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William Latham and Hong Yin

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Domestic Innovation and Chinese Regional Growth, 1991-2004

William Latham* and Hong Yin
Department of Economics
University of Delaware
Newark, Delaware 19716
latham@udel.edu
*Corresponding author

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1. Introduction

In this paper we examine the return to innovation in terms of economic growth at the provincial level to assess whether or not policies that promote R&D, such as China's Science and Technology Policy, have been productive for all of China's regions. The return to innovation at the provincial level is estimated using a value-added Cobb-Douglas production function. The measure of the effect of innovation (patenting activity) is valued-added industrial output. The data are a balanced panel for 30 provinces for the period 1991-2004. The estimation results indicate that technology plays a positive role in China's provincial growth, but the contribution from technology (and thus from China's Science and Technology Policy) is small.

The effects of inter-regional innovative-knowledge spillovers on value added industrial output are also examined. Econometric evidence of positive inter-regional knowledge spillovers is found, however, the magnitude of these spillover effects is even smaller than that of the own technology effect.

Section 2 describes the basic model specifications. Section 3 describes data sources and problems. Section 4 presents the results of estimating the models with the data. Section 5 describes alternative model specifications and estimation results. Section 6 presents the impact of knowledge spillovers on value-added industrial output and Section 7 presents conclusions and suggestions for further research. In an appendix we provide an extended list of references on Chinese patenting for researchers interested in pursuing this subject.

2. Basic Model Specification

Assuming a conventional Cobb-Douglas production function, the basic model specification is:

$$\log(Y_{it}) = \alpha_i + a(t) + \beta_1 \log(C_{it}) + \beta_2 \log(L_{it}) + \beta_3 \log(P_{it}) + \varepsilon_{it}, \qquad (1)$$

where Y_{it} is the value added industrial output in the region i at time t; a is the rate of exogenous technical progress; C_{it} and L_{it} are capital and labor inputs in the region i at time t; P_{it} is the technology input in the region i at time t, which proxied alternatively by either contemporaneous patent applications or patent stocks. Fixed effects of regional specific characteristics are controlled by α_i. In this equation the elasticity of valued added output to technology is measured by the coefficient β_3.

3. Data Sources and Problems

Fourteen years (1991-2004) of industrial data by province and by domestic and foreign-owned firms are available and are collected directly from the various issues of the China Statistical Yearbook (NBS, 1992-2005). These data are based on reporting by all the independent accounting units by regions.

Output, $Y_{it,}$ is constructed as the sum of value-added industrial output by domestic firms by region. Capital, C_{it}, is constructed as regional total assets of domestic firms. Total assets are a reasonable measure of capital input compared to fixed assets because total assets are the net values of funds used plus the fixed assets. Both value-added industrial output and total assets are reported in nominal terms and are adjusted to constant 2000 yuan by an ex-factory producer price index.

It is very difficult to find an accurate measure of labor input, $L_{it,}$ since no effective measure of working hours is reported in the statistical yearbooks. We have no alternative to using the official number of manufacturing employees in domestic firms for labor input, although China's employment data are considered to be deeply flawed (Banister, 2005; Wu, 2001), compared to the other official data.[1] Before the industrial restructuring of 1994-1999, unproductive working hours were common in state-owned enterprises (SOE) due to shirking, lack of jobs, shortages of energy and/or political reasons. Thus manufacturing employment figures were highly inflated. After 1995 there were massive lay-offs in the SOEs: total manufacturing employment in SOE's declined from 66.1 million in 1995 to 37.5 million in 2002. Figure 1 presents total manufacturing employment along with value-added industrial output for the years 1991–2004. The structural break in manufacturing employment is very clear: manufacturing employment has declined continuously since 1995, while valued added output has a continuous upward trend over the years. Because of the large measurement errors and the structural change in labor inputs, the precision of our estimation results will be greatly affected.

Technology input, P_{it}, is measured both by both contemporaneous patent applications and by a measure of patent stocks. The patent data and the construction of patent stocks are described in this and the following paragraphs. Chinese patent data are available both on-line and on CD-ROMs. There are at least two official databases distributed by the State Intellectual Property Offices (SIPO): (1) CNPAT ABSDAT, which is in Chinese, and (2) CNPAT ACCESS, which is in English and has been distributed worldwide. However, the covered periods of these

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[1] We attempted to adjust the employment data for changes in human capital as measured by years of education per worker in the provinces. However, data on the education levels of employees by province are only available from 1996 to 2000, so the education levels of employees for the years 1991-1995 and for the years 2001-2004 had to extrapolated. The equations were then estimated with labor input adjusted by educational levels, however, the estimation results were not significantly improved.

two databases vary slightly: CNPAT ABSDAT is the most comprehensive one which covers patent applications beginning in April 1985 when the first Chinese patent was filed. In contrast, CNPAT ACCESS began only in November 1985. Thus the CNPAT ABSDAT database is slightly more comprehensive and is the database used for this study.

There are two official on-line versions of the chosen database (CNPAT ABSDAT) that are maintained by the SIPO and which have the most complete patent documents up to the present.[1] Careful comparisons of search results retrieved from these two on-line databases and to the patent data published by SIPO revealed that the on-line databases are identical and comparable to the published patent data. Thus we used one of the official on-line databases (www.sipo.gov.cn) to retrieve the patent data for this study. All the patent data were retrieved between March 10, 2006 and April 30, 2006.

Patent applications are used as a proxy for innovation output in this study. There are two reasons for us to use patent applications rather than patent grants. First, there are potentially long lags between a patent's application and its grant: it might take three to five years for a patent to be examined and granted (and some patents may not be granted at all). Accordingly, if patent grants were used, the most dynamic and interesting period of 2000-04 would be excluded in the analysis.

Second, it has generally been observed that patents are applied for relatively early in the lifecycle of a research project. Most studies find that there is a very strong relationship between R&D and patent applications at the cross-sectional level: the median R-square is around 0.9 (Griliches, 1990). This relationship is close to contemporaneous with some small lags which are difficult to be estimated (Hausman, Hall, and Griliches, 1986). Thus most studies use patent applications as an indicator for innovation output.

There are three types of Chinese patents: (1) invention patents, (2) utility model patents and (3) design patents. An invention patent is comparable to a utility patent in the US. A

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[1] The two websites of on-line databases are www.sipo.gov.cn and www.cnipr.com.

utility model patent is a “petty” patent, not recognized in the US. A design patent is for improvement in aesthetic features rather than technical features. For the purpose of analyzing China’s true technological capabilities, only invention patents are used in this study. Hereafter, the term patent refers to an invention patent application.

Because patent documents are not accessible to the public until eighteen months after an application has been filed, the period of patent filings in this study is restricted to the period of Aprill 1, 1985 to December 31, 2004. It should be noted that the reported numbers of patents from 2004 might be slightly biased downward because some patent filings were not yet published when the data for this paper were collected due to the eighteen-months restriction before publication. In addition, there can be multiple patentees on a single patent located in different provinces. In this case, both provinces are recorded since the address of first patentees is not separated from those of other patentees in the patent documents. We carefully compared the results of a multiple-provinces search with those of a single-province search and found that the statistical error caused by double counting is very small, on average only about 2%.

There are several additional potential problems related to Chinese patent data. First, China’s patent law went through a significant change in 1992 and was further revised in 2000. Consequently, we may expect that those changes might have a considerable impact on both domestic and foreign filings. Our analysis should be considered within this context. Second, Chinese patents include filings from both domestic and foreign patentees, and the majority of invention patents are actually filed by foreigners. We treat domestic patents as those patents with patentees’ addresses from the thirty-one provinces and independent municipal cities of China. This raises the question of patents applied for by joint ventures with foreign firms. Compared to purely domestic firms, firms with foreign partners may be more competitive and may have more intensive innovation activities. However, unfortunately it is impossible to separate patents filed by joint ventures from other domestic filings in our data, as patentees from joint ventures are classified as having origins in China. With respect to the impact of foreign firms’ R&D and patenting activity, the evolution of technological development in China has been greatly influenced by and has benefited from its increasing exposure to world-class technologies from foreign firms. China's domestic innovation activities have been stimulated and pushed forward by their foreign competitors. In recent years, more and more R&D centers of multinational corporations have moved to China. It is not clear how many patents filed by multinational corporations are actually generated in these offshore R&D centers in China. Surely, intensive and high-quality innovative activities in these R&D centers will generate spillover effects on domestic innovation activity. Unfortunately, in our data it is impossible to separate these spillover effects of foreign inventions from domestic firms' own innovations efforts.

Table 1 presents summary statistics for the variables. The correlation matrix of the variables in logs is in Table 2. As expected, among the three inputs, labor is least correlated with value-added output: the correlation coefficient between the output and labor is only about 0.83. In contrast, the correlation coefficient is 0.98 and 0.92 between the output and capital and between the output and patents, respectively.

4. Estimation Results

Equation 1 is first estimated with both a fixed effects estimator and a random effects estimator. Table 3 presents the robust estimation results and the Hausman specification tests for comparisons of the fixed effects and random effects estimators. In columns (2) and (5), the contemporaneous patent applications are used as the technology input. In columns (3) and (6), the patent stocks are used as the technology input. The equation without the technology input are estimated and reported in columns (1) and (4).

First, we notice that the estimated coefficients of fixed effects models and random effects models are quite different. Although the random effects estimations seem to be better, with higher R-squared values and better-estimated coefficients, the Hausman tests reported in the first three columns reject all the random effects estimators. In the following analysis, only the estimation results of fixed effects estimators are reported. (column (1) to column (3)).

In column (1) without the technology input, the estimated elasticity of value-added output to capital is only 0.194, which is much smaller than the one usually found in the literature. The estimated elasticity to labor is 0.305. The overall fit of the model is improved when the technology input is included: the R-squared increases from 0.833 in column (1) to 0.871 in column (2) and 0.85 in column (3), respectively. The estimated elasticity of value-added output to technology is 0.26 for the contemporaneous patent applications and is 0.385 for the patent stocks. The higher coefficient for the patent stocks is not surprising, as the magnitude of cumulated patent stocks is much larger than that of contemporaneous patent applications.[2] The elasticity of labor drops significantly to 0.135 when the patent stocks are used. This result is common in the literature: an increase in the elasticity to technology is at the expense of a declining elasticity to labor.

Although the overall fit of models in columns (2) and (3) is good, the large measurement errors in the labor input may have biased the estimates of technology input upward: the elasticities to technology are even larger than those to capital input. The structure break in the manufacturing employment is obviously not captured by the model specifications. Further, it is found that the estimation results are sensitive to the price index used to deflate the capital input.[3] In addition, there might be an omitted variable problem: the R-squared increases significantly when the technology input is included in the estimations. Using a single time trend in the model may be also inappropriate as the exogenous technological change is unlikely to be linear over the years. Because of these problems, the model specification of equation 1 is modified to improve the estimation results in the next section.

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[2] The results are robust to the use of different depreciation rates in the construction of the patent stocks.

[3] The capital input (total assets) is also deflated by the fixed-asset price index and the equation is re-estimated. The precision of estimated coefficients of all variables drops sharply.

5. Alternative Specifications

As there are large labor shocks during the years 1995-99, we consider using a set of year dummies to capture these changes. The modified equation with year dummies is:

$$\log(Y_{it}) = \alpha_i + \sum_{t=1}^{14} a_t + \beta_1 \log(C_{it}) + \beta_2 \log(L_{it}) + \beta_3 \log(P_{it}) + \varepsilon_{it}, \qquad (2)$$

where a_t is a set of year dummies from1991 to 2004. Estimation results of fixed effects models are reported in Table 4. The estimation results with contemporaneous patent applications are presented in column (2); results with patent stocks are listed in column (3); and results without patent variables are reported in column (1).

5.1 Revised Results for Effects of Technology

Compared to the models reported in Table 3, the overall fit of the regressions has improved with an R-squared of about 0.91 for all the three models. The estimated elasticities have also increased: without the technology input the estimated elasticities to capital and labor are 0.449 and 0.326, respectively. Those elasticities are in line with the ones found in the literature (Movshuk, 2004; Wu, 1996). Wu (1996) reports that the elasticities of gross industrial output to capital and labor are 0.54 and 0.23, respectively, at the Chinese provincial level for the years 1985-1990.

Movshuk (2004) estimates a similar Cobb-Douglus production function for Chinese domestic firms for the years 1988-2000 and finds that the elasticities of gross industrial output to capital and labor are 0.14 and 0.63, respectively.

The estimated elasticity of output to technology is 0.099 for contemporaneous patent applications, which implies that a one percent increase in a region's patent applications results in a 0.099% increase in that region's valued-added industrial output, other things being equal. In comparison, the estimated elasticity to technology is 0.235 for the patent-stocks model. The impact of patent stocks is much larger as expected: a one-percent increase in a region's patent stocks increases the value-added output by 0.235%. However, the magnitude of technology's contribution to the value-added output is small, either with the patent applications or patent stocks. Similar studies conducted at the level of European regions and US states usually find that the elasticity coefficient of technology inputs is closer to that of capital input.

5.2 Time Effects

To see the effects of time in the analysis, the coefficients of the year dummies are plotted in Figure 2. The structural break due to the industrial restructuring of 1994-99 is clear: the coefficients of the year dummies started to drop in 1994 and were particularly low in 1995. The effects are most striking when patent stocks are used in the equation: there was practically no economy-wide exogenous technical progress during the period 1995-99. In contrast, the effects of technical progress increase linearly for the years 2000-04. Those results seem to suggest that using year dummies in the equation is a better choice to capture the effects of structural changes.

As a robustness check, capital input (total assets) is further deflated by the fixed asset price index and the equation is re-estimated. The estimation results are similar to those reported in Table 4. The results are also robust to the depreciation rates of patent stocks. Thus it can be concluded that the results in Table 4 are robust and equation 2 is more appropriate for estimating the knowledge production function at the Chinese provincial level. In the following analysis, only the results using patent stocks with a 7% depreciation rate are reported.

5.3 Effects in Three Macro Regions

The empirical results of our prior work (Latham & Yin 2008) point out that there are enormous regional differences in technological development (patenting activity) among the three major macro-regions of China. Here, the contribution of regional variations in technology to industrial growth is further explored.

Location dummies for the EAST, CENTRAL, and WEST regions, are created and are interacted with the technology input (the patent stocks). The estimated equation is:

$$\log(Y_{it}) = \alpha_i + \sum_{t=1}^{14} a_t + \beta_1 \log(C_{it}) + \beta_2 \log(L_{it}) + \sum_{j=1}^{3} \beta_j \log P_{it} + \varepsilon_{it}, \qquad (3)$$

where β_j is the elasticity of value-added output to technology input in the macro-region j.

Estimations with separate slopes of patent stocks are reported in column (1) of Table 5. The elasticity coefficient of technology in the eastern region is 0.23, compared to 0.21 in the central region and 0.155 in the western region. These estimates suggest that the separate treatment of three macro-regions is appropriate. The evidence points out how the western region lags behind in terms of technology's

contribution to valued-added output. With respect to the role of technology in industrial growth, the differences among the three macro-regions are relatively small, and are significantly smaller than the differences in the effect of R&D on patenting found in our prior work (Latham & Yin 2008). This result suggests that regional variations in the adoption of new technology are smaller than differences in the production of new technology. Given the small elasticities of output to technology input, the disconnect between innovations and commercialization of new technology seems to be a common problem across the regions.

5.4 The Effects of Industrial Reforms

The estimated coefficients of the year dummies only capture certain time-specific effects of industrial reforms on economy-wide rates of technical progress. In this section, the effect of industrial reform on technology's contribution to value-added output is further examined. Dummies are created for: (1) the pre-reform period of 1991-94; (2) the reform period of 1995-99; and (3) the post-reform period of 2000-04. The three time dummies are interacted with the technology input (patent stocks), so the separate slopes of patent stocks of three periods can be estimated. The estimated equation is:

$$\log(Y_{it}) = \alpha_i + \sum_{t=1}^{14} a_t + \beta_1 \log(C_{it}) + \beta_2 \log(L_{it}) + \sum_{T=1}^{3} \beta_T \log(P_{it}) + \varepsilon_{it}, \qquad (4)$$

where β_T is the elasticity to patent stocks for the period T. The results are presented in column (2) of Table 5.

The elasticity coefficient of patent stocks is 0.041 for the pre-reform period of 1991-1994 and is 0.039 for the post-reform period of 2000-04. In contrast, the coefficient of patent stocks for the period 1995-1999 is not only smaller (0.013) but also insignificant, which implies that there is no technology's contribution to the valued-added output at the provincial level during the industrial reform period. The empirical results here again support the findings in our previous work (Latham & Yin 2008) and point out that the effects of industrial reform on China's technological development during the period 1994-99 are very negative: there is no economy-wide technical progress and technology's contribution to industry growth is nonexistent.

We notice that the estimated coefficients of patent stocks for the three separate periods decrease significantly, while the coefficients of capital and labor increase. This is not surprising: the fixed effects estimators only use within variations of the data. The within-variations of the patent stocks decline substantially when fourteen years are divided into three sub-periods. Consequently, the precision of estimated coefficients of patent stocks declines sharply.

6 The Effects of Technology Spillovers

In this section, the impact of technology spillovers to value-added industrial output is investigated. Equation 2 is extended by including a spillover variable. This spillover variable is the weighted patent stocks from other regions, which are described in an appendix. The estimated knowledge-spillover production function is:

$$\log(Y_{it}) = \alpha_i + \sum_{t=1}^{14} a_t + \beta_1 \log(C_{it}) + \beta_2 \log(L_{it}) + \beta_3 \log(P_{it}) + \beta_4 W \log(S_{it}) + \varepsilon_{it}, \quad (5.5)$$

where W is the weight matrix and S_{it} is the technology stocks (patent stocks) from other regions. The spillover variable is represent by Wlog($S_{it.}$ Two different weights are used to construct the spillover variable: a contiguity weight and a gravity-weight.[4]

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[4] The equation with an unweighted spillover variable is also estimated and no evidence of spillover effects is found at all.

The robust estimation results of Equation 5 are presented in Table 6.[5] Results with the contiguity-weighted spillover variable are reported in column (1) and results with the gravity-weighted variable are listed in column (2). The coefficient of the contiguity-weighted spillover variable is 0.098, which implies that one percent increase in the patent stocks from the neighboring regions will lead to a 0.098% increase in the region's valued-add output. In comparison, the coefficient of the gravity-weighted spillover variable is 0.134, but it is only significant at 0.16 significance level.

The estimated results seem to suggest that geographical proximity is very important in the inter-regional technology spillovers: solid technology spillovers are only found with the contiguity-weighted spillover variable and the magnitude of technology spillover is much smaller than that of own technology. This implies that the inter-regional technology linkage only exists between the bordering provinces and even that linkage is not strong.

7. Conclusion

We find that the production function including innovation fits the Chinese provincial level data. The elasticities of value added industrial output to capital and labor are 0.425 and 0.224, respectively. The elasticity of value-added industrial output to the region's own technology is 0.099 for the contemporaneous patent applications and 0.235 for the patent stocks. These estimates indicate that technology plays a positive role in industrial growth at the provincial level; however, the contribution of technology is far too small which indicates that China's economic growth is largely driven by the factor inputs. The results here seem to support the views that the linkages between innovation activity and commercialization of new technology are weak within Chinese domestic firms (Sun, 2002). Domestic firms apparently have difficulties in exploiting and adopting the new technologies. This naturally raises the questions about the current technology policy in China: does current S&T policy emphasize too

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[5] Robustness checks for the results reported in Table 6 are conducted. The estimation results are insensitive to either the price index used to deflate the capital input or the depreciation rates of patent stocks.

much on the generation of new technology, compared to the adoption of new technology? For long-term sustainable economic growth, how to facilitate and encourage the adoption of new technology should be the main concerns for China's policymakers.

The results also indicate that the inter-regional technology spillovers are positive but relatively small and weak, compared to the European regions and the states in the US. The evidence here confirms the low developmental stage of China's industry as the ability to adopt and diffuse the new technology is weak across the Chinese provinces.

The estimated results further confirm that the impact of industrial reforms during the period of 1994-99 on China's technological development is negative, as there seems to be neither exogenous technical progress nor technology's contribution to the value-added industrial output at all in those years.

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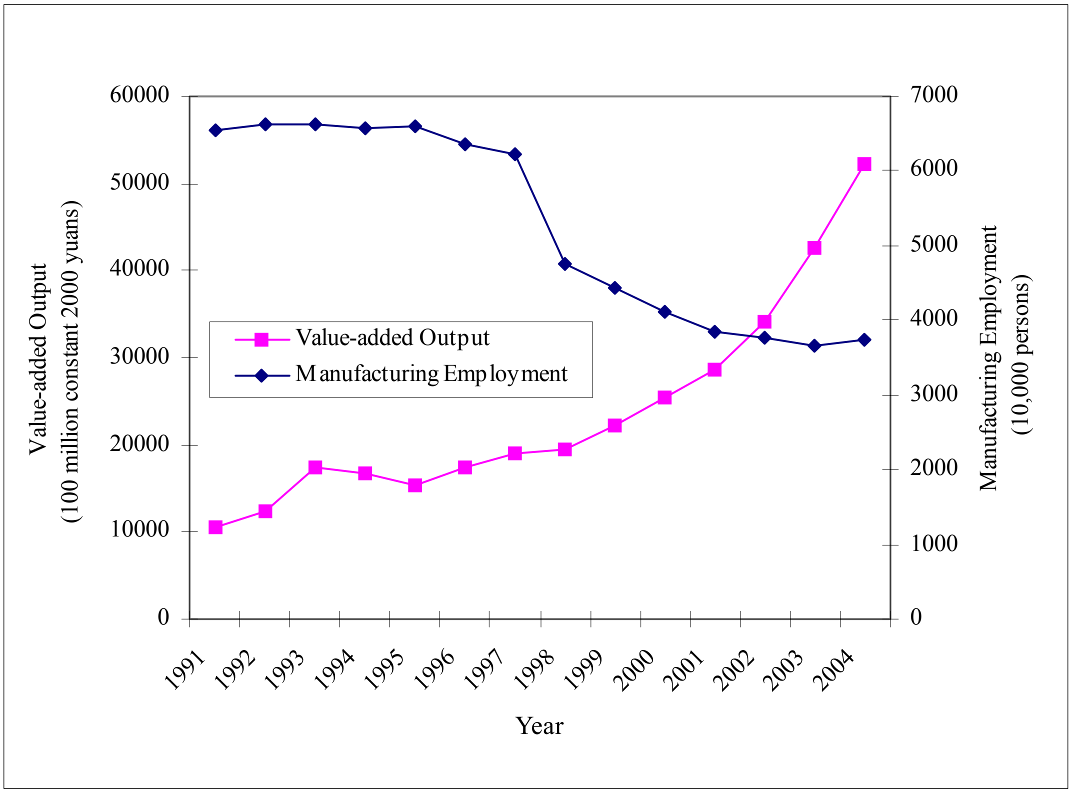

Figure 1 Aggregated Value-Added Industrial Output and Manufacturing Employment (Staffs and Workers) in China from 1991 to 2004

Notes: Data are based on the total manufacturing employees from thirty provinces reported in the various issues of China Statistical Yearbook (Tibet is excluded).

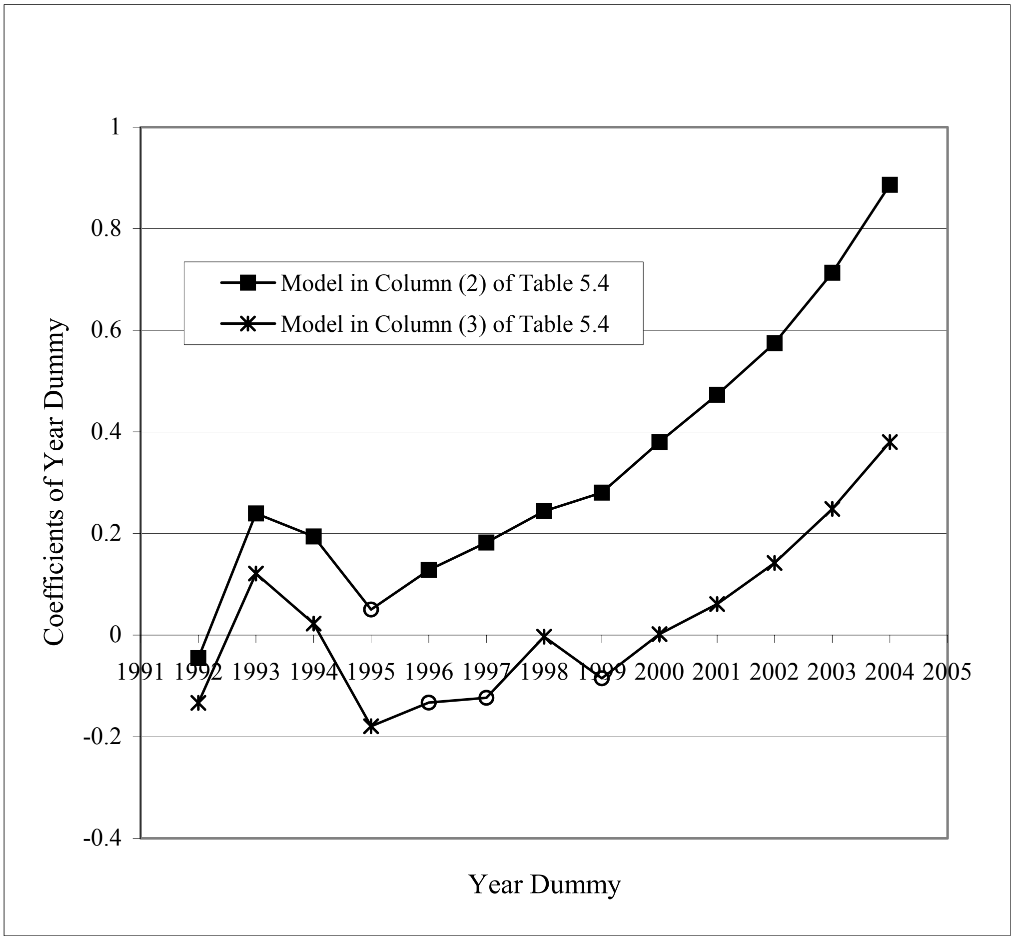

Figure 2 Estimated Coefficients of the Year Dummies of Equation 2.
Note: The data points marked with "o" mean that the estimated coefficients are not significant at the 10% significance level.

Table 1 Summary Statistics of Variables in Levels (1991-2004)

Variables	Observations	Mean	Std. Dev.	Min.	Max.
OUTPUT (Y) (Value-added industrial output in 100 million constant 2000 yuan)	420	793.97	933.63	2.12	6763.23
CAPITAL (C) (Total assets in 100 million constant 2000 yuan)	420	3572.27	3451.51	15.03	20805.20
LABOR (L) (Manufacturing employees in 10,000 persons)	420	175.87	125.37	1.30	547.60
PATENTS (P) (Patent applications)	420	612.08	973.76	2	6847

Table 2 Correlation Matrix of Variables in Logs.

Variables	OUTPUT	CAPITAL	LABOR	PATENTS
OUTPUT	1.000			
CAPITAL	0.980	1.000		
LABOR	0.829	0.812	1.000	
PATENTS	0.916	0.915	0.716	1.000

Table 3 Estimation Results of the Knowledge Production Function at the Chinese Provincial Level (1991-2004); Equation 1

Dependent Variable: LOG OUTPUT						
Independent Variables[a]	Fixed effects			Random effects		
	(1)	(2)	(3)	(4)	(5)	(6)
LOG CAPITAL	0.194*	0.168*	0.167*	0.629**	0.415**	0.468**
	(0.051)	(0.077)	(0.079)	(0.000)	(0.000)	(0.000)
LOG LABOR	0.305**	0.324**	0.135*	0.420**	0.374**	0.268**
	(0.000)	(0.000)	(0.070)	(0.000)	(0.000)	(0.000)
LOG PATENTS		0.261**			0.274**	
		0.000			0.000	
LOG PATENT STOCKS			0.385**			0.322**
			0.000			0.000
TIME TREND	0.094**	0.066**	0.033**	0.057**	0.042**	0.019*
	(0.000)	(0.000)	(0.027)	(0.000)	(0.000)	(0.071)
R-squared[b]	0.833	0.871	0.850	0.958	0.959	0.953
Observations	420	420	420	420	420	420
Hausman specification test:						
Chi-square Statistics[c]	24.320	17.850	45.490			
	(0.000)	(0.007)	(0.000)			

Notes: The P-values are reported in parentheses. All estimation results are based on robust standard errors. * Significant at the 0.10 level. ** Significant at the 0.05 level.

[a] PATENTS refers to the contemporaneous patent applications. PATENT STOCKS is constructed from a perpetual inventory model using by a 7% depreciation rate.

[b] The R-squared is within R-squared for the fixed effects estimators and overall R-squared for the random effects estimators.

[c] The Chi-square statistics are for the Hausman specification test for comparing the fixed effects models and random effects models (column (1) vs. column (4), column (2) v s column (5), and column (3) vs. column (6)).

Table 4 Estimation Results of the Modified Knowledge Production Function at the Chinese Provincial Level (1991-2004); Equation 2

Dependent Variable: LOG OUTPUT						
Independent Variables			Fixed effects			
	(1)		(2)		(3)	
LOG CAPITAL	0.449	**	0.419	**	0.424	**
	(0.000)		(0.000)		(0.000)	
LOG LABOR	0.326	**	0.304	**	0.237	**
	(0.000)		(0.000)		(0.000)	
LOG PATENT			0.099	**		
			(0.000)			
LOG PATENT STOCKS					0.235	**
					(0.000)	
YEAR DUMMY	YES		YES		YES	
R-squared	0.913		0.911		0.919	
Observations	420		420		420	

Notes: The P-values are reported in parentheses. All estimation results are based on robust standard errors. ** Significant at 0.05 level. PATENTS refers to contemporaneous patent applications. PATENT STOCKS is constructed from a perpetual inventory model using a 7% depreciation rate. The R-squared is within R-squared for the fixed effects estimators. Diagnostics tests reveal both heteroscedasticity and serial correlation. Therefore, the estimated results reported are heteroscedasticity and autocorrelation consistent (HAC) robust standard errors.

Table 5 Effects of Locations and the Year Dummies on the Estimations of the Knowledge Production Function at the Chinese Provincial Level (1991-2004); Equations 3 and 4

Dependent Variable: LOG OUTPUT				
Independent Variables	Fixed effects			
	(1)		(2)	
LOG CAPITAL	0.414	**	0.450	**
	(0.000)		(0.000)	
LOG LABOR	0.263	**	0.293	**
	(0.000)		(0.000)	
LOG PATENTSTOCKS_EAST	0.233	**		
	(0.000)			
LOG PATENTSTOCKS_CENTRAL	0.216	**		
	(0.001)			
LOG PATENTSTOCKS_WEST	0.155	**		
	(0.006)			
LOG PATENTSTOCKS_91_94			0.041	**
			(0.038)	
LOG PATENTSTOCKS_95_99			0.013	
			(0.515)	
LOG PATENTSTOCKS_00_04			0.039	**
			(0.018)	
YEAR DUMMY	YES		YES	
R-squared	0.920		0.915	
Observations	420		420	

Notes: The P-values are reported in parentheses. All estimation results are based on robust standard errors. **Significant at 0.05 level.PATENTSTOCKS_EAST (CENTRAL and WEST) is the interaction term between PATENT STOCKS and the macro region dummy, EAST (CENTRAL and WEST). PATENTSTOCKS_91_94 (95_99 and 00_04) is the interaction term between PATENT STOCKS and the time dummy D91_94 (D95_99 and D00_04). PATENT STOCKS is constructed from a perpetual inventory model using a 7% depreciation rate. The R-squared is within R-squared for the fixed effects estimators.

Table 6. Effects of Technology Spillovers on the Estimation Results of the Knowledge Production Function at the Chinese Provincial Level (1991-2004); Equation 5

Dependent Variable: LOG OUTPUT		
Independent Variables	Fixed effects	
	(1)	(2)
LOG CAPITAL	0.425 **	0.417 **
	(0.000)	(0.000)
LOG LABOR	0.224 **	0.232 **
	(0.000)	(0.000)
LOG PATENT STOCKS	0.225 **	0.227 **
	(0.000)	(0.000)
Spillover variable		
LOG SPILLOVER (PATENT STOCKS)	0.098**	
(Contiguity-weighted)	(0.038)	
LOG SPILLOVER (PATENT STOCKS)		0.134
(Gravity-weighted)		(0.164)
YEAR DUMMY	YES	YES
R-squared	0.918	0.917
Observations	420	420

Notes:The P-values are reported in parentheses. All estimation results are based on robust standard errors. ** Significant at 0.05 level. PATENT STOCKS is constructed from a perpetual inventory model using a 7% depreciation rate. SPILLOVER (PATENT STOCKS) refers to the knowledge stocks available in the other regions, proxied by the patent stocks in the other regions. The results are similar with patent stocks using a 0% depreciation rate and a 12 % depreciation rate. The R-squared is within R-squared for the fixed effects estimators.

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