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Nonlinear Effects of Science and Technology Policy Incentives to China's High-tech Product Exports

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ABSTRACT

This paper constructs a logistic model of a country's science and technology policy incentives in enterprise technology learning and innovation risk preference practices of high-tech product exports. On the basis of the classification and quantification of science and technology policy, science and technology policy incentive parameters are introduced, and under the influence of the science and technology policy incentives for enterprise innovation behavior, non-linear growth trajectory of high-tech products exports is described and explained with the model. Using empirical findings of China Statistical Yearbook and China Statistical Yearbook of Science and Technology from 1994 to 2010, Chinese high-tech product exports which vary with time have attractor phenomenon, synergies of science and technology policies in both aspects of stimulating enterprise learning and reducing the innovation risk promote the growth of Chinese high-tech product exports.

Keywords: Science and Technology Policy; High-tech Product Exports; Logistic Equation.

INTRODUCTION

In the complex technological innovation system, technology innovation requires companies to continuously invest in a higher level of learning, so that innovation cost and uncertainty risk are enhanced. Due to lack of long-term, high-cost and high-risk technology investments in market, technology innovation has wide positive externalities. Therefore, it needs government's incentives to overcome market failures and enhances the positive externality of technology innovation, which is the basic logic to introduce innovative model in science and technology policy parameters. This paper takes high-tech product exports as a measure of innovation output, and establishes dynamic nonlinear logistic growth model between science and technology policy accumulative effectiveness and high-tech products export growth. It attempts to explain the trajectory characteristics of industry innovation effects caused by domestic technology policy change. The research is important on how the government develops science and technology policy in the right direction.

1. LOGISTIC MODEL OF HIGH-TECH PRODUCT EXPORTS UNDER SCIENCE AND TECHNOLOGY POLICY INCENTIVES

1.1 Establishing logistic model of a national high-tech product exports growth

Models built in this paper are mainly inspired by information diffusion logistic models of Chen Ping (2004), and agree with the following views: there are two core driving forces in the process of developing countries acquiring and digesting advanced technology from developed countries. Firstly technology learning and secondly the courage to take the risk of entrepreneurial innovation spirit (Nelson, Pack, 1999). In this paper, two critical success factors are brought into the model, so logistic equation of high-tech products export is:

$$\frac{dy}{dt} = hy(s-y) - a_2 y\left(1 - a_1\frac{y}{s}\right) \tag{1}$$

Where y is the annual high-tech product exports; t is the time; h is the growth rate of high-tech product exports (h> 0); s is the annual total product exports.
A nonlinear exit rate function is established:

$$R = -a_2 y\left(1 - a_1\frac{y}{s}\right)$$

where a_1 is set to describe a country's innovation risk preference parameters ($-1 \le a_1 \le 1$). When $0 \le a_1 \le 1$, the company tends to avoid the innovation risk, and is unwilling and conservative to innovate, so exit rate R is large at this time; when $-1 \le a_1 \le 0$, the industry has the courage to carry out technological innovation activities and strong adaption to innovation risk, so exit rate R becomes smaller at this time. a_2 is set to describe parameters of a national enterprise technology learning practice ($a_2>0$), because enterprises' technology learning has an attribute of behavior practice in the long run. There is obvious technology learning effects in enterprises of technology-pursuing countries. With the constant introduction, imitation and absorption of the technology, the master of new technologies is more and more skilled, average costs continue to decline, and high-tech product exports continue to growing. The function of technology learning effect is:

$$L = Ay^{1-a_2} \tag{2}$$

L is the amount of research and development labour input. A > 0. a_2 is the measuring parameter of technology learning effect ($a_2 > 0$); the greater a_2, the more positive impact of technology learning to innovation output y, and vice versa. Values of y and L can be obtained from the actual statistic.

The simplification of equation (1) can obtain:

$$\frac{dy}{dt} = B_1 y - B_2 y^2 \quad (3)$$

Where $B_1 = hs - a_2$ and $B_2 = h - \frac{a_1 a_2}{s}$. According to equation (3), given normal solution $\frac{dy}{dt} = 0$ is as follows:

$$y_1 = 0 \;\; y_2 = \frac{B_1}{B_2} \quad (4)$$

Where y_1 and y_2 are corresponding to the equilibrium point of the system. Solving Logistic equation (Equation (3)) can obtain analytic solution as follows:

$$\boldsymbol{y} = \frac{\boldsymbol{y_0 e^{B_1 t}}}{\boldsymbol{1 - \frac{B_2}{B_1} y_0 (1 - e^{B_1 t})}} = \frac{\boldsymbol{y_0 e^{(hs-a_2)t}}}{\boldsymbol{1 - \left(\frac{hs - a_1 a_2}{hs^2 - a_2 s}\right) y_0 \left(1 - e^{(hs-a_2)t}\right)}} \quad (5)$$

1.2 Logistic model of a national high-tech product exports introducing science and technology policy parameters

The science and technology policy parameters are introduced into the model: modified technology learning and innovation risk preference, which are two parameters of corporate behavior practices.

$$\frac{dy}{dt} = \boldsymbol{hy(s - y)} - (a_2 + \boldsymbol{\beta})\boldsymbol{y}\left(\boldsymbol{1} - (a_1 - \boldsymbol{a})\frac{\boldsymbol{y}}{\boldsymbol{s}}\right) \quad (6)$$

In equation (6), β is incentive parameter of enterprise technology learning for the science and technology policy; α is incentive parameter for the science and technology policy to reduce the innovation risk. In order to define the connotation of α and β, it needs to establish technological innovation production function, in which science and technology policy is regarded as an institutional factor inputs.

$$\boldsymbol{y = I_1^{\alpha} I_2^{\beta} L^{\gamma} K^{\eta}} \quad (7)$$

In equation (7), I_1 is the policy input to reduce the risk of technological innovation; I_2 is policy input to stimulate technology learning; L is the R & D labor input; K is the R & D expenditure. α is the elasticity of y-I_1 (α> 0); β is the elasticity of y-I_2 (β> 0); γ is the elasticity of y-L (γ> 0); η is the elasticity of y-K (η> 0), showing contribution shares of various elements in the innovation output y. The greater α and β, the stronger positive impact on y growth by science and technology policy, and vice versa.

2. VARIABLE SELECTION, DATA SOURCES AND MODELING ASSIGNMENTS

2.1 Policy variable selection and data sources

We collected and screened more than 200 related science and technology policies promulgated by Chinese government to promote technological innovation from 1978 to 2010. Policies are classified according to two standards of "motivating technology learning" and "reducing innovation risk", and assignment database of science and technology policy incentives is chronologically built, including the enacting date, the enacting department, and policy category and evaluation score of policy effectiveness. Where in the policy enacting departments involve 15 ministries and commissions of the NPC, the State Council and so on. As to the evaluation of policy effectiveness, this paper has referred to the quantified research work on science and technology policy by Peng Jisheng *et al*. (2008), and specific scoring criteria is in Table 1.

Table 1 Scoring criteria of Science and Technology Policy effectiveness

Category of Science and Technology Policy	scoring criteria
Laws promulgated by National People's Congres and its Standing Committee	5 points
Regulations promulgated by the State Council, decrees by various ministries and commissions	4 points
National innovative projects, provisional regulations promulgated by the State Council, rules by various ministries and commissions	3 points
Views, methods, approvals, announcements, temporary provisions of various departments	2 points
Informs of various departments	1 point

It is particularly noted that the government has carried out 863 and 973 projects, implementing a series of tax cuts, government subsidies, platform construction and other special measures, in order to focus on the development of high-tech R & D and technology import and digestion. These projects encourage technology learning, and have made significant effect to reduce the innovation risk, but with the diminishing trend of the plan implementation, the scoring of the plan effectiveness is three points. Based on the above scoring criteria, the paper makes the annual total score of science and technology policy effectiveness over the years. There are cumulative effects of the policy effectiveness, so the annual total score of science and technology policy cumulative effectiveness in "incentive technology learning" and "reducing the risk of technological innovation" is further calculated, and it is used as the input assignment to science and technology innovation policy in the production function. Given the availability of data, empirical studies range selected in this paper is from 1994 to 2010, the cumulative score of science and technology policy effectiveness implementing from 1978 to 1993 is served as the initial endowment value of the evaluation in 1994, highlighting continuity and integrity of science and technology policy cumulative effectiveness since the reform and opening up. (Scores of specific science and technology policy effectiveness are omitted).

2.2 Selection of technological innovation input-output variables and data sources

In Table 2, in order to avoid the interference of exchange rate fluctuations, the paper takes the annual value of y and S in 1994 as a statistical base year, and takes numerical conversion as constant exchange rate 8.93RMB/$ with the US dollar against the RMB. The unit of y and S values is unified to one hundred million yuan at last. Full-time equivalence of the annual national R & D personnel is taken as an innovative labor input L, and the national R & D expenditure is taken as an innovative capital investment K. The annual cumulative scores of policy effectiveness are used to measure I_1 and I_2.

Table 2: Innovation Input-Output

t	y	S	L	K	I_1	I_2
Year	**National High-Tech Exports, Million RMB**	**National Exports, Million RMB**	**National Research & Development Staff Million Person-Year**	**National Research & Development Cost, Million RMB**	**Scores of Science & Technology Policy Reducing Innovation Risk**	**Lifting Technology Learning Science & Technology Policy Score**
1994	562.59	10805.3	78.32	306.3	19	15
1995	901.93	13287.84	75.17	348.7	23	15
1996	687.61	13493.23	80.40	404.5	25	22
1997	866.21	16315.11	83.12	509.2	31	22
1998	1812.79	16413.34	75.52	551.1	34	22
1999	2205.71	17404.57	82.17	678.9	51	24
2000	3304.1	22253.56	92.21	895.7	60	26
2001	4152.45	23771.66	95.65	1042.5	70	33
2002	6063.47	29076.08	103.51	1287.6	85	40
2003	9849.79	39149.12	109.48	1539.6	97	45
2004	14770.22	52990.62	115.26	1966.3	116	45
2005	19485.26	68046.6	136.48	2450.0	138	47
2006	25137.95	86522.77	150.25	3003.1	171	48
2007	31058.54	108767.4	173.62	3710.2	206	49
2008	37113.08	127761.5	196.54	4616.0	242	58
2009	33657.17	107302.9	229.13	5802.1	263	71
2010	43971.32	140906.5	255.38	7062.6	276	76

Data source: y, s data from the China Statistical Yearbook (1994-2010), L, K data from China Statistical Yearbook of Science and Technology (1994-2010).

2.3 Simulation assignment

(1) Assignments of a_1 and a_2

a_1 is an enterprise innovation risk preference parameter, fluctuating between (-1,1) under normal circumstances. When $0 \leq a_1 \leq 1$, the industry tends to be conservative and averse to innovation risk; $-1 \leq a_1 \leq 0$, the industry has the courage to bring forth new ideas and has strong adaption to innovation risk. In order to the convenience of the study, a_1 is taken the extreme value as 1, showing that Chinese industry is the absolute innovation risk averter, although this assumption has a certain deviation from reality, but is in line with reality. a_2 is the parameter to measure a national enterprise technology learning effect ($a_2 > 0$). According to Table 2 and equation (2), the national $a_2 = 0.729$ from 1994 to 2010 can be calculated.

(2) Assignments of α and β

According to Table 2, the elasticity $\alpha=1.2854$, $\beta=2.0237$ between1994 and 2011 can be obtained. According to n, differential equation of the equation (1) and (6) can be drawn correspondingly as follows, where the subscript n represents the year.

$$\boldsymbol{y_{n+1}} - \boldsymbol{y_n} = \boldsymbol{h}\boldsymbol{y_n}(\boldsymbol{s} - \boldsymbol{y_n}) - a_2\boldsymbol{y_n}\left(\mathbf{1} - a_1\frac{y_n}{s}\right) \quad (8)$$

$$\boldsymbol{y_{n+1}} - \boldsymbol{y_n} = \boldsymbol{h}\boldsymbol{y_n}(\boldsymbol{s} - \boldsymbol{y_n}) - (a_2+\boldsymbol{\beta})\boldsymbol{y_n}\left(\mathbf{1} - (a_1 - a)\frac{y_n}{s}\right) \quad (9)$$

According to equations (8), (9) and Table 6, the values of h can be obtained before and after the correction of a_1 and a_2 (Table 7):

$$\boldsymbol{h} = \frac{\boldsymbol{y_{n+1}} + a_2\boldsymbol{y_n}\left(\mathbf{1} - a_1\frac{y_n}{s}\right) - \boldsymbol{y_n}}{\boldsymbol{y_n}(\boldsymbol{s} - \boldsymbol{y_n})} \quad (10)$$

$$\boldsymbol{h} = \frac{\boldsymbol{y_{n+1}} + (a_2+\boldsymbol{\beta})\boldsymbol{y_n}\left(\mathbf{1} - (a_1 - a)\frac{y_n}{s}\right) - \boldsymbol{y_n}}{\boldsymbol{y_n}(\boldsymbol{s} - \boldsymbol{y_n})} \quad (11)$$

Where the correction of a_1 and a_2 are intended to consider the impact of the α and β,

$a_1 = a_1 - a = 1 - 1.2854 = -0.2854$

$a_2 = a_2 + \beta = 0.729 + 2.0237 = 2.7527$

3. EMPIRICAL ANALYSES

3.1 Comparisons of logistic simulation and actual statistic without science and technology policy incentives

Seen from Figure 1, equilibrium points of the national high-tech product exports have increased over time from 1994 to 2007, and all points are stable. In this period, the initial values of the annual logistic simulation y are smaller than the values of equilibrium points. Based on the analytical solution of Logistic equation (see equation (5)), logistic simulation y has exhibited nonlinear growth characteristics in this period, and the overall trend is more consistent with the actual statistic, but the change rules of simulation equilibrium points have deviated too much with the actual statistic over the growing time. Moreover, the change trends of equilibrium points are contrary to the change rules of actual statistical from 2008 to 2009 by calculating, and it may be because a_1 and a_2 have not introduced policy incentive parameters to modify models.

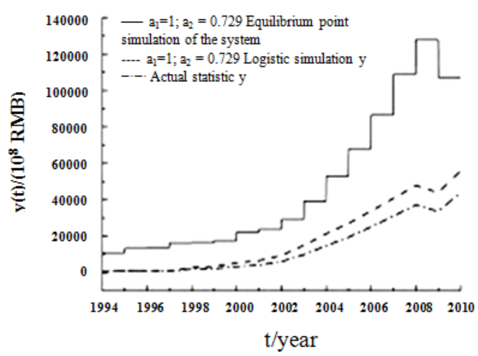

Figure 1 Comparisons of logistic simulation and actual statistic without science and technology policy incentives.
Equilibrium point simulation of the system
Logistic simulation y
Actual statistic y

3.2 Comparisons of logistic simulation and actual statistic introducing policy parameters to motivate enterprises technology learning

Seen from Figure 2, $a_1=1$ (uncorrected), and a_2 is corrected to $a_2+\beta=2.7527$. The change rules of the system are very similar to Figure 1, especially in the period from 2008 to 2009.

There is attractor phenomenon of rejection in the vicinity of the stable equilibrium point, and logistic simulation y has decreased with the growing time. It affects only a_2, and does not simulate the nonlinear rules of the actual statistic theoretically, so the domestic industry is still the absolute innovation risk averter, and policy parameter of motivating technology learning β makes little effect on the system.

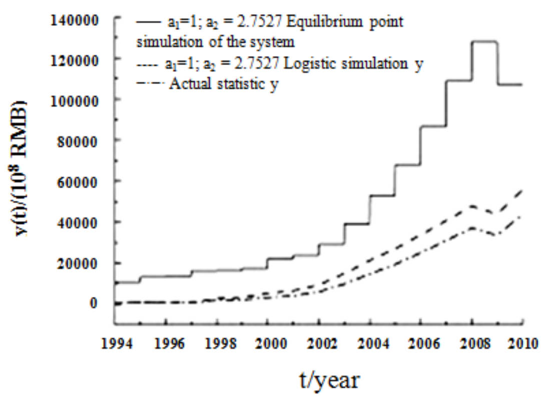

Figure 2 Comparisons of logistic simulation and actual statistic introducing policy parameters to motivate enterprises technology learning

3.3 Comparisons of logistic simulation and actual statistic introducing policy parameters to reduce the innovation risk

Seen from Figure 3, when a_1 is corrected, $a_2=0.729$. When a_1 is uncorrected, change rules of logistic simulation y are very consistent with data curve of the actual statistic over the growing time. This shows that science and technology policy effectively reduces the risk of industry technological innovation activities. Prior to the introduction of policy incentive parameters α, $a_1 = 1$, showing that the industry is absolutely averse to the risk for technological innovation, and unwilling to technological innovation activities.

The trajectory deviation of logistic simulation y and actual statistic is large. After correcting a_1, $-1<a_1-\alpha=-0.2854<0$, explaining that policy incentives substantially increase the affordability of the domestic industry in technology innovation risk, cost and historical inertia, and the technological innovation has become increasingly active. The logistic simulation y is very consistent with the trajectory of actual statistic, explaining that the correction a_1 to introduce α is necessary, and policy incentives to reduce the innovation risk are crucial for China to catch up with technology.

3.4 Comparisons of logistic simulation and actual statistic under synergistic science and technology policy incentives

Seen from Figure 4, when values of a_1 and a_2 are corrected at the same time, equilibrium point's y varying with time are all stable, and the variation of equilibrium points is matched with the actual statistic. However, in the period from 2008 to 2009, the initial value y in 2008 is less than the stable value of equilibrium point from 2008 to 2009, so logistic simulation y increases monotonically with the growing time, which does not match with the actual statistical laws. In reality, due to the international economic crisis in 2008, y decreases significantly in the period from 2008 to 2009. The unconformity between logistic simulation and actual statistic may be due to the correction of a_2. Policy incentives introduced by the parameter β may be due to a certain bias of incomplete statistic. In addition, the trajectory of logistic simulation y is overall in line with the curve of actual statistic in the period from 1994 to 2010.

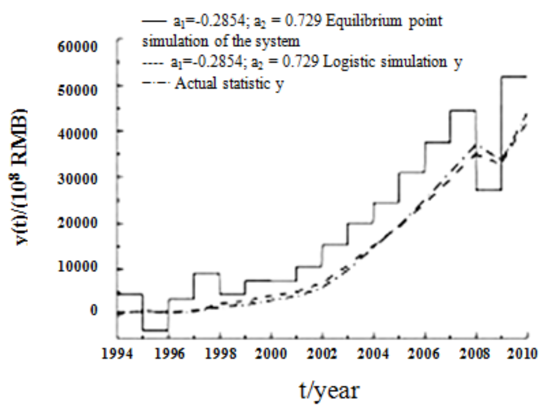

Figure 3 Comparisons of logistic simulation and actual statistic introducing policy parameters to reduce the innovation risk.

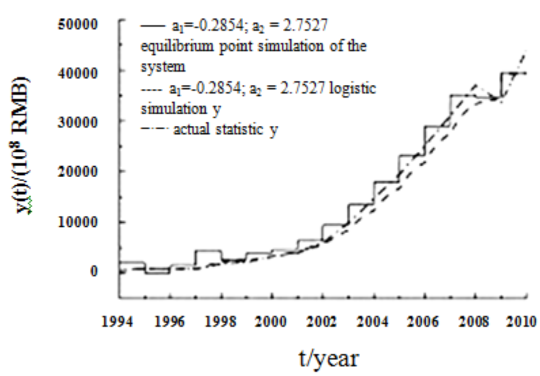

Figure 4 Comparisons of logistic simulation and actual statistic under synergistic science and technology policy incentives

4. CONCLUSIONS

First, this paper shows that key parameters of the enterprise behavior practices must be considered in the establishment of technological innovation input-output framework. The adjustment and optimization for Chinese science and technology policy system must follow the path of how to improve enterprise innovation behavior practices, focusing on the two main lines of how to promote enterprise technology learning and reduce the innovation risk.

Second, there is no unified centralized management for Chinese science and technology policy, repetition and overlap of inefficient management occurs in the government for technological innovation, which provides an opportunity space for enterprises' "policy seeking". Technological innovation cannot really become the preferred power for enterprises to create profits. In addition, China's current system of science and technology policy, temporary files such as notice, method, suggestion and interim provision occupy a large proportion. For example, the notice has most obviously accounted for 43.8% in the 32 screened science and technology policy stimulating technology learning; in the 160 screened technology policies reducing innovation risk and cost, the notice has accounted for higher proportion reached 51.3%, which reduces the impact of science and technology policy enforcement for continuous improvement of enterprises' innovation behavior practices.

To further enhance the effectiveness of policy, formulation and promulgation of the administration for science and technology policy should be streamlined, and management agencies should be unified. Enterprises are forced to establish long-term strategic concept and behavioral practices of technological innovation from institutional forces, and the poor effectiveness of notification is minimized. The development and implementation of wide coverage, strong execution and long aging regulations and laws are strengthened.

Third, in the process of catching up with technology, the impact of Chinese science and technology policy on enterprise innovation behavior practices, and thus enhancing the innovation performance should emphasize synergies.

The analysis of Figures 2-4 shows that when a policy incentive parameter is introduced separately to modify the model, the trajectory of logistic simulation y is overall consistent with the curve of actual statistic, but there is a certain deviation. Only after the correction of a_1 and a_2 are introduced with policy incentives parameters, logistic simulation y, actual statistic and the variation of equilibrium points of the system are very consistent, which shows that only the synergies of enterprise innovation behavior practices are improved in two aspects of stimulating technology learning and reducing innovation risk, technological policy system will have a significant role in promoting innovation output growth. Furthermore, the incentive effect of science and technology policy reducing business innovation risk and costs is significant on innovation output, and enhancing the policy incentive effects of technology learning should be improved. It needs to further strengthen the science and technology policy in technology absorption, stability and efficiency of the technology alliance, knowledge and information sharing, industry infrastructure facilities, as well as scientific and technological personnel training and incentives support.

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