

Econometric Study of Technology Innovation Performance in China

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Keywords: national innovation system, regional innovation system, innovation performance

Abstract. This paper adopts modern metering methods such as spatial statistics, spatial econometrics, spatial filtering, random leading edge model with heterogeneity, quantile regression, panel unit root, panel co-integration, and so on, to complete the research on the direct performance of regional technological performance; on the basis on theoretical analysis, this paper builds conduct model of regional technological innovation into national macro economic development and co-integration model of Chinese small macroscopic econometrics, which is undoubtedly innovative in the aspect of technological innovation performance evaluation.

1. Introduction

To study the phenomenon and laws of regional technological innovation system is an important part to promote regional technological innovation, an important measure to realize the regional sustainable and harmonious development in China, and also an important step to realize regional development strategy in our country. To build effective regional technological innovation system, the investment of regional technological innovation is necessary. On the basis of theoretical analysis, this paper analyzes and evaluates the influence of regional technological investment on the main macroeconomic variables in our country, and investigates regional technological innovation performance against the background of national macroeconomic development; comparing with the existing literature on technological innovation performance evaluation, this paper undoubtedly has great significance in the aspect of technological innovation performance evaluation.

2. Regional technological innovation performance

Performance is a polyseme, which has six difference meanings in English, and the common meaning refers to manifestation, achievement or result (Luo Yafei, 2010P58) Ilgen and Schneider (1991) believe that performance refer to what individuals or organizations do. Campbell et al. (1993) think that performance is a concept with multiple dimensions, and there is no single performance variable. Xiao Mingzheng (2007) considers that the connotation of performance has three aspects: the first refers to effect, and the degree to which the goal reaches, which is the appearance form of performance; the second refers to the relationship between investment and production; the third refers to benefit, which is the economic benefit, social benefit and time benefit to organizations or individuals by the final results. Therefore, performance can be understood as the achievements, efficiency and benefits organizations or individuals gained under certain external circumstances. In the research process, this paper focuses on the indirect performance evaluation of regional technological innovation, which is the issue of the indirect performance evaluation of regional technological innovation; thereafter, the influence of regional technological innovation on national macro economy, or the macroeconomic effect, of regional technological innovation on national macro economy, is abbreviated as macro performance of regional technological innovation.

3. Analytical model building of macro performance of Chinese regional technological innovation

Co-integration model building of Chinese macro econometrics

1. Theoretical basis for the model

(1) Relevant theories of the model. This paper applies the co-integration estimation method made by Gregory and Hansen (1996), which has the function of internal structural mutation inspection, so as to catch the mutation phenomenon that the model parameters may exist.

(2) Parameter estimation method. Gregory and Hansen put forward a method to estimate parameters of co-integration measurement model based on OLS; with this method, the discontinuous behaviors in economic behaviors can be caught, which refers to the structural mutation problem in economic behaviors. The standard co-integration model can be expressed as:

$$y_{1t} = \mu + \alpha' y_{2t} + \varepsilon_t, t=1, \dots, n \quad (2-1)$$

In the formula (2-1), the variables y_{1t} , y_{2t} are I(1) variables; while ε_t is I(0) variable. When the economic behaviors have such structural changes, they will show in parameters of μ and α , and to catch structural breaking point, dummy variables are set as following:

$$\varphi_{t\tau} = \begin{cases} 0 & \text{if } t \leq [n\tau] \\ 1 & \text{if } t > [n\tau] \end{cases}$$

In the formula, the parameter $\tau \in (0,1)$ is for the time of structural mutation of economic behavior (relative time), n for sample length, $[n\tau]$ for round number of $n\tau$. There are three expression forms of structural mutation in economic behaviors in econometric model, which is shown in Formulas (2-2) to (2-4).

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha' y_{2t} + \varepsilon_t \quad t=1, \dots, n \quad (2-2)$$

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha' y_{2t} + \varepsilon_t \quad t=1, \dots, n \quad (2-3)$$

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha_1' y_{2t} + \alpha_2' y_{2t} \varphi_{t\tau} + \varepsilon_t \quad t=1, \dots, n \quad (2-4)$$

In the formula (2-4), μ_1 stands for the constant term before mutation, μ_2 for the variable quantity of the constant term in structural mutation, α_1 for the equation slope before mutation, α_2 for the variable quantity of the equation slope in mutation.

(3) Main characteristics of the model. Firstly, a small macro econometric co-integration model is an annual macro economic measurement model of supply and demand double oriented model, based on Keynes's national income decision theory and built according to national products and revenue accounting system (SNA). Secondly, the equation design depends on the dual drive of economic theory and data characteristics. In the process of model building, the endogenous and exogenous variables of the model are defined according to economic theory. Thirdly, a small macro econometric model is a co-integration econometric model.

2. Model structure. Small macro econometric co-integration model is divided into seven modules of production module, labor force module, revenue module, consumption module, investment and fixed asset module, price model and foreign trade module;. The total data comes from *Statistical data assembly of New China's 60 years*, *CEinet Statistical Database*, *Statistical Yearbook of Chinese Science and Technology*, *Chinese Statistical Yearbook*, and so on.

All the models have passed F test with the significance level of 5%. The modules of macro econometric co-integration model and the model are as following:

① Production module

$$\text{LOG}(V1) = 25.5321 + 0.0364 * \text{D93} * \text{LOG}(\text{CSPA}) + 0.2640 * \text{LOG}(\text{KV1}) - 1.7319 * \text{LOG}(\text{L1})$$

$$\text{LOG}(V2) = -13.7444 + 0.5360 * \text{LOG}(\text{CSPA}) + 0.3549 * \text{LOG}(\text{KV2}) + 0.3654 * \text{LOG}(\text{L2}) + [\text{AR}(1) = 1.3429,$$

$$\text{AR}(2) = -0.5890]$$

$$\begin{aligned} \text{LOG}(V3) &= -13.7204 + 0.3074 * \text{LOG}(CSPA) + 0.1882 * \text{LOG}(KV3) + 1.8340 * \text{LOG}(L3) \\ \text{LOG}(GCF) &= 1.2302 + 0.8914 * \text{LOG}(IF) - 0.1399 * D02 * \text{LOG}(IF) + 1.5077 * D02 + [\text{AR}(1)=0.5147] \\ \text{OGAP} &= -389.2478 - 1.2398 * \text{GDPE} + 0.7711 * V1 + 1.69856 * V2 + 1.1226 * V3 \\ \text{GDP} &= V1 + V2 + V3 \quad V1C = V1 / PV1 * 100 \quad V2C = V2 / PV2 * 100 \quad V3C = V3 / PV3 * 100 \\ \text{GDPC} &= \text{GDP} / \text{PGDP} * 100 \quad \text{GDPE} = \text{GCF} + \text{CT} + \text{XT} - \text{MT} \end{aligned}$$

② Labor force module

$$\begin{aligned} \text{LOG}(L1) &= 26.0945 - 0.0958 * \text{LOG}(CT(-1)) - 1.2879 * \text{LOG}(AP) + 0.2828 * D00 * \text{LOG}(AP) - 0.2858 * D00 * \text{LOG}(CT) \\ \text{LOG}(L2) &= 7.6700 + 0.4881 * \text{LOG}(V2) - 0.3319 * \text{LOG}(UW) - 0.1549 * D92 \\ \text{LOG}(L3) &= 6.3307 + 0.3235 * \text{LOG}(CT) + [\text{AR}(1)=1.0810, \text{AR}(2)=-0.6365] \quad L = L1 + L2 + L3 \end{aligned}$$

③ revenue module

$$\begin{aligned} \text{LOG}(YA) &= 4.8019 + 0.4276 * \text{LOG}(YA(-1)) + 0.5344 * \text{LOG}(V1/L1) + 0.0840 * D89 + [\text{AR}(1)=0.5122] \\ \text{LOG}(YU) &= -0.5314 + 0.6361 * \text{LOG}(YU(-1)) + 0.4308 * \text{LOG}(UW) - 0.0121 * D00 * \text{LOG}(UW) - 0.1277 * D95 \\ \text{LOG}(UW) &= 6.9605 + 0.2860 * \text{LOG}(UCPI(-1)) + 0.7359 * \text{LOG}(GDP/L) + 0.3184 * D95 * \text{LOG}(GDP/L) + [\text{AR}(1)=0.6648] \\ \text{LOG}(GORV) &= 2.2222 + 0.5794 * \text{LOG}(GDP) - 8.1728 * D93 + 0.7545 * D93 * \text{LOG}(GDP) + [\text{AR}(1)=1.1110, \text{AR}(2)=-0.6093] \\ \text{LOG}(GEXE) &= -0.2090 + 0.2131 * \text{LOG}(GEXE(-1)) + 0.8219 * \text{LOG}(GORV) - 0.1039 * D04 \end{aligned}$$

④ Consumption module

$$\begin{aligned} \text{LOG}(CRAP) &= 0.2488 + 0.6984 * \text{LOG}(CRAP(-1)) + 0.2669 * \text{LOG}(YA) - 0.7186 * D92 * \text{LOG}(CRAP(-1)) + 0.6941 * D92 * \text{LOG}(YA) \\ \text{LOG}(CRNP) &= -1.6411 + 0.3065 * \text{LOG}(CRNP(-1)) + 0.9886 * \text{LOG}(YU) + 0.1018 * D85 - 0.0454 * @TREND \\ \text{LOG}(CP) &= -4.7004 + 1.5834 * \text{LOG}(GORV) - 0.9031 * D93 * \text{LOG}(GORV) + 7.8397 * D93 + [\text{AR}(1) = 0.8453, \text{AR}(2) = -0.4096] \\ \text{RC} &= \text{CRAP} * \text{AP} / 10000 \quad \text{RCC} = \text{RC} / \text{RCPI} * 100 \quad \text{UC} = \text{CRNP} * \text{NP} / 10000 \quad \text{UCC} = \text{UC} / \text{UCPI} * 100 \\ \text{RUC} &= \text{RC} + \text{UC} \quad \text{RUCC} = \text{RUC} / \text{PCR} * 100 \quad \text{CT} = \text{RUC} + \text{CP} \quad \text{CTC} = \text{RCC} + \text{UCC} + \text{CP} / \text{PR} * 100 \end{aligned}$$

⑤ Investment and fixed asset module

$$\begin{aligned} \text{LOG}(IF) &= -1.0727 + 1.0430 * \text{LOG}(CT) - 1.0347 * D02 * \text{LOG}(CT(-2)) + 1.1798 * D02 * \text{LOG}(GEXE(-1)) \\ \text{LOG}(IF1) &= 0.3228 + 0.9820 * \text{LOG}(IF1(-1)) - 5.075 * D02 + 1.3317 * D02 * \text{LOG}(IF) - 1.3346 * D02 * \text{LOG}(IF1(-1)) \\ \text{LOG}(IF2) &= -3.1461 + 1.2041 * \text{LOG}(IF) - 0.0158 * D96 * \text{LOG}(IF) + [\text{AR}(1)=0.8543] \\ \text{LOG}(IF3) &= 0.6992 + 0.8767 * \text{LOG}(IF) + 0.0146 * D96 * \text{LOG}(IF) + [\text{AR}(1)=0.7989] \\ \text{KV1} &= 0.95 * \text{KV1}(-1) + \text{IF1C} \quad \text{KV2} = 0.95 * \text{KV2}(-1) + \text{IF2C} \quad \text{KV3} = 0.95 * \text{KV3}(-1) + \text{IF3C} \\ \text{IF1C} &= \text{IF1} / \text{PI} * 100 \quad \text{IF2C} = \text{IF2} / \text{PI} * 100 \quad \text{IF3C} = \text{IF3} / \text{PI} * 100 \quad \text{IFC} = \text{IF1C} + \text{IF2C} + \text{IF3C} \end{aligned}$$

Table 2-1 Endogenous variable of macroeconomic model

Variable	Implication	Unit
AP	Rural population	Ten thousand
EXRA	Exchange rate (1 US dollar = RMB)	
NP	Urban population	Ten thousand
PIAM	Prize indices of agricultural means of production (1980=100)	
PPI	Purchase prize indices of raw materials, fuel, power (1990=100)	
OECDP	GDP comprehensive deflator of all the countries in OECD	
WD	World demand (import volume of world commodities and service (US dollar constant price in 2005))	One billion US dollars

The standard of model evaluation is Root Means Square, RMS, and the computational formula is (Zhao Guoqing, Yang Jian, 2003P81):

$$RMS_i = \sqrt{\frac{1}{T} \sum_{t=1}^T \left[\frac{F_{it} - A_{it}}{A_{it}} \right]^2} \quad (2-5)$$

In the formula (2-5), Fit is for estimated value, Ait for actual value, T for sample interval length. Obviously, when $RMS_i=0$, it means the estimated value of endogenous variable i matches the actual observed value completely. The Root Means Square of endogenous variable in all the behavior equation is shown in Table 2-3.

Table 2-2 Root Means Square of endogenous variable

Variable	Implication	Unit	Variable	Implication	Unit
CP	Government consumption (current price)	2.2584	MT	Gross import (current price)	7.9429
CRAP	Per capita consumption expenditure of rural residents (current price)	1.6145	PCR	Consumer price index	0.3177
CRNP	Per capita consumption expenditure of urban residents (current price)	2.0065	PGDP	GDP deflator	2.3771
CT	Total consumption (current price)	0.0010	PI	Fixed asset investment price index (1978=100)	3.2078
GCF	Gross capital formation (current price)	2.8861	PR	General price index of retail sales	3.7325
GEXE	Expenditure of national financial statements in this level (current price)	3.0498	RCPI	Consumer price index of rural residents	0.9339
GORV	Fiscal revenue (current price)	1.916	UCPI	Consumer price index of urban residents	0.7770
IF1	Fixed-asset investment of the primary industry (current price)	6.8767	UW	Average wage	4.2117
IF2	Fixed-asset investment of the secondary industry (current price)	5.0358	V1	The first industrial added value (constant price)	4.9969
IF3	Fixed-asset investment of the third industry (current price)	3.3620	V2	The second industrial added value (constant price)	3.5292
IF	Fixed-asset investment of the whole society (current price)	2.2380	V3	The third industrial added value (constant price)	2.1352
L1	Number of employees in the first industry	0.7917	XT	Gross export (current price)	4.4419
L2	Number of employees in the second industry	3.1798	YA	Per capita net income of rural households (current price)	1.2823
L3	Number of employees in the third industry	0.9924	YU	Per capita net income of urban households (current price)	3.8208

From Table 2-3, it can be seen that except for the three variables of Fixed-asset investment of the primary industry, Fixed-asset investment of the secondary industry, and Fixed-asset investment of the third industry, error rates of the Root Means Square of the other endogenous variables are under 5%, which occupies more than 90% of all the endogenous variables, which indicates that the prediction accuracy of the model's sample interval is high, the total imitative effect of model system is good, and this model can be taken to make situational analysis.

C. Connection of regional technological innovation and Chinese macro econometric model

The connective way of regional research and development innovation activities and national macro econometric model is through the connecting mechanism of innovation knowledge produced by regional knowledge production function influencing the research and development knowledge stock,

and the national research and development knowledge stock influencing national macro economic activities, whose theoretical basis is the endogenous economic growth theory and knowledge spillover theory. The regional knowledge production function to be used is:

$$\log(paap_{it}) = \alpha_{it} + \beta_1 \cdot \log(nstp_{it}) + \beta_2 \cdot \log(rdep_{it}) + \beta_3 \cdot \log(rfdi_{it}) + \beta_4 \cdot \log(rim_{it}) + \varepsilon_{it} \quad (6-6)$$

According to the analysis above, regional technological innovation activities have spacial correlation; therefore model (6-6) cannot take traditional method (such as OLS) to make regression analysis; otherwise, model will produce specification error (Anselin, 1988). Under this circumstance, the proper measurement model is:

$$\log(paap_{it}) = \alpha_{it} + \rho \cdot W \cdot \log(paap_{it}) + \beta \cdot \log(X_{it}) + \varepsilon_{it} \quad (6-7)$$

$$\log(paap_{it}) = \alpha_{it} + \beta \cdot \log(X_{it}) + \varepsilon_{it} \quad \varepsilon_{it} = \rho \cdot W \cdot \varepsilon_{it} + u_{it} \quad (6-8)$$

In formula (6-7), vector quantity X stands for the corresponding explanatory variable of model (6-6) or first-order lagged variable, and β for the corresponding coefficient matrix. Model (6-7) is called as panel spatial lag model, which can be used to explore and study whether the research object has the spillover effect in a region; model (6-8) is called as panel spatial error model, which is used for analyzing and studying whether the relations of the research object among regions can be embodied through error term (Elhorst, 2003).

The model above can be used to measure the quantitative relation between regional patent application amount $paap_{it}$ and its influencing factors, so as to calculate the national patent application amount of that year $paap_t$, which can be shown with formula (2-9):

$$paap_t = \sum_{i=1}^n paap_{it} \quad (2-9)$$

In formula (2-9), n is for the number of regions, t for year. After gaining the national patent application amount $paap_t$, formula (2-10) can be used to express the relation between national patent application amount $paap_t$ and the national innovation knowledge stock $cspa_t$, which can be expressed with non-parametric econometric model:

$$cspa_t = m(paap_t) + \sigma(paap_t)\varepsilon_t \quad (2-10)$$

In formula (2-10), $m(paap_t)$ is unknown function, $m(paap_t) = E(cspa_t | paap_t)$; ε_t is the sequence with mean value as 0, variance as 1, independent from explanatory variable; random error term $\mu_1 = \sigma(paap_t)\varepsilon_t$, with conditional variance as $\sigma^2(paap_t) = E(\mu_1^2 | paap_t)$. Model (2-10) has many ways for estimation and this chapter adopts non-parametric kernel estimation to estimate it (Sun Jian, 2010).

Regional knowledge production function suits panel time-space fixed effect model, whose specific form is:

$$\log(paap_{it}) = \alpha + \rho \cdot W \cdot \log(paap_{it}) + \beta \cdot \log(X_{it}) + \mu_i + \theta_t + \varepsilon_{it} \quad (2-11)$$

In the model (2-11), μ_i is the Region-Specific Fixed Effect in region i, which refers to the influence of the regional characteristics in the region i on regional technological innovation activities after controlling other explanatory variables. θ_t is the Time-Specific Fixed Effect in the year of t, which refers to the fixed influence of region's characteristics in the year of t on regional technological innovation activities after controlling other explanatory variables.

Table 2-3 Panel model’s test results

Test model	Test type	Test statistical values	Probability	Likelihood function log koc
POOL estimation test(1)	LM test no spatial lag	8.6936	0.003	-209.2131
	Robust LM test no spatial lag	0.0523	0.819	
	LM test no spatial error	26.2897	0.000	
Spatial fixed effect lag or error test(2)	LM test no spatial lag	78.6385	0.000	-21.5132
	robust LM test no spatial lag	109.9862	0.000	
	LM test no spatial error	14.6663	0.000	
	robust LM test no spatial error	46.0140	0.000	
Space-time fixed effect lag or error test(3)	LM test no spatial lag	22.3277	0.000	38.8193
	robust LM test no spatial lag	6.0684	0.014	
	LM test no spatial error	18.4924	0.000	
	robust LM test no spatial error	2.2330	0.135	

Model (2-11) takes Elhorst(2003)’s second order maximum likelihood estimation to estimate. Table (2-5) shows the situation of lag explanatory variables, without listing time and space fixed effect; as for the model, $R^2=0.9741$, $corr^2=0.8339$ and the likelihood function log koc is 38.8193. Table (2-6) shows the situation of model explanatory variables having no lag terms, without listing time and space fixed effect; as for the model, $R^2=0.9757$, $corr^2=0.8446$ and the likelihood function log koc is 32.8199.

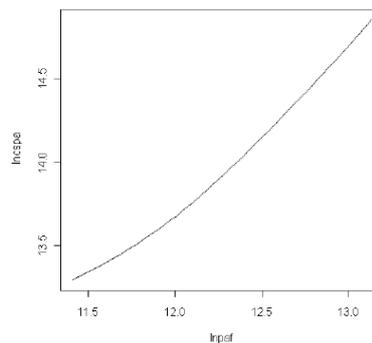


Figure 2-1 Model (2-10) non-parametric estimation results

According to the fundamentals of macro econometric model and considering the latest parameter estimation method in the econometric theory, this paper builds regional- macro econometric co-integration model of China, which can be used for the simulation study of the influence of regional technological innovation activities in China on Chinese macro economy’s main variables.

4. Conclusions

The study finds out that all the environmental factors influencing Chinese regional technological innovation efficiency are steady variables, and there is co-integration relationship between investment and output variables. Other factors such as government funding, financing institutions’ support have different influencing directions and significance degree on the technological innovation efficiency in the whole world and the three regions.

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