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An Empirical Research on Indigenous Technological Innovation Process in Shenzhen City of China Based on Time Series Model

[1]Zhaopeng Chu, [2]Bing Li, [3]Hai Xiao and [3]Lan Lu
[1]School of Business Administration, Northeastern University, Shenyang 110819, China
[2]Exchange, Development and Service Center for Science and Technology Talents, The Ministry of Science and Technology, Beijing 100045, China
[3]School of Economics and Business, Northeastern University at Qinhuangdao, Qinhuangdao 066004, China

Abstract: With the background of innovation-driven economic growth, how to establish the effective indigenous technological innovation process is the most important issue to improve national technological innovative ability. In order to explore the paths and mechanisms of technological innovation, this study conducts such an empirical study on the process of indigenous technological innovation in Shenzhen City of China based on co-integration test, error correction model and Granger causality test. The empirical results show that there exists the long-term stability of the dynamic equilibrium among expenditures on R&D, number of patents applications granted and value of intellectual property rights of high-tech products. The anti-driving mechanism reverses feedback from the terminal of technological innovation activities to the upstream of R&D investments and patents output. It is very important for improving the efficiency of indigenous technological innovation process to strengthen R&D process management, perfect the innovation cooperation mechanism and speed up the transformation of independent intellectual property rights achievements.

Key words: Indigenous technological innovation, co-integration test, error correction model, granger causality test

INTRODUCTION

Now-a-days, technological innovation has become the key to improve national competitive advantage and international status of one country. All countries regard improvement of innovative ability as basic strategy for national sustainable development and focus on the planning and construction of their own national innovation system (Yang and Liyi, 2011). In recent years, China' economic growth model has been changing from factor-driven to innovation-driven. Therefore, the needs of improving the country's indigenous innovation capability become increasingly urgent. Indigenous innovation refers to the leading innovative property rights acquired by the active efforts of innovation subjects and the access to gain long-term competitive advantage from innovation activities (Song *et al*., 2006). The most important characteristic of indigenous innovation is independent, that is, with independent intellectual property rights in core and unique technologies to achieve value creation process of new products. Indigenous technological innovation process is the area in accordance with its own characteristics, reshaping the innovation process, through factor mobility, resource sharing and interactive collaboration and gradually forms a technological innovation chain covering the whole process. The nature of indigenous technological innovation chain is used to describe a corporate group structure with some kind of inner link in the upstream and downstream relationships and mutual exchange of value. It is the upstream to the downstream part of the delivery of products or services, the downstream link to the upstream feedback (Xia, 2012). The coupling mechanism of the indigenous technological innovation process is an innovative and cooperative relation between R&D investment, intermediate patent output and the market transformation of final R&D achievements (Chu *et al*., 2009a). Thus such an indigenous technological innovation process is the main factor to promote the industrial structure adjustment and improve the national competitiveness.

Shenzhen City is the first area to implement the China's reform and opening policy, has obvious industrial, technological and regional advantages for indigenous innovation, more importantly and has the suitable system and mechanism to undertaken indigenous

Corresponding Author: Zhaopeng Chu, School of Business Administration, Northeastern University, Shenyang 110819, China

technological innovation. Since the early 1990s, indigenous innovation has been considered to be the leading urban development strategy and included in the long-term development planning objectives in Shenzhen City. "Shenzhen High-Tech Industrial Development of the" Ninth Five-Year "Plan and 2010 Plan", "Shenzhen Annual Guide of Science and Technology Development Projects" and "Shenzhen Annual Key Development Projects Plan" gives the planned projects a series of preferential policies from funding, taxation, project sites, staff mobility, etc to promote indigenous technological innovation activities. Recently, Shenzhen has been approved by the National Development and Reform Commission to become China's first national innovation pilot city. Therefore, we selected Shenzhen City as the object of study to deeply analyze how to encourage independent R&D, improve the capability and speed of the indigenous technological innovation and furthermore the measures to promote economic growth based on the whole process of the indigenous technological innovation from R&D investment, intermediate patent output to the market transformation of final R&D achievements.

METHOD AND IMPLEMENTATION

Method: The economic models established based on some economic theories aimed at conducting empirical studies on the correlation among variables, the general way of econometrics is to set up the regression equation with theoretical and practical significance. Conducting regression analysis, the time series of model variables must be stationary; otherwise it will cause spurious regression which affects the accuracy of model estimation. However, many of the macroeconomic series are non-stationary in practical application (Nelson and Plosser, 1982) which undermined the assumption of stationary. Generally, difference method is used to eliminate the non-stationary trend of level series and then establish model based on the difference sequence. However, the converted sequence ignores the economic information contained in level series, limits the range of economic issues discussed and sometimes the converted sequence does not have direct economic significance at result that the model does not suit economic interpretations. Co-integration theory provides an effective way for non-stationary time series modeling, (Engle and Granger, 1987) pointed out that even though some of the economic variables are non-stationary series themselves, there is a linear combination of them may be stationary. The stationary linear combination is known as co-integration equation which can be interpreted as the long-term stable equilibrium relationship of variables. Therefore, according to co-integration theory, we firstly test the stationary of level and first-order difference series of variables, secondly followed by testing co-integration relationship among variables, thirdly establish error correction model between co-integration variables and equilibrium and lastly test the causality relationship of co-integration variables.

Data: From the view of input and output, the process of technological innovation activity starts at R&D inputs and end in the market transformation of R&D achievements and the ultimate goal is the commercial application of technology which called for the smooth transformation of R&D achievements in industries to improve the quality and efficiency of economic operation. Therefore, we select the annual expenditures on R&D and number of patents applications granted as the input and output data of technological innovation activities in empirical analysis. As R&D achievements belong to high and new technologies (Fu *et al*., 2005), high-tech industries usually take the high and new R&D achievements as the main technologies and resources input and they are the main areas to practice R&D achievements. Thus, value of intellectual property rights of high-tech products can be used to measure the market transformation of technological innovation achievements.

The sample data we selected is annual data from 1998 to 2009. GDP deflation index is used to adjust the data of expenditures on R&D and value of intellectual property rights of high-tech products in order to remove the impact of price changes. The number of patents applications granted in 2003 missed and filled by interpolation. The data of expenditures on R&D and value of intellectual property rights of high-tech products before 2000 is obtained by backward calculating from 2001 in accordance with the annual growth rate. The data used in Table 1.

Table 1: Annual data of variables from 1998 to 2009

Year	Expenditure on R&D (100 million yuan)	No. of patents applications granted (piece)	Value of intellectual property rights of high-tech product (100 million yuan)
1998	0.67	1364	198.23
1999	1.51	2116	275.01
2000	2.50	2401	383.36
2001	2.80	3649	534.54
2002	3.25	7917	745.63
2003	3.18	7827	954.48
2004	5.30	7737	1386.64
2005	6.00	8983	1853.09
2006	6.50	11494	2824.17
2007	7.19	15552	3653.29
2008	7.50	18805	4454.39
2009	8.54	25894	5148.17

Data Source: "Statistical Yearbook of Shenzhen City" and "Shenzhen Statistical Bulletin" from 1998 to 2009

EMPIRICAL ESTIMATION

Stationary test of variables: Logarithmic transformation of raw data can avoid abnormal fluctuations in the time series of variables and eliminate heteroscedasticity effects. Moreover, logarithmic transformation does not affect co-integration relationship of primitive variables and the elasticity coefficient of the model is easier for economic interpretation. Therefore, natural logarithm is taken for variables expenditures on R&D, number of patents applications granted and value of intellectual property rights of high-tech product. The primitive and new transformed variables are respectively denoted as R&D, patent, value and ln(R&D), ln(Patent), ln(Value). Since co-integration variables must have the same unit root, unit root test must be conduct to determine whether the time series of variables is stationary before co-integration analysis.

The method of ADF (Augmented Dickey-Fuller) is used to test unit root of ln(R&D), ln(Patent), ln(Value) and the results are shown in Table 2. According to Table 2, the hypothesis of unit root existence is not rejected at the 5% significance level which indicates that the primitive variable sequence is indeed non-stationary. However, Dln(R&D), Dln(Patent) and Dln(Value) transformed by first-order difference reject the hypothesis of unit root existence at the 5% significance level which indicates that the first-order difference variable sequence is stationary. The results of ADF test show that ln(R&D), ln(Patent) and ln(Value) are all the process of I (1), on the contrary Dln(R&D), Dln(Patent) and Dln(Value) are all the process of I (0).

Co-integration test: Co-integration test can be divided into two main methods according to the test objects, one is the Engle-Granger two-step method based on the regression residuals (Engle and Granger, 1987), the other is Johansen co-integration test based on the regression coefficients (Johansen and Juselius, 1990; Johansen, 1991, 1995). The method of Johansen co-integration test has better small sample properties and is more suitable for analysis in the case of small sample data. Thus, the method of Johansen co-integration test is used in this paper. There is co-integration relationship among the variables in the case of first-order lag combined with intercept. The test results are shown in Table 3.

Co-integration test gradually starts with the null hypothesis which indicates there is no co-integration relationship. In Table 3, trace statistic is 70.5067, more than the 0.05 critical value 35.1928, indicating that the null hypothesis in which none co-integration variable is rejected. Similarly, the null hypothesis indicates there is at most one co-integration variable is rejected. In the following tests, trace statistic is 6.4742, less than the 0.05 critical value 9.1645, indicating there is one co-integration relationship among variables. Combined with the test results, it can be concluded that there is one co-integration relationship among ln(R&D), ln(Patent).

ln(Value) at the 5% significant level. 1.0000, 2.5416, -6.2600 and -0.9342 are the standardized co-integration vectors of ln(R&D), ln(Patent), ln(Value) and C. Therefore, ln(Value) is the dependent variable, ln(Patent) and ln(R&D) are independent variables and the long-term equilibrium equation is:

$$\ln(\text{value}) = 0.9342+2.5116\ln(\text{patent})+6.6200\ln(\text{R\&D})$$
$$\text{s.e} = (0.3245)\ (0.1462)\ (0.2207) \qquad (1)$$

By Eq. 1, as for value of intellectual property rights of high-tech product, the long-term elasticity coefficients of number of patents applications granted and expenditures on R&D are -2.54 and 6.26, indicating that when number of patents applications granted and expenditures on R&D increases 1%, it will result in value of intellectual property rights of high-tech product decreased by 2.54% and increased by 6.26%, respectively.

Error correction model: The long-term equilibrium relationship of variables can be found by means of co-integration test. While the actual economic data are generated by non-equilibrium process, so the long-run equilibrium relationship established by theoretical model should be approximated by non-equilibrium process of data. Error Correction Model (ECM) can solve the above problem (Davidson *et al*., 1978). The purpose of ECM is to study the degree of deviation from the long-run equilibrium of dependent variable in the short-term

Table 2: Unit root test with Augmented Dickey-Fuller

Variable	Test type (c, t, q)	ADF Test	0.05 critical value	Result
ln(R&D)	(0, 0, 0)	1.937	-1.978	Non-stationary
Dln(R&D)	(c, 0, 1)	-3.544	-3.213	Stationary
ln(Patent)	(c, t, 0)	-2.079	-3.933	Non-stationary
Dln(Patent)	(c, 0, 3)	-5.287	-3.403	Stationary
ln(Value)	(c, t, 0)	0.205	-3.933	Non-stationary
Dln(Value)	(c, t, 3)	-13.841	-4.450	Stationary

In the test type (c, t, q), c is intercept, t is time trend and q is the optimal lag order determined by SIC criterion. The unit root test model specification is determined according to whether the coefficients of c and t are significant

Table 3: Null hypothesis test of Johansen co-integration

Hypothesized No. of CE (s)	Eigen value	Trace statistic	0.05 critical value	Prob.
None*	0.9906	70.5067	35.1928	0
At most 1*	0.8232	23.7989	20.2618	0.0156
At most 2	0.4766	6.4742	9.1645	0.1571

*Indicates that the null hypothesis is rejected at the 5% significant level

Table 4: Pairwise Granger causality test with first-order lagged

Null hypothesis	F-Statistic	Prob
ln(Patent) does not granger cause ln(Value)	0.2574	0.6256
ln(Value) does not granger cause ln(Patent)	3.4452	0.0905
ln(R&D) does not granger cause ln(Value)	0.9825	0.3506
ln(Value) does not granger cause ln(R&D)	4.0228	0.0798
ln(R&D) does not granger cause ln(Patent)	0.6452	0.4450
ln(Patent) does not granger cause ln(R&D)	2.1505	0.1807

fluctuations. The short-term fluctuations of ln(value), ln(patent) and ln(R&D) adjust to the long-run equilibrium in the sample period, that is, ECM is:

$$\Delta \ln Value_t = 0.08420.1403\Delta \ln Patent_t + 0.1655\Delta \ln R\&Dt_{-} 0.1722ecm_{t-1}$$
$$t = (4.2192)\ (1.1050)\ (1.7031)\ (-1.2024) \qquad (2)$$

In Eq. 2, the difference reflects the short-term fluctuations. The short-term changes of value of intellectual property rights of high-tech product can be divided into two parts, one is the short-term fluctuations of number of patents applications granted and expenditures on R&D and the other is the deviation from long-run equilibrium. The coefficient of ecm_t (error correction term) reflects the adjustment of the deviation from long-run equilibrium. The coefficient is -0.1722, in line with the reverse correction mechanism, reflecting the adjustment of the short-term fluctuations to the long-run equilibrium relationship which means ecm_t makes value of intellectual property rights of high-tech product converge to the long-run equilibrium state with 17.22% adjustment.

Granger causality test: The results of co-integration test show that there is a long-run equilibrium relationship among value of intellectual property rights of high-tech product, number of patents applications granted and expenditures on R&D. However, does such a long-run equilibrium relationship constitute causality which needs further verification? Granger causality test can determine whether the change of a variable causes another variable changes. The test results with first-order lagged are shown in Table 4.

The results of Table 4 show that at the 10% significant level, value of intellectual property rights of high-tech product does Granger cause number of patents applications granted and expenditures on R&D, but there is no pairwise Granger causality among the variables.

ANALYSIS OF RESULTS

According to the results of co-integration test and ECM modes, there is a long-run equilibrium relationship among value of intellectual property rights of high-tech product, number of patents applications granted and expenditures on R&D, indicating that from the view of input and output, the mechanism of coordination and interaction in the whole indigenous technological innovation process of Shenzhen City does exist. Expenditures on R&D play an active role in promoting value of intellectual property rights of high-tech product, particularly in the long-term performance which reflects increasing investment on R&D can indeed greatly improve the capability of indigenous innovation in Shenzhen City. Compared with expenditures on R&D, number of patents applications granted plays a role in promoting value of intellectual property rights of high-tech product in the short run, but it has a negative effect on the increase of value of intellectual property rights of high-tech product in the long run. The reasons are mainly manifested in two aspects.

In the number of patents applications granted of China, there is a serious imbalance in the proportion of inventions, utility models and designs. The proportion of inventions and utility models with intellectual property rights is less than the other countries. The majority of inventions and utility models are researched and applied by the public R&D resources of universities and scientific research institutes. In fact, the regional distribution of public R&D resources in China is not balanced which results in the particularly serious imbalance in the proportion of patents applications granted in Shenzhen City, Guangdong Province (Chu *et al*., 2009a). Therefore, the shortage of patents invention activities with intellectual property rights and advanced technologies in accordance with industrial developments and market demands is one of the important reasons why the number of patents applications granted in Shenzhen City has a negative effect on the increase of the value of intellectual property rights of high-tech product in the long run.

Patents are typical of R&D achievements and the slow pace of R&D achievements transformation in market is another important reason which causes the number of patents applications granted in Shenzhen City has a negative effect on the increase of the value of intellectual property rights of high-tech product in the long run. Factually, the transformation of R&D achievements is a variety of complex system engineering, including a series of complex transactions, a larger time span and a high risk of uncertainty (Leng and Li, 2008). However, in China, there is no the effective and sound cooperation mechanism of R&D activities among governments, enterprises, universities and researches, resulting in the transformation efficiency of many R&D achievements serious lags in industrial development needs (Chu *et al*., 2009b). Therefore, the increase of number of patents applications granted does not really bring value of intellectual property rights of high-tech product growth.

The results of Granger causality test indicate that in the process of indigenous technological innovation of Shenzhen, the positive causality relationship does not exist among expenditures on R&D, number of patents applications granted and value of intellectual property rights of high-tech product which reflects that there is no positive feedback mechanism in indigenous technological innovation activities from R&D investments input and patents output to the achievements transformation. On the contrary, there is an anti-driving mechanism reverses feedback from the terminal of technological innovation activities to the upstream of R&D investments and patents output which reflects that the demand of indigenous technological innovation actuated by economic developments promote the upstream of R&D investments and patents output to increase rapidly in the process of indigenous technological innovation. The anti-driving mechanism reverses feedback from the terminal of technological innovation activities provides some significant policy implications which may effectively improve the quality of indigenous innovation for China.

For one thing, no positive feedback mechanism means that the investment direction and process management of expenditures on R&D are improperly used in indigenous technological innovation activities. R&D investments have not been fully utilized to effectively support the independent R&D activities and the absorption of imported technologies which results in the number of patents and other technological achievements with intellectual property rights decreased. Therefore, it is the top priority to strengthen the management and control of R&D activities in order to improve the capability of China's indigenous innovation.

For another, from the view of China's R&D institutions, Chuanjie and Xiaoli (2008) pointed out that the public R&D institutions of universities and research institutes focused on R&D activities with strong innovation capability and relatively stable and abundant R&D investments. Therefore, the patents output with intellectual property rights of the public R&D institutions are more efficient than enterprises. However, the public R&D institutions have a weak awareness of patent achievements transformation. Compared with the public R&D institutions, enterprises are short of R&D investments and focused on access to benefits and especially in the pursuit of short-term interests, majoring in experimental development activities. The weak awareness of patent achievements transformation of the public R&D institutions and the pursuit of short-term economic interests of enterprises make R&D activities not actuated by market demand, as a result, a number of patents with intellectual property rights and advanced technology do not put into use in economic developments. Therefore, it is very important practical significance in China for improving the quality of indigenous innovation and accelerating economic growth promoted by technologies to increase the R&D investments of enterprises, deepen reform of scientific and technological system, perfect the cooperation mechanism among governments, enterprises, universities and researches and speed up the transformation of independent intellectual property rights achievements.

CONCLUSION

In the current environment of innovation-driven economic growth, how to establish the effective indigenous technological innovation process is the most important issue to improve national technological innovative ability. This paper conducts an empirical study on the process of indigenous technological innovation in Shenzhen City of China based on co-integration test, error correction model and Granger causality test. The results show that there exists the long-term stability of the dynamic equilibrium among expenditures on R&D, number of patents applications granted and value of intellectual property rights of high-tech products. The anti-driving mechanism reverses feedback from the terminal of technological innovation activities to the upstream of R&D investments and patents output. It is very important for improving the efficiency of indigenous technological innovation process to strengthen R&D process management, perfect the cooperation mechanism among governments, enterprises, universities and researches and speed up the transformation of independent intellectual property rights achievements. Of course, it also requires government to guide and support from the aspects of mechanism, policy and law, etc.

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