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The Evolution Characteristics and the Problems of Science and Technology Policy in China-Based on the Number and Effectiveness of Policy from 1985 to 2011

XU Zhe[1], LI Chun-yan[1], MA Yu-song[2]
1 School of Business, Northeast Normal University, Changchun 130117, P.R. China
2 School of International Business, College of Humanities & Science of Northeast Normal University, Changchun 130117, P.R. China

Abstract: The purpose of this article is to discuss the evolution characteristics and the problems of S&T policy in China. The paper sets the standards to analyze the policy in three dimensions (i.e. effectiveness, objectives and instruments). On the basis of the standards, the paper carries out a statistical analysis of the policy from *Collection of Laws, Regulations and policies of science and technology from 1985 to 2011* and evaluates the S&T policy from the perspective of numbers and effectiveness. The paper argues that China's S&T policy undergoes the evolution paradigm of "Science - Technology – Innovation" with a higher growth rate compared to developed countries and the government should improve the policy effectiveness, especially the policy in favor of the enterprises' technology innovation. In the policy objective system, there is a balance in numbers, but insufficient attention to some policy that is more conducive to technological innovation. The demand-side policy has not only a shortage of quantity but also low effectiveness.

Keywords: effectiveness, evolution characteristic, number, S&T policy

1 Introduction

Science and technology (S&T) policy is the principles taken by a government in order, on one hand, to guide, stimulate and support innovation activities and the application of the achievements according to the objectives of the development of S&T in a certain historical period, and on the other hand, to point out the direction of S&T and provide the strategies and tactics[1]. Since World War Ⅱ, S&T policy had appeared which was science policy at the beginning and then gradually converged to the evolution paradigm of "Science – Technology – Innovation"[2]. In short, there is a high synergy of the S&T policy evolution and the S&T practice.

It is well known that China has formulated a series of policies in line with S&T development and the situation of China, however, the coordination and effectiveness of the policy has raised concern. Then, how to evaluate China's S&T policy systematically has become a big topic. Much of the literature focuses on qualitative analysis from an economic perspective (Huiwu Liu and Shengguang Wang, 2009[3]; Zhengmao Zhan and Zhibiao Shu, 2010[4]; Zhengkui Zhu, 2013)[5]. There is also some quantitative analysis, for example, Fengchao Liu and Yutao Sun (2007) tries to answer the evolution characteristics and trends by analyzing 289 policies issued by China's government between 1985 and 2005[6]. This paper takes a different classification and statistical approach.

This paper is organized as follows. First, the paper sets the standards to analyze the policy in three dimensions (i.e. effectiveness, objectives and instruments). Second, the paper carries out a statistical analysis of the policy from *Collection of Laws, Regulations and policies of science and technology from 1985 to 2011* [7][8] according to the standards. Finally, the paper evaluates the S&T policy from the perspective of numbers and effectiveness[9], to find the evolution characteristics and the problems, and to give a set of recommendations for further adjustment and optimization.

There are significant advances in this paper: (1) this paper has a sufficient understanding of the characteristics because the policies analyzed are in large numbers from 1985 to 2011; (2) different from current qualitative analysis, the paper makes a statistical analysis from the perspective of numbers, coordination and effectiveness.

2 Classification of S&T policy

The evaluation of policy often involves the classification of S&T policy, there is no proper method to compare different national S&T policy yet. Freitas & Tunzenlm Ann(2008) argue that S&T policy is generally classified into policy objectives, policy implementation, policy instruments by reviewing relevant research[10]. Johansson et al. (2007) classify innovation policy instruments into general instruments

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and specific instruments. Oltra(1999) makes a point that the aim of making technology innovation policy is to support the technical and scientific knowledge production, use and diffusion[11]. The policy is mainly classified into three categories which are policies to encourage research, innovation and selection mechanism . Gaudin notes that innovation policy should include the policy to support innovators, to develop innovation culture and to remove obstacles. According to the influence of policy instruments on the science and technology activity, Rothwell and Zegveld (1985) classify the policy instruments into "supply-side", "environment-side" and "demand-side" policy[12].

Peng Jisheng (2008) classifies the policy according to the objectives and measures[13]. The main policy objectives include intellectual property protection, capital introduction, technology introduction, technology digestion and absorption, innovation, S&T achievement transformation. The measures are as follows: administrative measures, foreign exchange measures, fiscal and tax measures, other economic measures, personnel measures. Fengzhao Liu and Yutao Sun (2007) classify the policy by effectiveness and categories. Nan Zhang (2010)[14], Hongru Wu and Changde Hu (2010)[15], Zhengmao Zhan and Zhibiao Shu (2010) also do the similar work according to the related standards.

Of course, rational classification methods have been associated with the evolution of innovation policy. S&T policy was mentioned for the first time in the report by Vannevar Bush "Science, the Endless Frontier". In this report, he said that the government should make policies to guide and support the development of science, and the key point of view was that we should pay more attention to the basic research. Under the guidance of this theory, the USA government promoted the establishment of the R&D alliance and university alliance, strengthening basic research. Obviously, S&T policy during this period is knowledge -oriented, called science policy.

In the 1950s, because of the Cold War and Arms Race，the policy-makers focused on "big science" research, so that some basic research in technology had made a breakthrough during that time. Until the 1970s, the science policy was actually a combination of science-technology policy. In the 1980s, the Cold War ended, and the policy-makers realized that the importance of combination of technology and business besides Arms Race and the scientific expedition. So how to promote the development and commercialization of technology had become the policy focus, which we called 'technology-oriented' policy. In contrast with 'science-oriented' policy, the goal of 'technology-oriented' policy was to use tax policy, government procurement and other policy instruments to guide, encourage and support the development and application of technology.

Innovation policy appeared in the 1970s and during the 1980s, the policymakers made a number of innovation policies. Until the 1990s innovation policy had become really popular. Innovation policy was not independent of the science policy and technology policy, but intersected with each other. Thus, with the concept of the national innovation system proposed and the improvement of the innovation theory, innovation policy has been applied in a number of areas, including technology, education, human resources, industry, business management system etc, whose instruments are fiscal support, taxation and financial aid[16]. According to the different situations and cognition, the framework of the innovation policy was different. Innovation policy system of EU included the Development Plan, SME policy, human resource policy and intellectual property policy. The evolution feature of innovation policy of Japan was from dissemination and diffusion to innovation of knowledge. Our innovation policy also experiences a process in which S&T policy is separated from industrial policy gradually[17]. Specifically, in the first phase, we reconstructed S&T system during 1978-1985; we established the R & D investment mechanism in the second stage from 1986 to 1998; In the third phase from 1999 to 2006, we promoted the transformation of S&T achievements. Since 2006, we stepped in the phase of constructing the comprehensive national innovation system[18].

Based on the study above, referring to current experts' classification criteria and taking full account of the evolution process of innovation policy, the paper classifies the innovation policy into three categories, including policy effectiveness, policy objective, and policy instrument. The policy objectives are to encourage the basic research, S&T achievement transformation and innovation system improvement. Policy instruments include demand-side, supply-side, and environment-side policy[19]. Policy effectiveness reflects the categories and hierarchy of power of the state administrative authority who issues S&T policy (see Fig.1).

3 Statistical analysis of S&T policy

3.1 The number

In general, the number of S&T policy in China from 1985 to 2011 shows a gradual change in the characteristics and has been increasing (see Fig.2). In the first period (1985-1996), though the number is less than 5 per year, there are a few important laws issued, such as *Patent Law of the People's Republic of China, Standardization Law of the People's Republic of China and Science and Technology Progress Law of the People's Republic of China.*

In the second period (1997-2005), it is the deepening phase of the S&T system reform (OECD, 2008)[20]. The number significantly increases and reaches an extreme point. Furthermore, this paper analyzes the distribution of the policy (see Tab.1), and finds that the number of S&T achievement and intellectual property policy is at the top which is 29, followed by policy of S&T condition and standard, management of S&T plan, S&T personnel, and firms' technical progress and industrialization of high technology. The S&T policy is

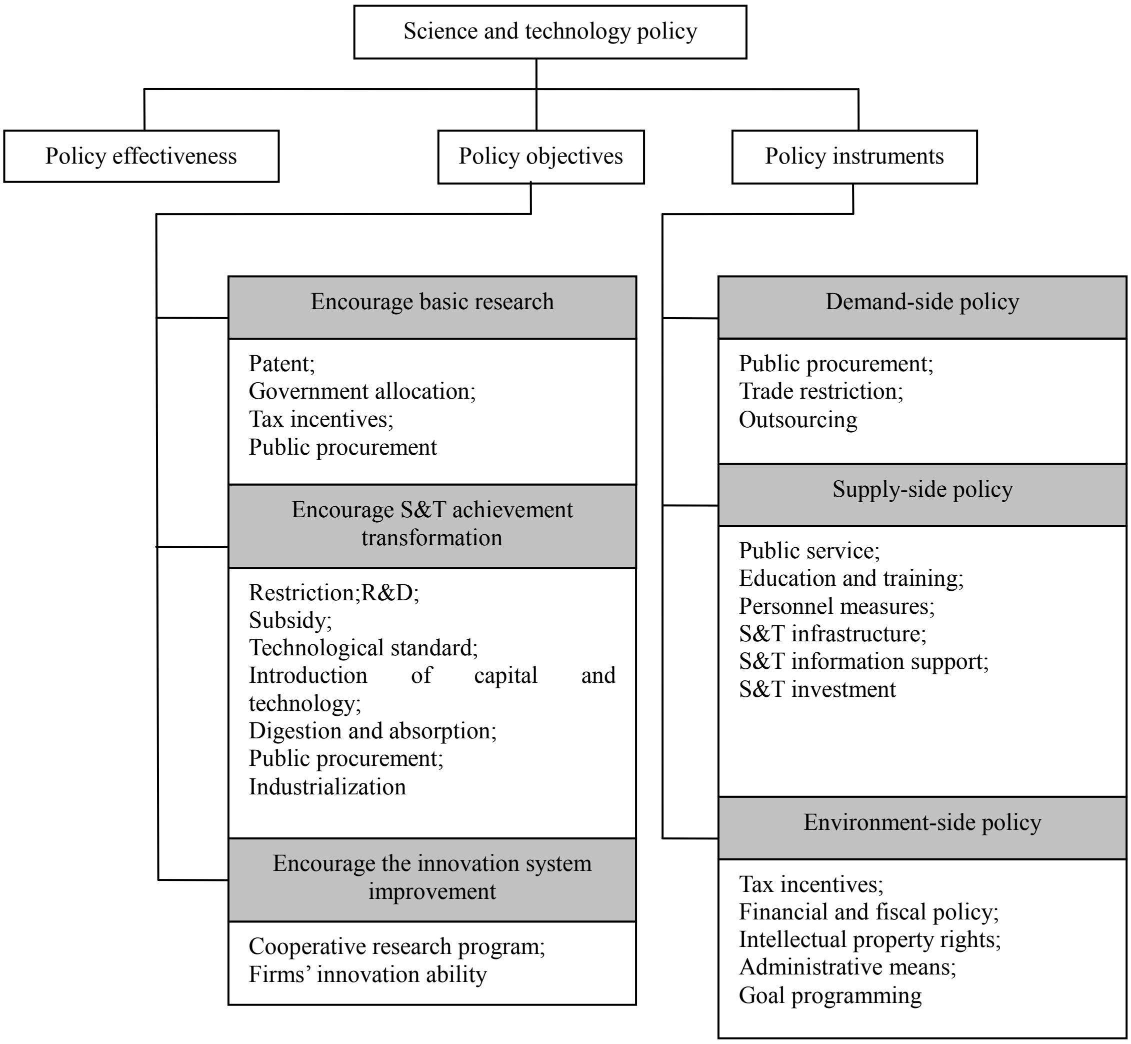

Fig.1 Typology of S&T policy

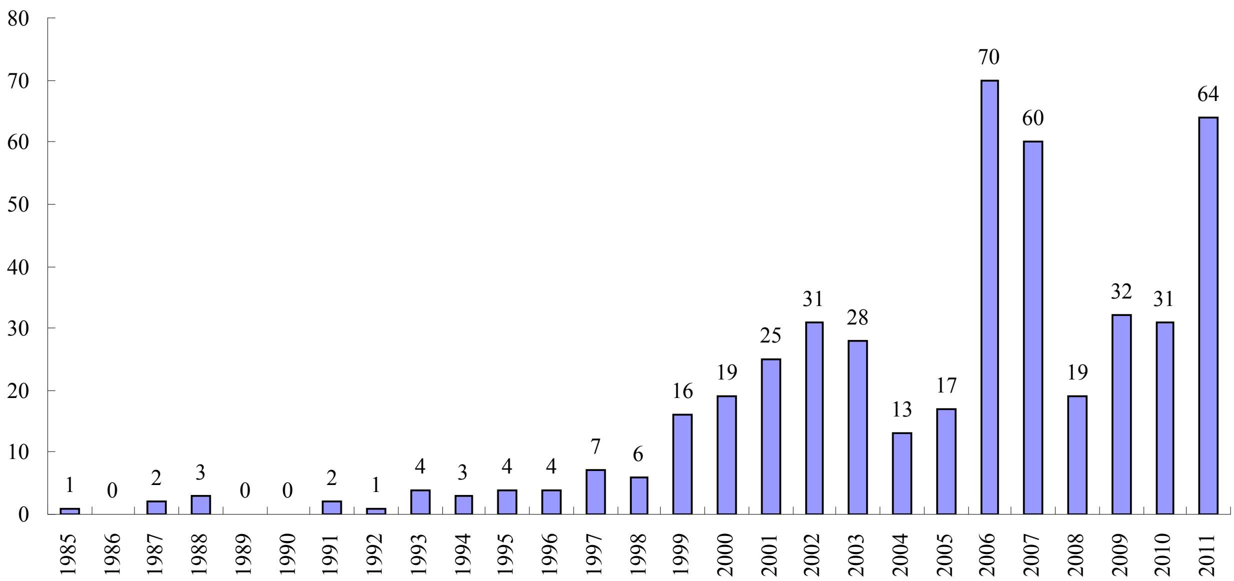

Fig.2 The number of S&T policy in China from 1985 to 2011

Tab.1 Comparison of S&T policy numbers in different periods

Policy	Number of policies		
	1985-1996	1997-2005	2006-2011
comprehensive policy	4	2	6
reform of S&T institution	0	7	8
management of S&T plan	1	22	16
S&T fund and finance	1	3	15
basic research and S&T base	1	5	17
firms' technical progress and hi-tech industrialization	2	17	43
rural S&T and social development	0	9	19
S&T personnel	2	20	27
S&T intermediary service	1	6	13
S&T condition and standard	4	23	9
S&T finance and tax	0	7	70
S&T achievement and intellectual property right	3	29	19
S&T popularization	1	3	6
S&T prize	0	5	3
international S&T cooperation	0	4	5

mainly science policy, and technology policy has already emerged.

In the third period (2006 until now), the release of the *Medium- to Long- Term Strategic Plan for the Development of Science and Technology (2006-2020)* in 2006 and its supporting policies make the S&T policy number to be 70, the biggest since the year 1985. The number in this period always maintains high levels (bigger than the biggest number in the second period) except 2008. In terms of the distribution (see Tab.1), the number of S&T financial and tax policy is the most which has reached 70, followed by firms' technical progress and industrialization of high technology to be 43, and the number of other policy is also at high levels. The S&T policy during this period presents the following characteristics: the number of science policy has decreased, but it still plays an important role, and technology policy and innovation policy significantly are enhanced.

3.2 The effectiveness

This paper adopts the quantitative standards made by Jisheng Peng (2008), which classifies the policy into 5 levels using score from 5 to 1 according to the effectiveness[21]:

5-Laws issued by the National People s Congress and its Standing Committee

4-Regulations issued by the State Council

3-Interim regulations issued by the State Council; regulations and norms by the various ministries and commissions

2-Opinions, interim regulations, plans and programs by the various ministries and commissions

1- Notices and announcements

With the above standards, this paper goes on the following analysis of the 462 S&T policies in China from 1985 to 2011.

3.2.1 The structure of the effectiveness

There are 84 policies at Level 1 and 311 policies at Level 2, which account for 85% of the 462 policies, while the policies at high levels (3-5) account for only 15% (see Fig. 3).

The structure of the effectiveness is obviously unreasonable, and there are more policies at low levels than those at high levels. So the S&T policy in China is less coercive than the European and American developed countries'.

3.2.2 The distribution of the effectiveness

The paper combs the policies of *Collection of Laws, Regulations and policies of science and technology from 1985 to 2011* and divides them into 15 aspects. The paper further locates the 15 aspects in different effectiveness levels through calculating the arithmetic mean of the effectiveness of the policies in each aspect and ranks them (see Tab. 2).

Tab. 2 shows that the effectiveness levels are not high except comprehensive policies. And among the other 14 aspects, the highest level appears in S&T achievement and intellectual property right policy, which is always the regulations and norms issued by the State Council and the various ministries and commissions and occasionally issued by law, such as *Patent Law of the People's Republic of China, Copyright Law of the People's Republic of China, Contract Law of the People's Republic of China and the Law on the Promotion of S&T Achievement Transformation*. China has paid more attention to the intellectual property protection. In terms of the composition of innovation policies, the intellectual property is regard as one of the oldest and the most fundamental institutions because it

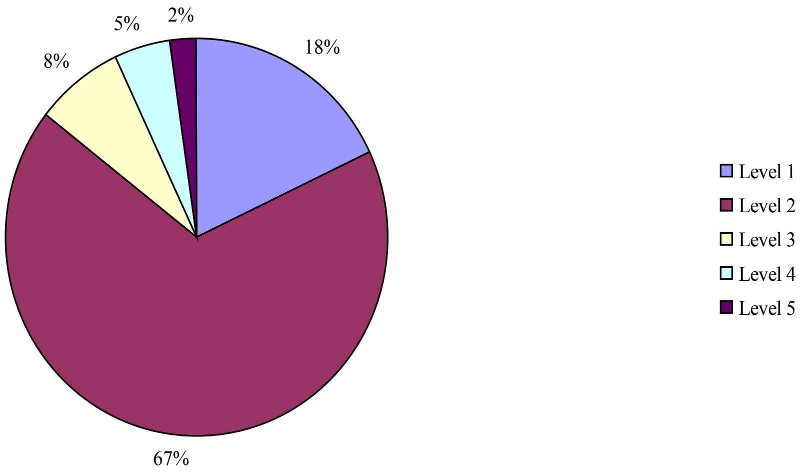

Fig.3 The effectiveness of S&T policy in China from1985 to 2011

Tab.2 The effectiveness levels of S&T policies in China from 1985 to 2011

Validity level	Policy
3-4	Comprehensive policy
2-3	S&T achievement and intellectual property right; S&T prize; S&T condition and standard; Rural S&T and social development; International S&T cooperation; S&T popularization; Basic research and S&T base; Management of S&T plan
1-2	S&T intermediary service; Firms' technical progress and hi-tech Industrialization ; S&T fund and finance; S&T personnel; Reform of S&T institution; S&T finance and tax

can lure innovation by property rights. As Douglass Cecil North said, the intellectual property right protection is one of the most important factors to promote economic growth in human history. There will not be much innovation if there is no enough intellectual property right protection. Though China has paid much attention to the S&T achievement and intellectual property right, the protection level still ranks lower in the world[22].

Besides S&T achievement and intellectual property right, there is policy of S&T prize, S&T condition and standard, rural S&T and social development, international S&T cooperation, S&T popularization, research and S&T base, management of S&T plan in the middle level. The policy mainly encourages the basic research, belonging to science policy. In effect, there is a growing awareness of the importance of basic research for S&T development, so many developed countries have provided more budget on it[23]. The policy at lowest level includes S&T intermediary service, firms' technical progress and hi-tech industrialization, S&T fund and finance, S&T personnel, reform of S&T institution and S&T finance and tax, which mainly belongs to technology policy and innovation policy and obviously the effectiveness is not enough. Actually, most countries have experienced the evolution paradigm shift from science policy to the cooperative policy of science, technology and innovation policy.

3.3 Policy objective

3.3.1 Policy to encourage basic research

The policy to encourage basic research includes patents, government allocation, tax incentives and public procurement, and the number involving each aspect is 106,140, 96 and 38 respectively. 266 policies are related to basic research, accounting for 57.6% of the total.

In view of the number, the government prefers patents and government allocation. But many studies show that tax incentives are effective and highly efficient for the basic research which can bring out more return for the society than the company itself. Thus, there should be more tax incentives[24].

Public procurement is applied in many other countries as a useful means of triggering innovation by demand-side impulse. As Roswell notes, public procurement can promote innovation in more fields than R&D subsidy[25]. Apparently, China does not make full use of public procurement and ranks lower than other countries[26].

As for the effectiveness, most policies are at the lowest level except several patent policies whose effectiveness reaches 5 (see Tab. 3), which means a lack of policy effectiveness to encourage basic research.

3.3.2 Policy to encourage S&T achievement transformation

The policy to encourage S&T achievement transformation includes restriction, R&D, subsidy, technological standard, introduction of capital and technology, digestion and absorption, public procurement and industrialization. 244 policies are related to S&T achievement transformation, accounting for 52.8% of the total. Tab. 4 shows the number and the effectiveness.

From Tab. 4, it can be seen that the number is huge while the effectiveness is low as a whole. The share of Level 1 and Level 2 is over 80%.

The paper takes full consideration of the funding, personnel and facility from the perspective of nation and firms[27], and finds that the number of R&D policies is large which is 307 from 1985 to 2011. In the R&D policies, there are 55.4% at Level 1 and 29.3% at Level 2, which means they are mostly notices, announcements or opinions of the various ministries and commissions. Therefore, the policy intensity is not enough and the performance is always poor.

The number of the policy of capital and technology introduction (104) is much larger than the digestion and absorption policy (60), so is the effectiveness. Undoubtedly, it is one of the most important reasons why China depends on foreign technology heavily and can not set up the mechanism “introduction-digestion and absorption-innovation”.

There is not much policy on restriction, subsidy, technological standard and public procurement aimed to increase the expected return of technology adoption and lock the technology at a higher level[28], especially restriction policy whose number is only 24. The consequence is the repetition of inferior technology, which would block firms’ innovation.

Fig. 4 shows the number of industrialization policy from 1985 to 2011 and the characteristics of its evolution. There are few industrialization policies between 1985 and 1990 and they are enacted gradually between 1991 and 2000. From 2001 to 2011, the number grows rapidly which means a transition from science policy to technology and innovation policy. China has began to pay more attention to the combination of S&T and economic construction, especially the application of technology and innovation policy[29].

3.3.3 Policy to encourage the innovation system improvement

The policy to encourage the innovation system improvement include cooperative research program and firms’ innovation ability, and the number is 290, accounting for 62.8% of the total. And the effectiveness level is higher than the policy to encourage basic research and S&T achievement transformation (see Tab. 5). Innovation system improvement policy has been an important part of S&T policy according with the evolution paradigm, and the government is constituting the institutional environment of “scientific progress-technology application-innovation”.

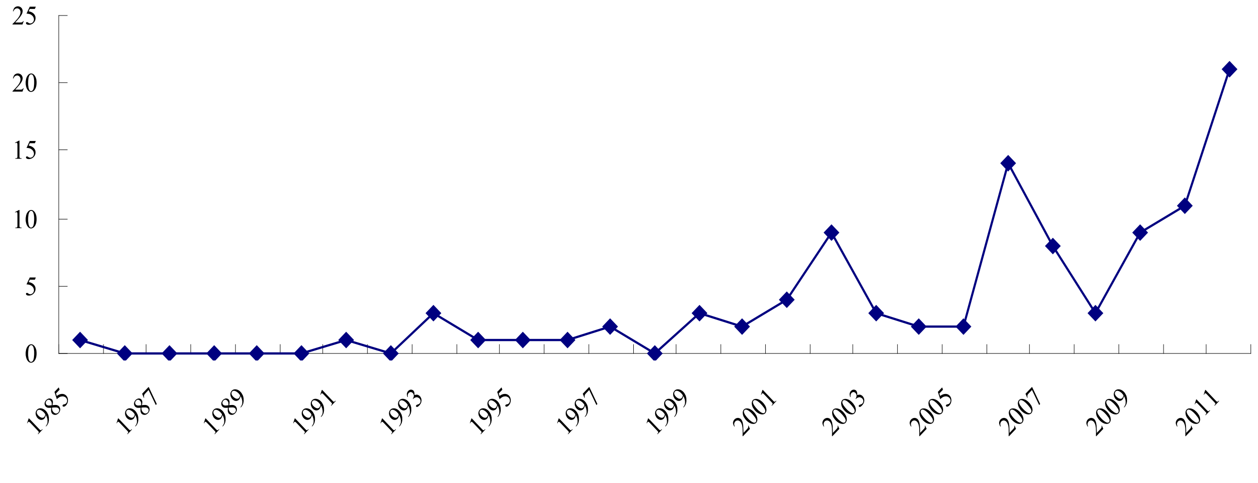

Fig.4 The number of industrialization policy in China from 1985 to 2011

Tab.3 The effectiveness of the policy to encourage basic research from 1985 to 2011

Effectiveness	Patents (%)	Government allocation (%)	Tax Incentives (%)	Public Procurement (%)
5	4.7	0	0	0
4	1.9	2.9	3.1	0
3	5.7	15.0	15.6	15.8
2	8.5	37.1	26.0	15.8
1	79.2	45.0	55.2	68.4

Tab.4 The number and effectiveness of the policy to encourage S&T achievement conversion from 1985 to 2011

	Restriction	Technological standard	R&D	Subsidy	Introduction of capital and technology	Digestion and absorption	Public procurement	Industrialization
Number	24	63	307	74	104	60	43	101
Level 5	0	4.8%	0.3%	1.4%	0	0	0	2.0%
Level 4	8.3%	0	3.9%	2.7%	4.8%	3.3%	4.7%	2.0%
Level 3	8.3%	11.1%	11.1%	12.2%	6.7%	11.7%	9.3%	6.9%
Level 2	37.5%	15.9%	29.3%	36.5%	22.1%	10.0%	14.0%	15.8%
Level 1	45.8%	68.3%	55.4%	47.3%	66.3%	75.0%	72.1%	73.3%

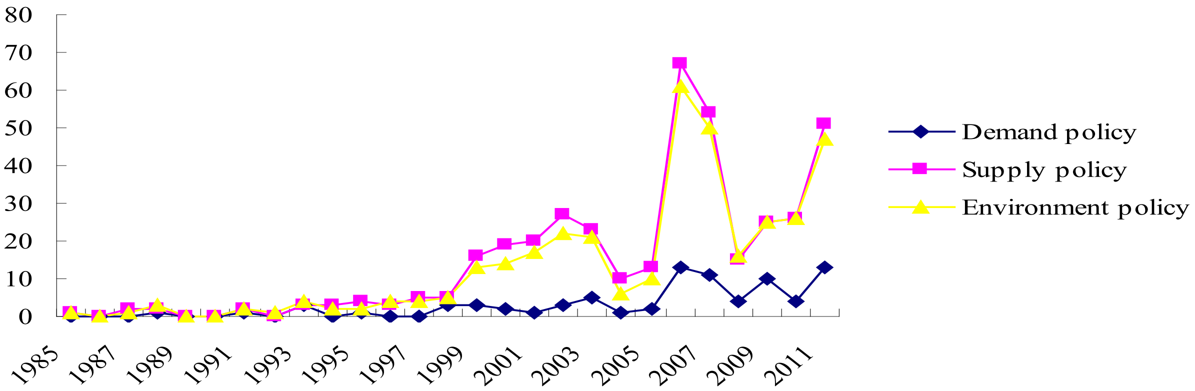

Fig.5 Trends of policy investments in China from 1985 to 2011

Tab.5 The number and effectiveness of policy to encourage innovation system improvement from 1985 to 2011

	Cooperative research program	Firms' innovation ability
Number	186	253
Level 5	2.2%	1.2%
Level 4	3.8%	8.3%
Level 3	14.5%	13.4%
Level 2	28.0%	30.4%
Level 1	51.6%	46.6%

3.4 Policy instrument

Policy instruments are the means and measures that government can grasp and apply to reach selected objectives[30]. Supply-side policy includes public service, education and training, personnel measures, S&T infrastructure, S&T information and S&T investment; demand-side policy includes public procurement, trade restriction and outsourcing; environment-side policy includes tax incentives, financial and fiscal policy, intellectual property rights, administrative means and goal programming. Among the 462 S&T policies, there are 81 policies involving demand, 396 involving supply and 357 involving environment, accounting for 17.5%, 85.7% and 77.3% respectively. Obviously, demand-side policy is insufficient compared to supply-side policy and environment-side policy. Moreover, the development of demand-side policy is slower which can be seen in Fig. 5.

The number of supply-side and environment-side policy gradually increases since 1999 and has a fast growth rate, while until 2006 demand-side policy has been strengthened, and the growth rate is slow. In a word, there is no coordinated development between policy instruments.

3.4.1 Demand-side policy

Demand-side policy refers to the government support policy to reduce the market uncertainty, aiming to stabilize the market of technological innovation application, and to stimulate technological innovation[31].

Tab. 6 provides the number and effectiveness of demand-side policy from 1985 to 2011. There are more policies for public procurement and trade restriction and less for outsourcing because outsourcing policy appeared in 2006 with the promulgation of *The Notice "On the Construction of Export and Innovation Base for the*

Tab.6 The number and effectiveness of demand-sidepolicy from 1985 to 2011

	Public procurement	Trade restriction	Outsourcing
Number	40	41	15
Level 5	0.0%	0.0%	0.0%
Level 4	7.5%	2.4%	0.0%
Level 3	12.5%	14.6%	13.3%
Level 2	17.5%	58.5%	20.0%
Level 1	62.5%	24.4%	66.7%

Trade by Science and Technology". Except 7.5% public procurement policy and 2.4% trade restriction policy, the effectiveness level is generally low with no policy promulgated by law. The lack of the number and effectiveness of demand-side policy, to a certain extent, hinders the pace of indigenous innovation of firms.

3.4.2 Supply-side policy

Supply-side policy refers to the government support policy to promote technological innovation by influencing factor supply[32]. On one hand, the number of supply-side policy is significantly large (see Tab. 7), indicating that the government has attached great importance to supply-side policy. Among these policies, the number of the S&T investment policy is the most, up to 252, and the number of S&T infrastructure policy is the least hitting 199. There is a balanced development among the policies. On the other hand, the effectiveness level is high. Many policies are released at high levels rather than low levels.

3.4.3 Environment-side policy

Noticing the great importance of technological innovation, the government begins to focus on creating a good environment in order to promote technological innovation indirectly. As a result, environment-side policy has been strengthened. Most of the attention is paid to the intellectual property right policy, with a total number of 215 (see Tab.8). The number reaches the peak at 2002 and 2006 (see Fig.6), exceeding other policies. The following are financial and fiscal policy and tax incentives, whose number is 165 and 127, respectively. As for administrative means and goal programming policy, the number of the former is always larger than the latter in most of the years before 2006, while the number of goal programming policy increase rapidly after 2006 (see Tab. 6).

Overall, the effectiveness level of environment-side policy is high. Except administrative means, each category has policies issued by law, especially goal programming policy. The policy at middle levels has a big share. Consequently the environment-side policy is growing fast.

Tab.7 The number and effectiveness of supply-side policy from 1985 to 2011

	Public service	Education and training	Personnel measures	S&T infrastructure	S&T information	S&T investment
Number	247	201	244	199	211	252
Level 5	1.6%	3.5%	1.2%	1.5%	1.4%	0.0%
Level 4	7.3%	7.0%	6.6%	11.1%	4.7%	4.4%
Level 3	27.5%	11.9%	19.7%	19.1%	15.2%	13.5%
Level 2	29.1%	19.9%	29.9%	30.7%	30.8%	37.7%
Level 1	34.4%	57.7%	42.6%	37.7%	47.9%	44.4%

Tab.8 The number and effectiveness of environment-side policy from 1985 to 2011

	Tax incentives	Financial and fiscal policy	Intellectual property rights	Administrative means	Goal programming
Number	127	165	215	63	92
Level 5	1.6%	1.8%	3.3%	0.0%	7.6%
Level 4	5.5%	10.3%	4.2%	1.6%	6.5%
Level 3	25.2%	18.8%	21.4%	12.7%	15.2%
Level 2	22.0%	27.3%	20.9%	49.2%	37.0%
Level 1	45.7%	41.8%	50.2%	36.5%	33.7%

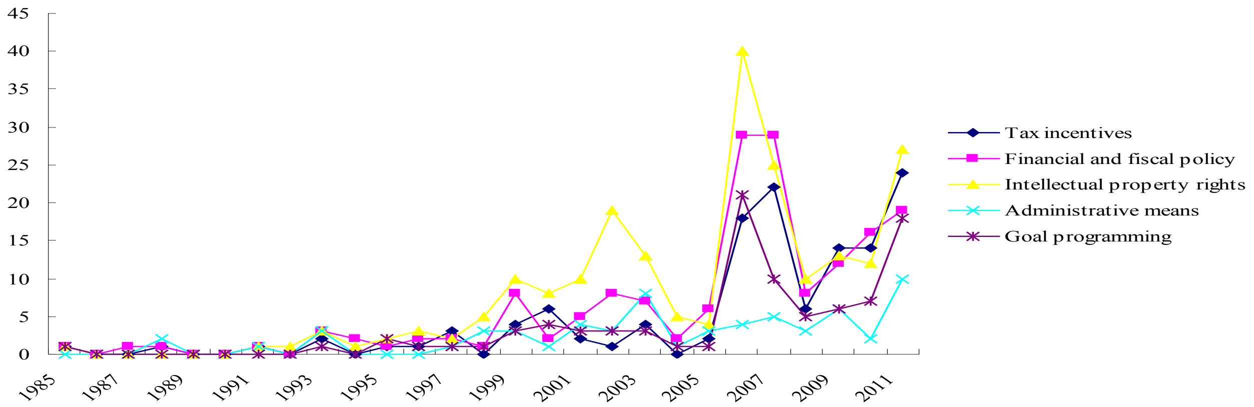

Fig.6 Trends of environment-side policy in China from 1985 to 2011

4 Conclusion

From the angle of policy effectiveness, objectives and instruments, we classify the S&T policy. According to the standards，we take a statistical approach of policies in *Collection of Laws, Regulations and policies of science and technology from 1985 to 2011*. Through analyzing the number, synergy and effectiveness, we draw the following conclusions:

First, China's S&T policy undergoes the evolution paradigm of "Science - Technology – Innovation". Compared with developed countries, China is marked with late start but rapid growth (China spent 20 years, whereas the developed countries spent nearly 30 years).

Second, the effectiveness level of China's S&T policy is generally low, mainly in the forms of opinions, interim provisions, notices and announcements, whereas the S&T policy of European and American countries are mainly issued by law, so the effectiveness of the policy in China is low, especially the technology policy and innovation policy,

Third, in the policy objective system, the policy of encouraging basic research, S&T achievement transformation and innovation system improvement has almost the equal share, which is 57.6%, 52.8% and 62.8% of the total number separately, but effectiveness level of policy on encouraging the innovation system improvement is relatively high, showing that encouraging policy on innovation system is increasingly becoming an important part of China's S&T policy, which is in line with the evolution paradigm[33]. In addition, through the above analysis, we can see that the government pays more attention to the patents, government allocation, R & D, introduction of capital and technology and industrialization, while some policy more conducive to technological innovation, such as government procurement, digestion and absorption, the policy on the level of the selection mechanism receives insufficient attention. Obviously, this is one of the important reasons why the innovation capacity of Chinese enterprises has not been improved effectively[34].

Fourth, as to the policy instrument system, the demand-side policy has not only a shortage of quantity, a late start, and slow growth, but also low effectiveness level, whereas supply-side policy and environment-side policy is just the opposite, illustrating the policy instruments do not have coordinated development, and the government has paid inadequate attention to the demand-side policy.

We can conclude that: (1) in terms of the adjustment of technology policy, the government should improve the effectiveness of policy, especially those policies in favor of the enterprises' technology innovation. (2) the government should take the policy coordination seriously, and pay attention to not only the innovation policy promoting the technical progress directly but also to the guidance policy indirectly affecting innovation .(3) The government should make more demand-side policies in favor of the policy instrument coordination in line with the policy objectives.

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