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INNOVATION AND ECONOMIC GROWTH IN CHINA

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Innovation and Economic Growth in China

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Abstract China has enjoyed high economic growth for three decades since the initiative of economic reform in 1978. This growth has however been driven mainly by labour-intensive, export-oriented manufacturing activities. Has innovation played a role in China's economic growth? What are the determinants of innovation in the Chinese economy? These are some of the questions which are to be explored in this study. Answers to these questions have important policy implications for China's economic development in the future as innovation is vital for the transformation of the country's growth model.

Key words Innovation, economic growth, Chinese economy

JEL codes O33, O53

Innovation and Economic Growth in China

1. Introduction

Since the initiative of economic reform in 1978, China has enjoyed high economic growth for three decades. This growth has however been driven mainly by export-oriented, labour-intensive manufacturing activities. In 2008 the total value of China's export accounted for 32% of the country's GDP.[1] In the mean time, tens of millions of workers were employed in the export sector. As a result the Chinese economy is very vulnerable to external shocks such as the 2008 US sub-prime credit crisis and the resultant recession and decline in demand for Chinese exports. To sustain economic growth in the future, China's policy makers are keen to boost the role of innovation in the country's economic development so that the economy will eventually be transformed into a knowledge-intensive one which is less dependent upon external markets (Schaaper 2009, Zhang et al. 2009). This goal is clearly envisaged in the country's "Medium-to-Long Term Plan of National Science and Technology Development (2006-2020)" announced in February 2006.[2]

However, knowledge about China's innovation capacity and potential is very limited. Has innovation played a role in China's economic growth in the past three decades? What are the determinants of innovation in China's regional economies? How can the capacity of innovation be boosted? These are some of the questions which are to be explored in this study. A thorough understanding of these questions is vital for policy making and hence the transformation of China's economic growth model towards a sustainable pattern. In the existing literature, there are many studies which investigated the contribution of total factor productivity (TFP) changes to economic growth in China.[3] Innovation in those studies is treated as part of the TFP contribution or the residual of economic growth which is not explained by changes in factor inputs. This study extends the current literature by focusing on innovation only and by measuring innovation in an alternative approach. The latter is based on Chinese patent data and probably attempted for the first time in this paper. The rest of the paper begins with a brief review of the main issues associated with innovation in China. This is followed by the description of the analytical framework. The estimation results and discussions are then presented. Subsequently sensitivity analysis is conducted in order to examine the robustness of the main models. Finally the paper concludes with some remarks.

2. The Link between Innovation and Economic Growth

Economists have for a long time been interested in the role of innovation in economic development or growth. In the neoclassical framework, the impact of innovation is treated as part of the Solow residual and hence a key contributing factor to economic progress and long-term convergence (Solow 1957, Fagerberg 1994). In recent decades, due to the popularity of endogenous growth theories, economists are increasingly of the view that differences in innovation capacity and potential are largely responsible for persistent variations in economic performance and hence wealth among the nations in the world (Grossman and Helpman 1991). It is also argued that the effects of innovation on economic growth cannot be fully understood without considering the social and institutional conditions in an economy. For example, Rodriguez-pose and Crescenzi (2008) showed how the interaction between research and social-economic and institutional conditions shapes regional innovation capacity.

China has become the recent story of economic success. Having enjoyed three decade (1979-2008) double-digit growth which has mainly been resource-intensive, the Chinese economy is now at the cross road. Due to resource constraints at home and abroad as well as raising costs, China's policy makers are steering the economy towards an alternative growth model in which knowledge and technology would play the key role. For this reason, innovation is becoming increasingly important and vigorously promoted in the Chinese economy. This is reflected in several indicators. First, China's R&D expenditure as a proportion of GDP has expanded from 0.71% in 1990 to 1.52% in 2008.[4] This figure is expected to reach 2.5% in 2020 (Schaaper 2009). By then, the gap between China and the world's advanced economies in terms of R&D spending would be reduced substantially as the latter typically spend about 2-3% of their GDP on R&D. In 2006, China spent a total of about 87 billion dollars on R&D which was ranked no.3 in the world (Table 1). A major change is the increasing role of Chinese business enterprises in innovation. Of the total R&D spending in 2006, the enterprise sector accounted for over 72% (Table 1). This sector's contribution to China's total R&D investment also amounted to about 70% in the same year. This is impressive given that three decades ago almost all economic activities were government controlled in China. In fact, ten years ago (1997) Chinese business enterprises were responsible for only about a third of the country's R&D expenditure.[5]

[Insert Table 1 here]

Second, in 2007, China's R&D sector had more than 1.7 million employees of which more than 80% (about 1.4 million) were scientists and engineers.[6] This figure is close to the total number of researchers in Japan, the UK, France and Germany together. Meanwhile, in the same year, there were about 4.3 million science and engineering students enrolled in Chinese universities including about 1.2 million new enrolments (excluding 861,834 fresh graduates).[7] It can be anticipated that China will soon, if not now, have the world's largest number of R&D researchers.

Finally, as R&D inputs expand, China's innovation capability increases too. For example, the number of domestic patents applied and granted grew from 69,535 and 41,881 items in 1995 to 586,498 and 301,632 units in 2007, respectively.[8] During the same period, the number of Chinese applications for patent registration offshore also increased from 13,510 to 107,419 with the number of granted patents rising from 3,183 to 50,150. In addition, between 1995 and 2006, the number of publications by Chinese scientists and engineers increased from 7,980 to 71,184 according to the science citation index.

The rising role of innovation in China has attracted the attention of scholars both inside and outside the country. Examples include several recent studies. Wei and Liu (2006) found positive impacts of R&D activities on productivity performance at the firm level. Their finding is consistent with observations at the sector level by Wu (2006, 2009) who showed that R&D contribution to productivity growth in manufacturing is statistically significant. Some authors also provided evidence using cross-regional data (Kuo and Yang, 2008). Others focused on firms within particular region (Hu and Jefferson 2004). This study extends the existing literature in several ways. In this paper, innovation is measured using patent statistics while the existing literature follows the traditional approach of estimating total factor productivity (TFP) growth using a production function. This study also differs from the existing literature by considering both innovation and growth models and their links.

3. Modelling the relationship between R&D, Innovation and Growth

Idea-based economic growth models have been wide documented in the literature in recent decades. The empirical literature can be broadly divided into two camps, i.e. the first generation models such as Romer (1990) and Aghion and Howitt (1992) and the second generation models such as Jones (1995) and Segerstorm (1998).[9] The core objective of developing those models is to understand the mechanism through which resources are transformed into new knowledge or innovation and hence the contribution of the latter to economic growth. The transformation process can be symbolically expressed as follows

$$Y = I(Z)K^{\alpha} \tag{1}$$

Equation (1) implies that output per worker (Y) depends on innovation (I) and physical capital per worker (K) and that innovation in turn is the result of R&D efforts (Z). Taking logarithms and then derivatives of both sides of equation (1) with respect to time gives the following

$$y = i(Z) + \alpha k \tag{2}$$

The variables in lower cases in equation (2) indicate rates of growth. In the long run, due to decreasing returns to capital, growth converges to a balanced growth path in which all variables grow at constant exponential rates (Jones 2005, Bottazzi and Peri 2007). Therefore, along a balanced growth path,

$$y = i(Z)/(1-\alpha) \quad (3)$$

That is, economic growth is proportional to the rate of innovation. In the meantime, the latter is determined by research inputs. To examine the above relationships using the Chinese economy as the setting, the following empirical models are considered

$$inn_{it} = \varphi(rd_{it}) \quad (4)$$

$$g_{it} = \phi(inn_{it}) \quad (5)$$

where rd_{it}, inn_{it} and g_{it} represent R&D density, the rate of innovation and rate of economic growth in the ith region at time t, respectively. Equations (4) and (5) are the baseline models. In empirical estimation, these equations are augmented by adding control variables (*X*) which may also affect the rates of economic growth and innovation. Thus,

$$inn_{it} = \varphi(rd_{it}, X) \quad (6)$$

$$g_{it} = \phi(inn_{it}, X) \quad (7)$$

are the empirical models to be estimated. There are of course some econometric issues involved in the estimation of equations (6) and (7). These are to be discussed in the empirical analysis.

4. Data Issues and Preliminary Analysis

The estimations of equations (6) and (7) are based on a balanced panel dataset of 31 Chinese regions for the period of 1998-2007. The size of the full sample is thus 310. All data employed in this paper are drawn from China Statistical Yearbook and China Statistical Yearbook of Science and Technology.[10] The variables are detailed in the following paragraphs.

R&D intensity (*rd*) is defined as R&D expenditure per unit of gross regional product (GRP). The rate of *economic growth* (*g*) is the real growth rate of GRP expressed in constant prices. The rate of *innovation* (*inn*) is measured using the ratio of the number of patent applications over the stock of patents. The number of patent applications rather than the number of patents granted is employed here so that the lengthy processing of patent applications is taken into consideration. Jaffe and Palmer (1997) and Ulku (2007) also considered the number of patent applications. For the calculation of patent stock, the standard perpetual inventory method is employed. The rate of knowledge depreciation is assumed to be 7 per cent. The initial stock is estimated to be the number of patent applications in year one divided by the sum of the rate of depreciation and the mean growth rate of patent applications in the initial five years (patent data are available from 1991 onwards). Though the use of patent data as a measure of innovation may be controversial, it has been widely supported (Griliches 1990, Ace et al. 2002 and Ulku 2007).[1] Some authors derived their own innovation indicators using production functions. This type of measurement is vulnerable to biases and inconsistencies inherited from the specification and estimation of the production functions.

The control variables include infrastructure, government spending, foreign capital, nonstate sector and enrolment. The *infrastructure* variable is defined as the geometric mean of road and railway densities (length over land areas) among the regions. The *government* spending variable is measured as the ratio of government spending over GRP. The *foreign capital* variable captures the share of foreign capital over total capital.[11] The *nonstate sector* variable is introduced as an indicator of the degree of economic reform and measured as the ratio of nonstate sector employment over total employment in the regions. The *enrolment ratio* of junior high school graduates in senior high schools is employed to reflect human capital development among the regions.

Summary information about those variables is presented in Table 2. It is clearly shown that the mean R&D intensity almost doubled between 1998 and 2007. Associated with this growing trend are the mean rates of innovation and economic growth. Other indicators exhibiting an upward trend include infrastructure development, government spending, nonstate sector development and (senior) high school enrolment ratio. The only variable which experienced a decline is the mean share of foreign capital over total capital in China. The scatter charts in Figures 1 and

[1] It is noted that, as discussed in the text, the use of patent data as a measure of innovation is sensitive to the choice of the rate of knowledge depreciation. It also ignores other indicators such as scientific publications, new products, the quality of patents and so on.

2 demonstrate the existence of a positive linear relationship between innovation and R&D intensity as well as between economic growth and innovation, respectively.

[Insert Table 2 here]

[Insert Figures 1 and 2 here]

5. Estimation Results

The dataset described in the preceding section is applied to the empirical models. The baseline models defined in equations (4) and (5) are considered first. The estimation results (not reported) can confirm easily that R&D intensity positively affects the rate of innovation while the latter is positively related to economic growth, other things being equal. However, the link between R&D efforts, innovation and economic growth cannot be isolated from social and economic conditions. Thus, Equations (4) and (5) are extended to incorporate a variety of factors which may influence innovation and hence economic growth. Sala-i-Martin (1997) identified more than 60 country-specific variables which may affect economic growth across the nations in the world. The number of factors is however reduced substantially if the focus of research is limited to a single country as it is in this study. A main advantage of regional studies of individual countries over cross-country studies is that the former should be less affected by heterogeneity associated with the latter.

Given the availability of Chinese regional data, several factors are considered here as the control variables (*X*). They reflect regional variation in government spending, infrastructure development, participation of foreign capital, degree of economic liberalization and human capital endowment. The estimation results of the extended models are reported in the third column of Table 3. For both innovation and growth equations, the standard panel least squares method is considered first (Models 1 and 2 in Table 3). In both cases, the fixed effect model is accepted as the preferred one through a test for the fixed effects against a common intercept (F – fixed effects) and a Hausman test for the fixed effects against the random effects (χ^2 - Hausman test). A redundant variable test (F - control variables) shows that the inclusion of the control variables cannot be rejected. The estimated results imply that an increase of 0.1% in R&D intensity is estimated to lead to innovation growth of about 0.38% and hence economic growth of around 0.02%.

Due to the presence of the R&D intensity and innovation variables as an explanatory variable in the two models, respectively, endogeneity may be a problem. To overcome this problem, the two models are re-estimated using the two stage least square method (Models 3 and 4). The exogenous and lagged endogenous variables are used as the instrumental variables. The Hausman test shows that the fixed effect model is preferred to the random effect model with the inclusion of the control variables being statistically significant. The estimated results imply that an increase of 0.1% in R&D intensity is estimated to lead to innovation growth of about 0.36% which is close to the estimate from Model 1. However, the resultant impact on economic growth is around 0.06% which is three times as much as that from Model 2. Thus, the presence of endogeneity may lead to the underestimation of the impact of an increase in R&D intensity on economic growth. The estimated effect on ecomomic growth is also much higher than 0.038% which was reported in an empirical study of OECD economies (Zachariadis, 2004).

[Insert Table 3 here]

Table 3 also shows that infrastructure development and participation of foreign capital have played a significantly positive role in innovation. In terms of economic growth, the significantly positive contributing factors include government spending, the development of the private sector and an increase in human capital. Foreign capital share variable is surprisingly negatively related to economic growth. This may reflect the fact that in recent years foreign capital shares have been declining and economic growth has mainly relied on domestic capital expansion. As a result, the larger the domestic capital share is, the higher economic growth rates tend to be.

Finally, the preceding analyses are largely based on fixed-effect models with constant slope coefficients. To explore regional variation further, one can incorporate some dummy variables into the models. Following the conventional classification, China can be grouped into three regions, that is, the coastal, middle and western regions.[12] The estimation results are reported in Table 4 (Models 5 and 6). It seems there is significant regional variation in response to R&D efforts. Innovation response to a change in R&D efforts in the western region is much smaller than that in the coastal and central regions. For example, an increase of 0.1% in R&D intensity is likely to boost innovation by 0.40% in the coastal region, 0.38% in the middle region and only 0.08% in the western region, other things being equal. In terms of economic growth, it is least responsive to changes in R&D efforts in the western region too. Surprisingly, economic growth in the middle region seems to be more responsive to an increase in R&D efforts than in the coastal region according to the estimation results in Table 4.

[Insert Table 4 here]

6. Further Analysis

The findings in the preceding section are subjected to several qualifications. For this reason, further analysis is conducted to address those issues. First, the estimation of equations (6) and (7) is incomplete without consideration of the existence of unit roots in the time-series dependent variables and hence the problem of spurious regressions. Given the nature of the dataset with a short time period, several unit root tests using panel data are conducted. The testing results are reported in Table 5. Apparently unit roots existed in most variables. One way of dealing with these problems is to estimate the models using the generalized method of moments (GMM) approach. The latter is also an appropriate technique to overcome endogeneity problems in the growth model. In addition, the Durbin-Watson statistics presented in Table 3 imply the presence of autocorrelation in Models 1 to 4. As a result, equations (6) and (7) are re-estimated using GMM approaches. Both difference GMM technique proposed by Arellano and Bond (1991) and Arellano and Bover (1995) and system GMM approach by Blundell and Bond (1998) are attempted.

[Insert Table 5 here]

In general, the differencing GMM models (Models 7 and 8 in Table 6) can pass the Sargan test as well as the test for AR(2) while both tests are rejected for the system GMM models (Models 9 and 10 in Table 6 f). Roodman (2009) argued that the system GMM method is more suitable for models with dependent variables behaving like random walk.[2] In this study both innovation and growth rates are expected to be strongly correlated with the past. Thus the differencing GMM method is the preferred technique. According to the differencing GMM results, an increase in R&D intensity by 0.1% would lead to an increase in innovation by 0.89% and subsequently economic growth by 0.08%. These changes are much higher than the findings reported in Table 3. Thus, the impact of R&D on innovation and economic growth is likely to be underestimated if endogeneity or unit roots are not taken into consideration. In addition, the sign of the coefficient of the 'non-state sector' variable in model 7 is negative but statistically insignificant. However, the negative sign of the coefficient of government spending in model 8 is surprising. Furthermore, Models 7 and 8 are also re-estimated by incorporating regional dummy variables as it is done in Models 5 and 6. Both differencing and system GMM results cannot pass the Sargan test as well as the test for AR(2). Thus discussion about regional variation is not pursued in this case.

[Insert Table 6 here]

Second, the rate of innovation is a key variable in the exercises and may be sensitive to the assumption of the rate of depreciation used in the estimates of patent stock. The exercises described in the preceding section are repeated and the results are reported in Table 7. The findings in the table demonstrate some sensitivity in the estimated coefficient of the R&D intensity variable. With the rate of depreciation rising from 4% to 10%, the impact of an increase in R&D intensity of 0.1% on innovation

[2] In contrast, Hayakawa (2001) argues that the system GMM estimator is less biased than differencing GMM estimators.

increases while that on economic growth tends to decrease (Table 7). This finding implies that the existing studies may overestimate or underestimate the response of innovation and hence growth to a change in R&D intensity due to the application of either a high or a low rate of deprecation. For example, the rate of depreciation is assumed to be 0.2% in Ulku (2007), and 15% in Hu et al. (2005) and Wu (2009).

[Insert Table 7 here]

7. Conclusion

To sum up, this study applied regional data to examine the impact of R&D efforts on innovation and hence economic growth in China in recent decade. It is found that innovation affects China's economic growth positively while R&D intensity has a positive impact on regional innovation. Both innovation and economic growth respond to R&D investment significantly and the calculated elasticities are comparable with those reported in studies of other economies. However these results are sensitive to the estimation methods. Traditional panel data approaches may lead to the underestimation of the impacts of R&D investment on innovation and hence economic growth. The differencing GMM may correct potential biases associated with endogeneity and nonstationarity. Subsequently the estimation results show that R&D investment in China has substantial impacts on innovation and economic growth.

In addition, the findings also show some sensitivity to the choice of the rate of depreciation in knowledge. There is also evidence of regional variation between the coastal, middle and western areas in the country. Furthermore, infrastructure development, the degree of economic reform, government spending, foreign capital and human capital endowment also play a role in affecting China's innovation and economic growth. The direction of impacts is however mixed according to the estimation approaches employed in the exercises. This calls for caution in interpretation of the results.

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Table 1 World's Top R&D Spenders in 2006

Countries	Ranking	Total spending (ppp$ billion)	Shares (%)		
			Firms	Government	Other
US	1	348.7	65.2	29.1	5.7
Japan	2	138.8	77.1	16.2	6.7
China	3	86.8	72.4	25.9	1.7
Germany	4	66.7	68.1	27.8	4.1
France	5	41.5	52.4	38.4	9.2
UK	6	35.6	45.2	31.9	22.9

Sources: OECD database for science, technology and patent (www.oecd.org).

Table 2 Summary statistics of the sample

	1998			2007		
Indicators	Mean	Max	Min	Mean	Max	Min
Growth	0.093	0.114	0.073	0.141	0.190	0.121
Innovation	0.145	0.257	0.085	0.200	0.357	0.147
R&D intensity	0.006	0.043	0.001	0.012	0.056	0.002
Infrastructure	0.588	2.176	0.029	1.115	3.205	0.042
Government	0.122	0.495	0.057	0.197	0.805	0.087
Foreign capital	0.062	0.329	0.001	0.053	0.212	0.002
Nonstate sector	0.814	0.911	0.506	0.888	0.948	0.766
Enrolment ratio	0.514	0.885	0.344	0.793	1.121	0.569

Source: Author's own calculation.

Table 3 Estimation results

Variables	Innovation *(Model 1)*	Growth *(Model 2)*	Innovation *(Model 3)*	Growth *(Model 4)*
Intercept	0.041 (0.022)*	-0.078 (0.039)*	0.052 (0.037)	-0.107 (0.037)***
R&D intensity	3.756 (0.845)***		3.568 (1.720)**	
Innovation		0.066 (0.024)***		0.165 (0.063)***
Infrastructure	0.041 (0.008)***	0.009 (0.004)**	0.039 (0.010)***	0.003 (0.005)
Government	0.078 (0.053)	0.123 (0.041)***	0.084 (0.071)	0.139 (0.047)***
Foreign capital	0.468 (0.073)***	-0.137 (0.024)***	0.334 (0.046)***	-0.176 (0.036)***
Nonstate sector	0.014 (0.029)	0.126 (0.050)**	0.018 (0.048)	0.143 (0.051)***
Enrolment ratio	0.018 (0.014)	0.083 (0.007)***	0.013 (0.016)	0.083 (0.008)***
$\overline{R}^2$	0.85	0.79	0.84	0.79
F - control variables	15.78***	113.64***	8.21***	67.64***
χ^2 - Hausman test	24.15***	44.34***	10.94*	42.95***
F - fixed effects	25.52***	8.90***	n.a.	n.a.
Durbin-Watson	1.22	1.30	1.26	1.40

Notes: ***, ** and * represent significance at the level of 1%, 5% and 10%, respectively. A significant F (fixed effects) value implies the acceptance of the fixed effect model (against the model with a common intercept) while a significant χ^2 (Hausman test) value means the rejection of the random effect model (against the fixed effect model). A significant F (control variables) value indicates the acceptance of the inclusion of the control variables. Models 1 and 2 are estimated using panel generalized least squares (GLS). Models 3 and 4 are estimated using panel two-stage GLS. All models are estimated with cross section weights, and White cross-section standard errors and covariance..

Table 4 Estimation results incorporating regional dummies

Variables	Innovation *(Model 5)*	Growth *(Model 6)*
Intercept	0.053 (0.024)**	-0.109 (0.029)***
R&D intensity	3.828 (1.075)***	
R&D intensityC	0.193 (0.798)	
R&D intensityW	-2.999 (1.618)*	
Innovation		0.267 (0.069)***
InnovationC		-0.159 (0.064)**
InnovationW		-0.040 (0.091)
Infrastructure	0.039 (0.008)***	0.002 (0.005)
Government	0.100 (0.061)*	0.122 (0.041)***
Foreign capital	0.458 (0.072)***	-0.171 (0.064)***
Nonstate sector	0.003 (0.032)	0.145 (0.039)***
Enrolment ratio	0.021 (0.014)	0.082 (0.012)***
$\overline{R}^2$	0.85	0.78
F - control variables	15.122***	50.187***
χ^2 - Hausman test	27.142***	40.499***
F - fixed effects	26.126***	n.a.

Notes: ***, ** and * represent significance at the level of 1%, 5% and 10%, respectively. A significant F (fixed effects) value implies the acceptance of the fixed effect model (against the model with a common intercept) while a significant χ^2 (Hausman test) value means the rejection of the random effect model (against the fixed effect model). A significant F (redundant variables) value indicates the acceptance of the inclusion of the control variables. The innovation and growth equations are estimated using panel GLS and two-stage GLS with cross section weights and White cross-section covariance, respectively. C and W represent the coastal and western dummies.

Table 5 Unit root test results

	LLC	IPS	ADF	PP
Innovation	-0.28 (0.391)	1.19 (0.883)	67.15 (0.305)	79.78 (0.064)
Growth	-1.63 (0.051)	3.34 (1.000)	34.07 (0.999)	15.78 (1.000)
GOV	-2.76 (0.003)	1.88 (0.970)	37.62 (0.994)	56.63 (0.669)
INF	4.93 (1.000)	7.64 (1.000)	12.24 (1.000)	24.54 (1.000)
FKK	-0.75 (0.226)	4.61 (1.000)	31.33 (1.000)	46.09 (0.935)
Enrol	-2.59 (0.005)	6.25 (1.000)	28.42 (1.000)	25.59 (1.000)
Nonstate	-12.19 (0.000)	-2.46 (0.007)	98.13 (0.002)	264.26 (0.000)
R&D density	-8.65 (0.000)	-1.95 (0.026)	94.02 (0.005)	109.50 (0.000)

Notes: The tests were conducted without trends using Eviews 6. The results are similar for tests including trends. The p-values for the tests are presented in the parentheses. LLC, IPS, ADF and PP are short for Levin, Lin and Chu (2002); Im, Pesaran and Shin (2003); ADF-Fisher (Dickey and Fuller, 1979) and PP-Fisher (Phillips and Perron, 1988) tests.

Table 6 GMM Estimation Results

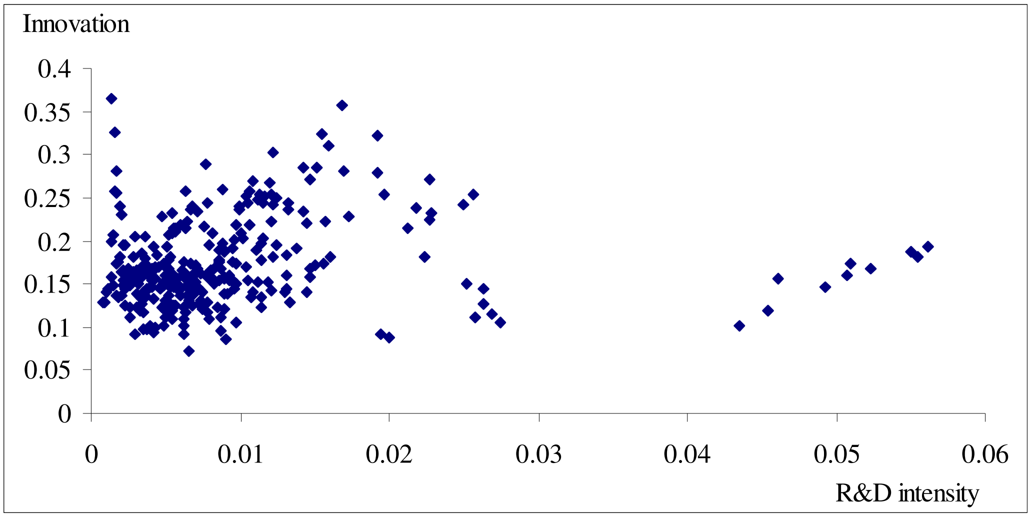
	Difference GMM		System GMM	
	Innovation *(Model 7)*	Growth *(Model 8)*	Innovation *(Model 9)*	Growth *(Model 10)*
R&D intensity	8.9220 (3.260)***		0.5522 (0.478)	
Innovation		0.0904 (0.052)*		0.0752 (0.035)**
Infrastructure	0.0092 (0.013)	0.0039 (0.006)	0.0088 (0.005)*	-0.0012 (0.001)
Government	-0.2492 (0.067)***	0.0525 (0.045)	0.0794 (0.012)***	0.0041 (0.007)
Foreign capital	0.6380 (0.182)***	-0.2090 (0.108)*	0.3214 (0.018)***	0.0286 (0.014)**
Nonstate sector	-0.0003 (0.149)	0.3224 (0.125)**	0.2443 (0.019)***	0.0800 (0.011)***
Enrolment ratio	0.0690 (0.036)*	0.0681 (0.020)***	0.0756 (0.012)***	0.0888 (0.005)***
AR(2) test	*(0.464)*	*(0.098)**	*(0.048)***	*(0.108)*
Sargan test	*(0.132)*	*(0.291)*	*(0.017)***	*(0.000)****

Notes: The p-values for AR(2) and Sargan tests are reported in parentheses. ***, ** and * represent significance at the level of 1%, 5% and 10%, respectively.
Sources: Author's own calculation.

Table 7 Innovation and growth responses to R&D density

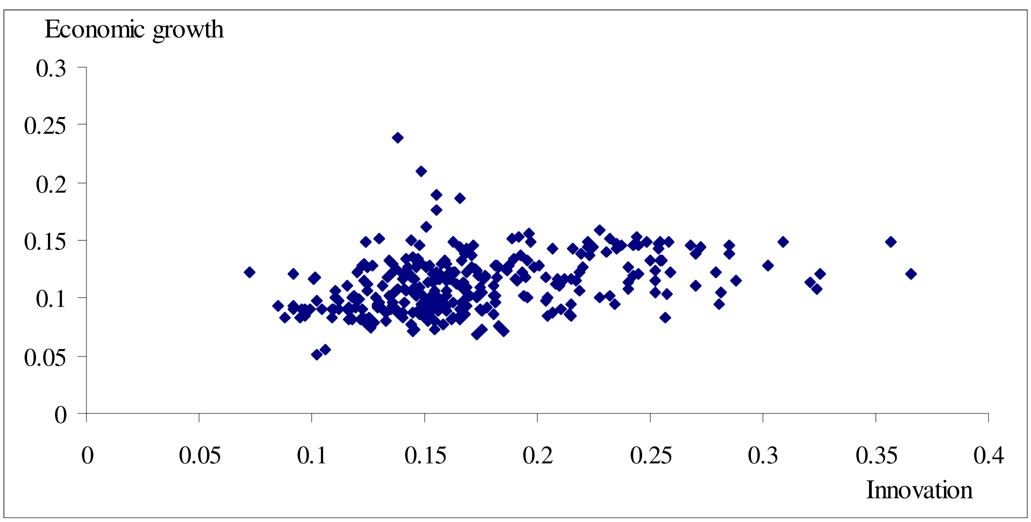
Rate of depreciation (%)	Innovation	Growth
4	0.746	0.088
7	0.892	0.080
10	1.038	0.061

Notes: The numbers are based on differencing GMM results.
Sources: Author's own calculation.



Source: Author's own work.

Figure 1 Scattergram between Innovation and R&D Intensity



Source: Author's own work.

Figure 2 Scattergram between Economic Growth and Innovation

Endnotes

[1] Calculated using information from the *2008 Statistical Communiqué of National Economy and Social Development*, National Bureau of Statistics of China (released on February 26, 2009, www.stats.gov.cn).

[2] The State Council, People's Republic of China (www.gov.cn/jrzg/2006-02/09/content_183787.htm).

[3] See Woo (1998), Young (2003) and Wu (2008), to cite a few.

[4] These numbers for 1990 and 2008 are drawn from China Statistical Yearbook of Science and Technology and *2008 Statistical Communiqué of National Economy and Social Development*, National Bureau of Statistics of China (released on February 26, 2009, www.stats.gov.cn), respectively.

[5] This figure was drawn from *2005 China Statistical Yearbook on Science and Technology* compiled by National Bureau of Statistics and Ministry of Science and Technology, Beijing: China Statistics Press.

[6] China's 2007 R&D expenditure, employment and investment data are drawn from the Annual Statistics of Science and Technology, National Bureau of Statistics of China (www.stats.gov.cn).

[7] Student numbers are drawn from China Statistical Yearbook 2008 compiled by National Bureau of Statistics of China (www.stats.gov.cn).

[8] China's patent and publication data are drawn from the Annual Statistics of Science and Technology published by National Bureau of Statistics of China (www.stats.gov.cn).

[9] For a comprehensive literature survey, see Jones (2005).

[10] The e-copies of these yearbooks are available on the web site of National Bureau of Statistics of China (www.stats.gov.cn).

[11] For the estimation of China's capital stock series, refer to Wu (2008).

[12] In details, the three regions are the coastal region (Beijing, Tianjin, Shanghai, Fujian, Guangdong, Hebei, Jiangsu, Liaoning, Shandong, and Zhejiang), the middle region (Shanxi, Hainan, Jilin, Anhui, Heilongjiang, Guangxi, Jiangxi, Hubei, Hunan, Henan and Hainan) and the western region (Inner Mongolia, Ningxia, Tibet, Xinjiang, Gansu, Guizhou, Qinghai, Shaanxi, Sichuan, Yunnan and Chongqing).

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