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# Study on the Economic Growth of Patent Output in the High-tech Industry

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**Abstract**

This paper makes the empirical research for the relationship between patent output and economic growth in the high-tech industry by panel data model. On the whole, the result shows that there is a significant long-run equilibrium relationship between patent output and economic growth. Moreover they are the Granger reason mutually, with the interactive mechanism. Patent output contributes to economic growth with a significant lagged effect, displaying the function of patent output is a dynamic accumulation process. Subsequently, through constructing the individual fixed effect regression model and analyzing it, this paper finds that there is the conspicuous difference among the spontaneous effects of economic growth among high-tech industry. Finally, this paper proposes that the science and technology input should be arranged reasonably according to the various development characteristic of each industry, instead of one-sidedly pursuing the equalization in industry distribution of the science and technology input.

**Keywords:** patent output, economic growth, panel data, individual fixed effect

## 1. Introducation

High-tech industry is the main support forces of economic sustainable growth in the knowledge economy era. For the last 20 years, high-tech industry development has made great contribution for economic growth of some emerging industrialized countries in America, Japan, West Europe and East Asia (Derek, 2002). In recent years, high-tech industry develops quickly in China, which has grown as an important dynamical type guide industry of the national economy. For the period between 1995 and 2010, China's high-tech industry total output value increased from 409.8 billion yuan to 7.47 trillion yuan, and the proportion of gross domestic product rose from 6.74% to 18.62%. High-tech industry gross output value's share of GDP continues to rise, which strengthens unceasingly to the national economy impetus function. Overall, China's high-tech industry has maintained rapid, healthy, and coordinated development, and the role for stimulating national economic growth and optimizing the industrial structure is increasingly apparent.

In order to further clarify the high-tech industry development situation, this paper focus on the perspective of patent output, and use panel data model to make a quantitative analysis for five typical industries' economic growth in the high-tech industry.

Many scholars have made a large number of empirical studies on the relationship between patent output and economic growth. Liu (2002) made an empirical analysis for the operation performance of China's patent system on the basis of theoretical analysis, which found that the patent system had a role of stimulating innovation, and patent output continued to promote economic growth, but invention patents had a low correlation degree with GDP and independent innovation ability was not strong. Based on new contemporary economic theory, Xu (2004) studied the economic performance of patents, which showed that patent activities and technology innovation were closely related to the level of economic development, and increasing innovation resources investment and improving patents' level would have a noticeable economic performance. Ju (2005), Gao and Sun (2006) used causal analysis and regression analysis method respectively to analyze the relationship between economic growth and patent output for China during 1985-2002. The results showed that there was a long-term dynamic equilibrium relationship between patent output and economic growth, but they did not constitute a causal relationship. Patent output played a certain role on economic growth, but it was not very useful. Zhang and Wu (2007) adopted spatial autocorrelation Moran index model, spatial lag model and spatial error model to study the relation mechanism of patent innovation and regional economic growth of China's 31 provinces. Ge and Wei (2005), Tan (2005), Ju (2007) studied the dynamic equilibrium relationship between patent output and economic growth among provinces respectively, which showed that there was a correlation between patent output and economic growth.

The existing literatures affirm the inherent relationship between patent output and economic growth, but there are still two shortcomings. One is the existing literatures only considered the current value of the patent output variables, did not consider the impact of lagged variables. That patents turn into products, then to bring economic benefits needs a certain amount of time lag. Namely, patent output does not significantly impact on the current year's economic growth, but does significantly impact on the subsequent years' economic growth. Thus introducing lag explanatory variables for analysis is more accord with theory and reality. The other is most of research regard panel variable cross-section sequence as a whole to study, but did not analyze the differences along each cross-section of panel variables. Therefore, this paper establishes the individual fixed-effects regression model to analyze the differences of economic growth spontaneous effect among various industries and their causes in the high-tech industry.

## 2. Data

Taking into account the availability and measurability of data, in this paper, various industries' gross product (GP) stand for economic effect; various industries' patent applications (PA) stand for patent output effect. $PA_{i,t-i}$ represent lag value of the patent output, where $i = 1, 2, \cdots, m$ , $m$ is the lag length.

In this paper, there are three reasons to select patent applications as a measure of patent output, instead of patent granted. Firstly, patent granted demonstrate a strong linear correlation with patent applications, and information contained in patent applications has already covered to a large extent the information of patent granted. Secondly, compared with patent applications, patent granted have heavier time lag characteristic, which should more prone to cause information distortion. Finally, the gap between patent applications and patent granted, to a great extent, is caused by immature technology of patent applications, imperfect function of the patent application intermediary organizations, and low efficiency of the patent licensing authority. With the improvement of market intermediaries function and work efficiency of the relevant government departments, the gap will decrease and the proportion of patent granted account for patent applications will continue to increase.

In order to enhance the validity of parameter estimation, panel data analysis must rely on large sample size. According to high-tech industry classification scheme developed by the Ministry of Science and Technology, China's high-tech fields includes Pharmaceuticals (Ps), Aircraft and spacecraft (AS), Electronic and telecommunication equipments (ETE), Computers and Office equipments (COE), as well as Medical Equipments and meters (MEM). We select the five major industries as cross-sections of panel data, and the time dimension is 1995-2010. All of the data came from China Statistics Yearbook on High Technology Industry and China Statistical Yearbook on Science and Technology. In order to eliminate the heteroscedasticity as well as enable the model to have the practical significance, all of the data was converted into natural logarithms before conducting the empirical analysis.

## 3. Empirical Analysis

### *3.1 Model*

The general form of the panel data model can be expressed as:

$$y_{it} = \alpha_i + \beta_i x_{it} + \mu_{it},\ i = 1, 2, \cdots, N; t = 1, 2, \cdots, T \qquad (1)$$

where $x_{it}$ is a $k \times 1$ vector, $\beta_i$ is a $1 \times k$ vector, $k$ is the number of explanatory variables. The error term, $\mu_{it}$ is assumed to be independent and identically distributed with a zero, mean and a constant variance. $i$ , $t$ represent cross-section and time of panel data, respectively.

Following the empirical literature on the relationship between patent output and economic growth, it is plausible to form a long-run relationship between patent output and gross product in linear logarithm form, as follows:

$$LnGP_{it} = C + \alpha LnPA_{it} + \sum_{j=1}^{m} \beta_j LnPA_{i,t-j} + v_i + \varepsilon_{it} \qquad (2)$$

where $LnGP_{it}$ $LnPA_{it}$ and $LnPA_{it-j}$ epresent natural logarithms of gross product, patent applications and lag value of the patent output. $m$ is lag length, $v_i$ represents the individual differences in cross-sections, $\varepsilon_{it}$ is random disturbance term, $i$ , $t$ represent industry and years respectively, $\alpha$ , $\beta_j$ represent elasticity coefficients.

*3.2 Model Estimation*

Cross-section data of five different industries in the high-tech industry are checked through variance analysis, which indicates that heteroscedasticity does not exist among various cross-sections data. Namely, heteroscedasticity does not exist in the random error term of various cross-sections equations, and the covariance among various cross-sections and periods are zero. i.e. $\mathrm{cov}(\mu_{it}, \mu_{it}) = \sigma_0^2$, $\mathrm{cov}(\mu_{is}, \mu_{jt}) = 0 \ (i \neq j, s \neq t)$.

In order to determine the specific form of model (2), we first made F-test for the model, which shows that variable-intercept model should be adopted. Then, we made Hausman test for the model. The results that Chi-square value is 9.701 and probability is 0.008 indicate the rejection of a null hypothesis at 1% level of significance. That is to say, coefficient exist systematic differences and fixed effect model should be selected.

Fixed effects regression model is as follows:

$$LnGP_{it} = (2.878+0.031)D_1 + (2.878-0.792)D_2 + (2.878+0.624)D_3 + (2.878+0.727)D_4 + (2.878-0.589)D_5 + 0.269LnPA_{it} + 0.296LnPA_{i,t-2} \quad (3)$$

（23.887*） （3.932*） （4.452*）

$R^2$=0.98，SSE=2.12

where $D_1, D_2, \cdots, D_5$ represent dummy variable and is defined as the following

$$D_i = \begin{cases} 1, \text{ belongs to the ith individual}, & i = 1, 2, \cdots, 5 \\ 0, \text{ else} \end{cases}$$

Note: Figures in parentheses are t-statistics, * indicates the rejection of a null hypothesis at 1% level of significance.

From equation (3) can be seen, there is a long-term equilibrium positive relationship between economic growth and patent output in China. Productive elasticity of current year patent output (0.269) is lower than previous two years' (0.296). The contribution of patent output to economic growth has an obvious time lag characteristic, and lag length is about two years. The findings show that the accumulation of patent output is a dynamic process. In the short term, patent output is not really noticeable impact on economic growth. But in the long term, the contribution of patent output to economic growth is accumulated year by year.

In addition, Spontaneous effect values of various industries' economic growth are displayed in Table 1.

Table 1. Spontaneous effect values of five industries' economic growth in high-tech industry

| Industries | Ps | AS | ETE | COE | MEM |
|---|---|---|---|---|---|
| Spontaneous effect values | 2.878+0.031 | 2.878-0.792 | 2.878+0.624 | 2.878+ 0.727 | 2.878-0.589 |

In a typical Cobb-Douglas production function, labor force, fixed assets and science and technology level are the main determining factors of industrial economy system development level, and patent output, to some extent, reflect science and technology level. Therefore, intercept term in equation (3), i.e. spontaneous effect values of economic growth, can be understood as changes in economic growth caused by changes in labor force, fixed assets and other factors in the case of science and technology level remains unchanged. Overall, labor force, fixed assets and other factors in high-tech industry of per increase of 1% can pull high-tech industry gross product of the average increase of 2.878%. With the different industries, spontaneous effect values of economic growth in various industries have obvious differences. Labor force, fixed assets and other factors in ETE and COE of per increase of 1% can pull corresponding industry production value of increase of 3.502% and 3.605%, respectively, which is about 0.68% higher than the average level in high-tech industry. Labor force, fixed assets and other factors in AS and MEM of per increase of 1% can pull corresponding industry production value of increase of 2.086% and 2.289%, respectively, which is about 0.69% lower than the average level in high-tech industry.

Labor force, fixed assets and other factors in Ps of per increase of 1% can pull corresponding industry production value of increase of 2.909%, which equal to the average level in high-tech industry. The findings indicate that from the perspective of the dynamic development of high-tech industry, the contribution of labor force, fixed assets and other factors in AS and MEM to economic growth is little, while the contribution of patent output in

AS and MEM to economic growth is relatively strong.

In order to ensure the validity of model estimation, we need to test panel data stationarity. First step is to extract the residual sequence of panel data regression model, i.e. $\varepsilon_{it}$. Then, the residual sequence, $\varepsilon_{it}$ is checked through three types of panel unit root tests, namely LLC test, Hadri test and IPS test. The LLC and IPS panel unit root tests employ a null hypothesis of a unit root. The results are displayed in Table 2.

Table 2. Panel unit root tests of residual sequence

| Test methods | LLC test | Hadri test | IPS test |
|---|---|---|---|
| Test results | -4.1849* | 0.2662 | -3.9195* |

Note: * indicates the rejection of a null hypothesis at 1% level of significance.

The LLC and IPS tests reject the null hypothesis at 1% level of significance and the Hadri test accepts the null hypothesis, which indicates that the residual sequence is stationary. Therefore, the panel data is stationary and the model estimation is validity.

*3.3 Panel Error Correction and Panel Causality Test*

Panel data model constructs a long-run dynamic equilibrium relationship between patent output and economic growth. The existence of co-integration indicates that there is (at least) one long-run equilibrium relationship among the variables, and thereby Granger causality among them in at least one direction (Engle and Granger, 1987; Oxley and Greasley, 1998). The VECM is used for correcting disequilibrium in the co-integration relationship, captured by the ECT, as well as to test for long-run and short-run causality among co-integrated variables. For insufficiently long time series, using panel data allows us to gain more observations by pooling the time series data across sections, leading to higher power for the Granger causality tests (Pao and Tsai, 2010). To test for panel causality, a panel-based VECM is specified as follows:

$$\Delta LnGP_{it} = \alpha_{10} + \sum_{i=1}^{m} \alpha_{11,i} \Delta LnGP_{i,t-i} + \sum_{i=1}^{m} \alpha_{12,i} \Delta LnPA_{i,t-i} + \lambda_1 ECT_{it} + \varepsilon_{1,t} \quad (4)$$

$$\Delta LnPA_{it} = \alpha_{20} + \sum_{i=1}^{m} \alpha_{21,i} \Delta LnGP_{i,t-i} + \sum_{i=1}^{m} \alpha_{22,i} \Delta LnPA_{i,t-i} + \lambda_2 ECT_{it} + \varepsilon_{2,t} \quad (5)$$

where Δ denotes first-order difference operation, $ECT_{it}$ denotes long-term equilibrium error. $\varepsilon_{it}$ is assumed to be independent and identically distributed with a zero mean and constant variance. In Eq.(4), when $\alpha_{12}$ is not equal to zero obviously, then patent output Granger-cause economic growth in the short term; when $\lambda_1$ is not equal to zero obviously, then patent output Granger-cause economic growth in the long term. In the same way, in Eq.(5), when $\alpha_{21}$ is not equal to zero obviously, then economic growth Granger-cause patent output in the short term; when $\lambda_2$ is not equal to zero obviously, then economic growth Granger-cause patent output in the long term.

In order to meet the requirements of errors classic assumptions, lag length, i.e. $m$, sets at 2. The estimated results of the error correction model are displayed in Table 3.

Table 3. Panel data error correction model test results

| Dependent variable $\Delta LnGP_t$ | Coefficient | Standard error | t-statistics | Probability |
|---|---|---|---|---|
| $\Delta LnGP_{t-1}$ | 0.299 | 0.122 | 2.451 | 0.017 |
| $\Delta LnPA_{t-1}$ | -0.100 | 0.053 | -1.896 | 0.063 |
| $\Delta LnGP_{t-2}$ | 0.035 | 0.128 | 0.273 | 0.785 |
| $\Delta LnPA_{t-2}$ | 0.142 | 0.049 | 2.933 | 0.005 |
| ECT | 0.037 | 0.011 | 3.317 | 0.002 |
| Dependent variable $\Delta LnPA_t$ | Coefficient | Standard error | t-statistics | Probability |
| $\Delta LnGP_{t-1}$ | 0.074 | 0.306 | 0.243 | 0.809 |
| $\Delta LnPA_{t-1}$ | -0.053 | 0.132 | -0.398 | 0.692 |
| $\Delta LnGP_{t-2}$ | 0.422 | 0.321 | 1.314 | 0.192 |
| $\Delta LnPA_{t-2}$ | -0.038 | 0.122 | -0.308 | 0.759 |
| ECT | 0.090 | 0.028 | 3.209 | 0.002 |

In Eq.(4), the coefficient of ECT is 0.037 and is not equal to zero obviously at 1% level of significance, which indicates that patent output Granger-cause economic growth in the long term; the coefficient of $\Delta LnGP_{t-2}$ is 0.142 and is not equal to zero obviously at 1% level of significance, which indicates that patent output Granger-cause economic growth in the short term. In Eq.(5), the coefficient of ECT is 0.090 and is not equal to zero obviously at 1% level of significance, which indicates that economic growth Granger-cause patent output in the long term; t-statistics of regression coefficients of $\Delta LnGP_{t-1}$ and $\Delta LnGP_{t-2}$ are not significant, which indicates that economic growth does not Granger-cause patent output in the short term. Therefore, in the high-tech industry, there is a bidirectional Granger causality running between patent output and economic growth in the long term, and there is a Granger causality running from patent output to economic growth in the short term, which indicates that the interaction mechanism of patent output and output growth is basically formed.

## 4. Conclusion

This study seeks to determine the long-run equilibrium relationship between economic growth and patent output. Analysis of the output elasticity of economic growth to patent output has confirmed the existence of long-run equilibrium relationship between patent output and economic growth in high-tech industry. Displaying the function of patent output is a dynamic accumulation process. Overall, there is a bidirectional Granger causality running between patent output and economic growth in the long term, and there is a Granger causality running from patent output to economic growth in the short term. The interaction mechanism of patent output and output growth is formed. From the perspective of individual, economic effects of patent output in various industries have differences, patent output play a higher efficiency in AS and MEM, but play a lower efficiency in ETE and COE. Therefore, when making a strategy about high-tech industry economic development, the government should fully take into account the interaction relationship between patent output and economic growth. While greatly increasing the investment in science and technology, the government should distribute resources rationally according to the characteristics of various industries development themselves, instead of pursuing unilaterally the balance of investment in science and technology in various industries. Thereby, we can achieve the optimal allocation of scientific and technological resources, further enhance the interaction mechanism between patent output and economic growth and promote the stable and orderly development of high-tech industry.

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