. Besides, the share of high-tech products exports increased from less than 10% before 1999 to 29.10% in 2008. We can find that the industries of China were more preliminary and products of China were lower-end before 1999. It seems that invention patent viewed as original invention is not very consistent with the feature of China's industry development before 1999, and the utility model patent and design patent may be more fit to the industry development of China during this period.

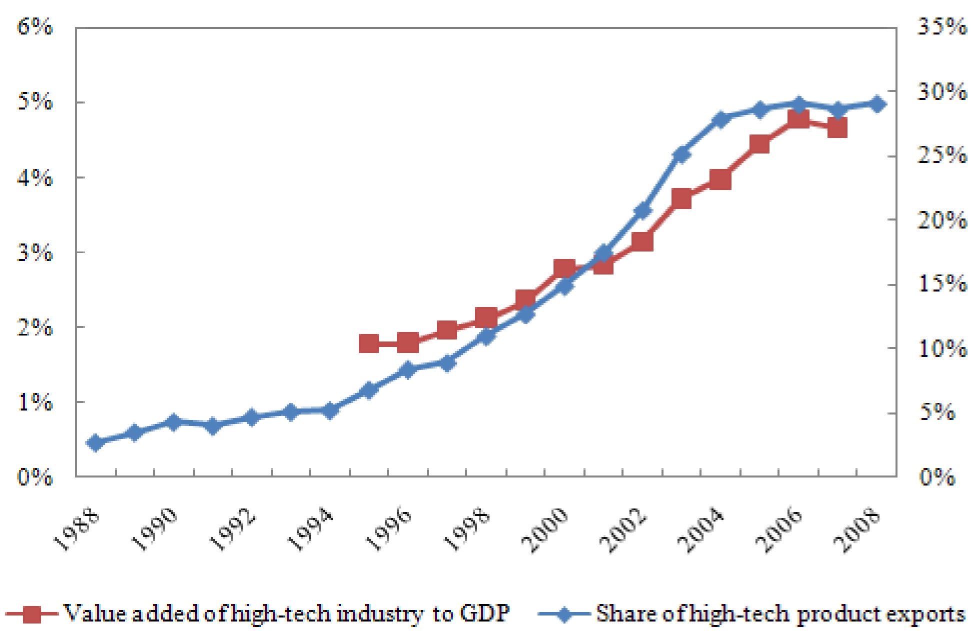

Figure 4 High-tech industry development of China

Firm's status in technology innovation has greatly enhanced since 1999, which we think is the most important factor promoting the invention patents transformed into real productive force during the period 1999-2009. As Figure 5 shows, the ratio of enterprise's invention patent applications during the period 1999 -2009 is much higher than that during the period 1988-1998. University, scientific research institution and organization are indeed important for knowledge production, whereas they are not very good at realizing the potential economic value of new technology. Therefore, University, scientific research institution and organization's dominant role in innovation during 1988 to1998 may not be beneficial to commercialization of invention patent. What's more, the innovation network among firms, universities and scientific research institutions is very imperfect before 1999, and the technology trade market of China is also not well developed during this period, which is also not good for the commercialization of innovation output.

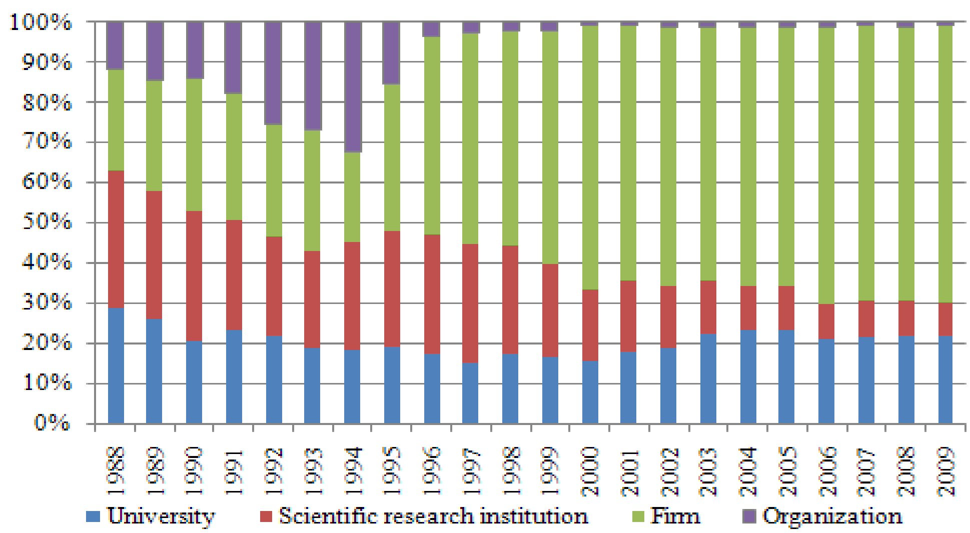

Figure 5 Distribution of China's domestic invention patent applications by innovation subjects

China government is an important factor we can't neglect in promoting high-tech industry development and enterprise's status in technology innovation. China government has enforced a great deal of innovation policies and reformations of science and technology system, and here we just discuss some important ones[6].

Firstly, China government carry out "torch program" to establish many science and technology industrial parks (STIP) which play an important role in the rapid development

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[6]The development strategy of founding innovative country proposed by China government in 2006 is also an important innovation policy. As this strategy has just implemented, it is very hard for us to evaluate the effect of the strategy.

of high-tech industries in recent years. The statistical data shows that the proportion of gross industrial output value of STIP to total was only 0.27% in 1991, 2.79% in 1998, and sharply reaches to 10.38% in 2008. STIP make great contribution to high-tech industries development after 1998. It is necessary to state that China governments are very vital to the foundation, development and expansion of STIP, which is quite different from western countries such as Silicon Valley.

Secondly, science and education strategy proposed by China government in 1995 had deeply influence on innovation capacity, high-tech industries development and commercialization of new technology of China. This strategy emphasizes the core effect of education and innovation driving economy growth and stresses the linkage between innovation and economy. The strategy makes the society start to attach importance to innovation. The statistical data shows that the proportion of R&D expenditure to GDP fluctuated around 0.7% before 1995 and declined continuously since 1992.Whereas, the declined trend stopped in 1996 when the strategy has been proposed. The R&D intensity of China's economy has fast increased continuous after 1999 and went to 1.70% in 2009 (see Figure 6). What's more, the strategy emphasizes the dominant status of enterprise in technology innovation, which directly led to the reform of science and technology system in China.

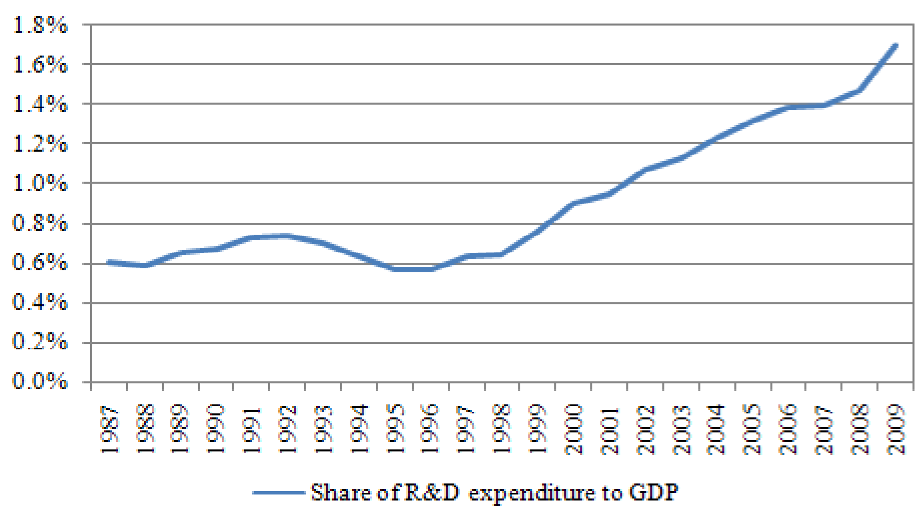

Figure 6 Share of R&D expenditure to GDP in China

Thirdly, the reformation of science and technology system since 1999 has promoted the status of enterprise in technology innovation and strengthened the linkage between technology and economy. The reform transforms more than 1200 scientific research institutes into enterprises. As Figure 5 shows, the strategy makes the share of scientific research institutes' invention patent applications declined sharply since 1999. As a result, the ratio of firm's invention patent applications increased rapidly after 1999. Some sampling surveys also suggest that both innovation capacity and management achievement of scientific research institutes have enhanced obviously after the reformation[7].

5. Conclusions

This paper does empirical research about the effect of China's domestic patents on the TFP by panel data of 29 provinces in 1988~2009, and we get the conclusions as followed: (1) Different kinds of China's domestic patents both have positive impact on TFP from 1988 to 2009, and the effect of invention patents is higher than utility model patents and design patents for higher quality. (2) Invention patents have positive effect on TFP of both coastal China and inner China. However, utility model patents and design patents just have significant on the TFP of inner China, and the effect of utility model patents and design patents is much lower than invention patents. (3) Invention patents don't have significant effect on TFP before 1999, whereas the effect of invention patents is much larger than utility model patents and design patents in 1999-2009.We believe industry development, promotion of firm's status in technology innovation and innovation policy enforced by the government are main reasons why the economic effect of patents have changed in different periods.

Our empirical results also have some policy implications. As for China, it is necessary to own more innovation output for continuous economy development in the future, but it may be more important for China especially coastal China to purse high quality innovation output. Some of our findings based on the reality of China may also have some policy lessons to developing countries: Firstly, innovation also has positive effect on the economy development of developing countries. Secondly, the technology level should be fit with the industrialization level and the feature of industry development. Thirdly, enterprise's dominant status in technology innovation may be more beneficial to commercialization of innovation output. Finally, the role of the government of developing countries in innovation should be highly valued.

[7] http://www.gmw.cn/01gmrb/2006-03/09/content_385746.htm

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Appendix

Table A Variables in empirical study

Variables	Measurement	Source of data
Y	GDP	China statistical yearbook
K	Perpetual inventory method	Data of 1988~2000 is from Zhang et al.(2004), data from 2001 to 2009 is calculated by the author.
L	Number of employed persons	Statistical yearbook of each province
H	Average years of schooling	Data before 2002 is from Chen and Lu(2004), data from 2003 to 2009 is calculated by the author.
S	Ratio of industry and service value added to GDP	China statistical yearbook
P	Share of non-state-owned enterprises' investment in fixed assets	China statistical yearbook
O	Ratio of imports and exports value to GDP	China statistical yearbook
I /UD	Number of patent applications	China patent statistical yearbook

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