Endogenous Growth Model and Error Correction Model of China's Science and Technology Activity

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Abstract – In present research on science and technology activity with economic growth being output, there are some research gaps such as shortage of theoretical model and simplex explanatory variable. In this paper, relations between input in science and technology and output of certificated patents and scientific papers are researched within research and development department. Following research results are gained. First, in three kinds of basic endogenous growth models, capital promotion endogenous growth model could explain China's science and technology activities best. Second, intellectuals, apparatus and knowledge accumulation could significantly explain and exactly predict output of science and technology. Third, variability between patent model and paper model reflects their internal difference. It's suggested to reinforce investment in apparatus for scientific research to raise integrated level of science and technology, and reasonably allocate input resources according to different demands in order to raise output efficiency.

Index Terms - Science and technology activity, certificated patent, scientific paper, endogenous growth model, error correction model

1. Introduction

According to endogenous growth model, knowledge accumulation is primitive dynamic resource of economic growth, and long-term economic growth derives from knowledge accumulation and technology advance brought by scientific investment. Consequently, it's important to clarify internal relations between input and output of science and technology (Abr. S&T) activities. First, it's helpful optimize configuration of S&T input to promote output efficiency. Second, it's helpful to differentiate variability between different S&T activities and to arrange input resource according to demand scientifically. In some researches on relation between S&T input and economic growth, significant t-value of OLS and co-integration between them are used to explain economic growth by S&T input [1] [2] [3] [4]. But research gap is shortage of theoretical basis of growth model, which leads to neglect of other important input factors such as labor and capital, and then incomplete explanation of economic growth and exaggerated function of scientific input. In some other researches on the relation, though endogenous growth model is adopted [5] [6], but research gap still exists. Under China's transition economy, total factor productivity for economic growth comes from not only scientific advance, but also from dynamic factors as system reform and industrial structure change, which can't be set to be constant.

If the research is based on endogenous growth model and confined in research and development (Abr. R&D) department, it's helpful to make up the research gaps. Then input and output model will be constructed exactly to distinguish growth characters of different S&T activities, which is key to explain fluctuation of S&T output and to correctly estimate and improve S&T resource configuration. In endogenous economic growth theory, scientific advance is viewed as output of R&D department, and a model should be built up for output of new technology to reasonably allocate input resource [7]. Modern methodologies of econometrics and endogenous growth model will be used in this paper. Within R&D department, S&T input and patent and paper output for about 17 year in China will be analyzed and their endogenous model will be built up to exactly find input-output relationship and configuration optimization method.

2. Model and Index Selection

A. Growth Model Types and Index Selection

According endogenous economic growth theory, technology becomes endogenous variable in the model function, and labor, capital and present technology are input and new technology are output in R&D activities [7]. Growth model is as (1) and has three types: Harold-neutral endogenous growth model, Hicks-neutral endogenous growth model and capital-promotion endogenous growth model. Each model has different elasticity of A_t respectively [7]. Historical data will be used to verify feasible model for Chinese status.

$$\dot{A}_t = BK_t^{\alpha} A_t^{\theta} L_t^{\beta}, \ \alpha + \beta = 1. \quad (1)$$

Note: $\dot{A}_t$, K_t, A_t, L_t represent S&T advance, capital, S&T level and number of scientist and engineers in S&T activity respectively in t year, in which α, θ, β are elasticity for the latter three indexes respectively. Constant returns to scale is supposed in this model, which means sum of elasticities of capital and labor to be one.

Patent is a major carrier of intellectual property rights, and patent R&D is an inventive work with output of certificated patent based on S&T. It's one kind of core competition power for an industry or even for a country. Scientific paper is fruit of scientific theory and practice research, which represents scope and depth of S&T research activity and forms basis of advance of S&T level. Patent R&D and Paper research are major kind of S&T activities, in which certificated patent and scientific paper are their major output. Patent R&D and Paper research are tightly connected, interact with each other, and promote each other. They become huge power to promote development

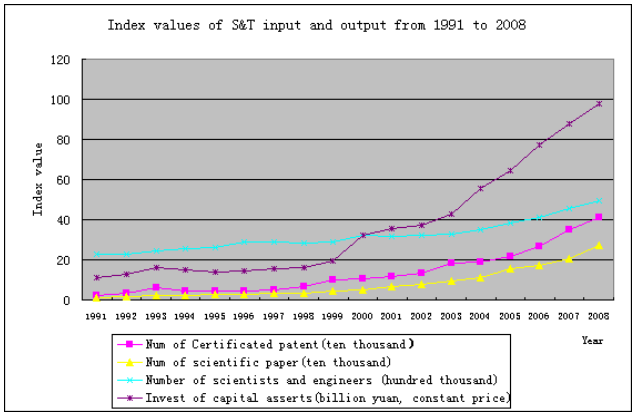
of economy and society. Lian etc. evaluated S&T activity in Chinese industries and enterprises with converted scientific research expenditure being S&T input and patent and paper being output [8]. Zhao formed the evaluation index system with number of scientists and engineers in S&T activity and S&T activity expenditure being input, and with number of scientific papers and inventive patents being output [9].

1) Output index: New added numbers of certificated patents and scientific papers are used as evaluation indexes of $\dot{A}_t$ respectively, which reflect annual S&T activity output (degree of S&T advance).

2) Input index: Accumulated number of certificated patents and scientific papers are used as evaluation indexes of $A(t)$ respectively, which reflect current level of S&T[1]; S&T capital asserts is evaluation index of $K(t)$; Number of scientists and engineers in S&T activity is evaluation index of $L(t)$.

B. Index Values and Data Processing

Data from China S&T statistics yearbook issued by the Ministry of Science and Technology since 1991 are cited. From 1991 to 2007, number of scientists and engineers in China increased from 2.28 million to 4.96 million by 2.2 times; S&T capital asserts investment rose from 11.4 billion yuan to 262.6 billion yuan (current price) by 23 times; Number of three types of certificated patents at home and abroad increased from 24 thousand to 412 thousand by 17.2 times; Number of foreign retrieved Chinese scientific papers rose from 12 thousand to 240 thousand by 20 times. In order to eliminate Inflation factor, annual deflators with 1990 being basis year are used to curtail S&T capital asserts investment and quoted GDP data. Fig. 1 lists all index values in 18 years.



Source: China Statistical Yearbook on Science and Technology (1991-2008)

Fig. 1 Index values of S&T input and output from 1991 to 2008

Equation of stock of Capital is shown in (2).

$$K_t = K_{t-1}(1-\delta) + I_t \qquad (2)$$

In (2), δ is depreciation rate, usually evaluated to be 5%; K_0 is evaluated to be value of GDP (constant price) in 1990 multiplied by 2.75%； I_t is annual expenditure for purchase and construction of S&T capital asserts.

Equation of Stock of certificated patents is shown in (3).

$$Z_t = \dot{Z}_t + Z_{t-1} \qquad (3)$$

In (3), original value Z_0 is total number of certificated patents from 1986 to 1990. China has just started to execute newly established law of patent in 1985.

Equation of stock of scientific papers is shown in (4)

$$P_t = \dot{P}_t + P_{t-1} \qquad (4)$$

In (4), original value P_0 is total number of scientific papers from 1986 to 1990.

C. Model Selection and Co-integration Test

According to Table I: 1) Under Hicks model, capital per capita shows significant negative influence on output per effective capita, which breaches basic economic principles and experience. The values of $\bar{R}^2$ show lower goodness of fit. 2) Under Harold model, capital per effective capita has no co-integration relation with output per effective capita, which show no stable relation in the long term between them. The values of $\bar{R}^2$ are not in the largest ones. 3) Under capital promotion model, X and Y are stationary time series, or have the most significant integration and co-integration. They also have best adjusted coefficient of determination and possess the most significant t-test values. With consideration of compliance of principle economic theory and goodness of explanation capability in econometrics synthetically, capital-promotion endogenous growth model corresponds with input and output relation of China's S&T activity best.

Known from Table I, for any model, time series stationary character of patent is more outstanding than that of paper, with the latter's X and Y being co-integrated. The differences in econometrics for these two S&T activities are obvious. In practice, patent possesses higher practicability and economic values, and is combined with industry more tightly, while scientific paper has lower requirement on practicability and then possesses bigger space in content. On the other hand, certificated patent belongs to typical private goods with strict rivalrousness and exclusiveness, while scientific paper could be more easily to be used for reference, which benefits overflow and dissemination of knowledge. The variability between them could lead to difference in econometrics. Accumulation of scientific papers could have larger and longer influence on subsequent output than that of certificated patents, which means larger auto-correlation of time series, slower decrease speed of auto-correlation function and then worse time series stationary character for scientific papers.

[1] Numbers of scientific papers and certificated patents represent R&D level of S&T largely, and are important evaluation indexes of S&T advance.

TABLE I lists results of analysis result of relativity and co-integration between explanatory and explained variables

Growth Model	Explanatory Variable X	Explained Variable Y	X-t value	X-signifi-cance	X-coefficient	F
Patent Hicks	$Log(K_t / L_t)$	$Log(\dot{Z}_t/(Z_t L_t))$	-5.841	***	-0.814	34.12
Paper Hicks	$Log(K_t / L_t)$	$Log(\dot{P}_t/(P_t L_t))$	-7.028	***	-0.504	49.4
Patent Harold	$Log(K_t /(Z_t L_t))$	$Log(\dot{Z}_t/(Z_t L_t))$	8.617	***	0.718	74.25
Paper Harold	$Log(K_t /(P_t L_t))$	$Log(\dot{P}_t/(P_t L_t))$	11.456	***	0.469	131.23
Patent Cap-Prom	$Log(K_t Z_t / L_t))$	$Log(\dot{Z}_t / L_t)$	12.606	***	0.424	158.91
Paper Cap-Prom	$Log(K_t P_t / L_t))$	$Log(\dot{P}_t / L_t)$	36.772	***	0.507	1352.21
Growth Model	**D.W.**	R^2	$\bar{R}^2$	**Y-Statio-nary**	**X-Statio nary**	**X-Y Co-inte gration**
Patent Hicks	0.807	0.695	0.674	I(0),***	I(1),***	-
Paper Hicks	0.942	0.767	0.752	I(1),***	I(1),***	**
Patent Harold	1.434	0.832	0.821	I(0),***	I(2),***	-
Paper Harold	1.698	0.897	0.891	I(1),***	I(1),**	**
Patent Cap-Prom	1.299	0.914	0.908	I(0),***	I(0),**	--
Paper Cap-Prom	1.67	0.989	0.988	I(1),***	I(1),***	***

Note: *, ** and *** represent significance of 90%, 95%, 99% respectively; - and -- represent inexistence of co-integration or being unnecessary to do co-integration.

3. Model Establishment and Evaluation

A. Growth Model Establishment and Coefficient

According to above result of model selection, endogenous growth models for patent and paper are shown in (5) and (6).

Endogenous growth model for patent is shown in (5).

$$\dot{Z}_t = B\ (Z_t K_t)^{0.424} L_t^{0.576} \tag{5}$$

Endogenous growth model for paper is shown in (6).

$$\dot{P}_t = B\ (P_t K_t)^{0.507} L_t^{0.493} \tag{6}$$

If index values of each year are substituted in (5) and (6), all values of coefficient B in each year for two models are determined, shown in Table II. Fluctuation of B reflects influence of residuals, which mean function of external factors.

TABLE II Calculation result of models' B efficient

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Patent B(×0.001)	2.840	3.003	4.429	2.604	2.386	1.979	2.093	2.543	3.244	2.784
Paper B(×0.001)	1.196	1.333	1.364	1.366	1.261	1.104	1.242	1.110	1.264	1.103
Year	2001	2002	2003	2004	2005	2006	2007	Ave.	Std. Dev.	W. Ave.*
Patent B(×0.001)	2.683	2.708	3.221	2.839	2.657	2.768	2.980	2.809	0.536	2.866
Paper B(×0.001)	1.234	1.254	1.284	1.258	1.386	1.255	1.219	1.249	0.087	1.252

Note: *In weighted average value (Abr. "W. Ave.") of B is computed, weights in 2005, 2006 and 2007 are 0.125, 0.25, 0.5 respectively, and weight in each year from 1991 to 2004 is 0.00893.

Known from above two models, capital input elasticity of patent output is lower than labor input elasticity of patent output, but capital input elasticity of paper output is larger than labor input elasticity of paper output.

B. Causality Analysis

Two simplified VAR (vector auto-regression) models between X1 (explanatory variable) and Y1 (explained variable) for patent model, and between X2 (explanatory variable) and Y2 (explained variable) for paper model, are established. Then VAR Granger Causality tests are done respectively with results listed in Table III.

TABLE III Result of VAR Granger causality test

Dependent variable: X1				Dependent variable: X2			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
Y1	0.910881	2	0.6342	Y2	0.296863	1	0.5859
Dependent variable: Y1				Dependent variable: Y2			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
X1	8.563095	2	0.0138	X2	6.497608	1	0.0108

The test results indicate single-direction Granger causality from effective capital per capita (X) to output per capita (Y). Consequently, increase or decrease of effective capital per capita could lead to corresponding increase or decrease of output per capita, but not necessarily contrariwise. Above conclusion support the explanation capacity of these models.

C. Error Correction Model

Based on aforementioned growth model and co-integration relation of variables, the error correction model for paper model could be gotten in (8).

$$\Delta Y2(t) = -0.11 + 1.46 * \Delta X2(t) - 0.75 * ecm(t-1) + u(t) \quad (8)$$

Note: $X2 = Log(K_t P_t / L_t)$, $Y2 = Log(\dot{P}_t / L_t)$,

$$ecm(t-1) = Y2(t-1) + 2.91 - 0.51 * X2(t-1)$$

Known by (8), model could force unbalance status back to balance status by potency of 0.75. Thought the potency is rather strong, but there is still influence from some other factors.

D. Prediction of Model

In order to verify the veracity of models, with given number of scientists and engineers in S&T activity and investment in S&T capital asserts in 2008, Forecast of numbers of certificated patents and scientific papers in 2008 are done with weighted average B and average B respectively. The results listed in Table IV, which indicate strong prediction capability of these two models.

TABLE IV Result of output prediction of 2008 by models

Growth model	Number of S&T person in 2008	S&T capital asserts in 2008 (billion Yuan) (constant price)	Real Output in 2008 (item)	Prediction value of 2008 (weighted average B) (item)	Prediction error	Prediction value of 2008 (average B)(item)	Prediction error
Patent	4967480	549.017	411982	408460	-0.85%	399870	-2.94%
Paper			270878	265040	-2.16%	264450	-2.37%

Note: Absolute values of forecast error are all in acceptable scope of 5%.

4. Conclusion and Suggestion

First, capital-promotion endogenous growth model could explain input and output relation of China's S&T activity best, and single-direction Granger causality, strong balance mechanism of error correction model and strong prediction capability of growth models also support it. Second, judged by econometric result, S&T capital asserts, number of scientists and engineers in S&T activity and accumulated knowledge could explain S&T output effectively, and input shows significant positive influence on output. Finally, two models have some different explanation on input-output relation: capital input elasticity of patent output is less than labor input elasticity of patent output, while labor input elasticity of paper output is less than capital input elasticity of paper output.

Based on above conclusion, here are three suggestions. First, because the scientific advance is more to be capital-promotion, investment in S&T research apparatus should be reinforced to raise integrated science and technology level. Second, in order to improve output efficiency of S&T activity, we should not only increase investment on cultivation of talented persons and R&D apparatus, but also reinforce accumulation and share of knowledge. Finally, input factors should be allocated reasonably according to types of S&T activities to raise output efficiency. For example, enterprises who care mainly about economic benefit should emphasize more on introduce and cultivation of talented persons, but high schools that care more on academic research should emphasize more on investment of laboratory apparatus and establishment.

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