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The influence of environmental regulation on technological innovation

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Abstract: *Since the reform and opening up, China's economy has grown rapidly and gradually become the world's second largest economy. However, it is accompanied by the increasingly severe environmental problems caused by the extensive development mode. Therefore, the central and local governments have formulated a series of environmental regulations to restrain pollution behavior. For China in the period of economic transition, the formulation of environmental regulations should be adapted to economic development, and the goal should be to promote green technology innovation and achieve high-quality growth. Based on the data of 31 provinces and cities in China, this paper studies the relationship between environmental regulation and technological innovation. The results show that: (1) appropriate environmental regulation can improve the level of technological innovation, which supports 'Porter hypothesis';(2) Environmental regulation is to encourage enterprises to adopt cleaner technologies by increasing the expected punishment level of enterprises, reallocating social resources, and providing green subsidies for high-tech industries and new energy industries, so as to improve the technological innovation level of the whole society. On this basis, some policy suggestions are put forward, such as improving the intensity of environmental regulation appropriately, paying attention to the implementation of regulation measures, and increasing the intensity of financial expenditure on science and technology.*

Keywords: *Environmental regulation; Expenditure on energy conservation and environmental protection; Technology innovation*

1. Question raising

Since the reform and opening up, China's economy has grown rapidly and gradually become the world's second largest economy. However, it is accompanied by increasingly severe environmental problems caused by extensive development mode. In the "Annual Global Environmental Performance Index" report jointly released by Yale University and Columbia University in 2012, China ranked 116th among 132 countries, reflecting the severity of China's environmental problems and the urgency of strengthening environmental regulations (Jiang Fuxin et al., 2013). The report to the 17th National Congress of the Communist Party of China for the first time proposed building a socialist ecological civilization. The report to the 18th National Congress of the Communist Party of China further emphasized "vigorously promoting ecological civilization construction and reversing the trend of ecological and environmental deterioration." In the outline of the 11th and 12th Five-Year plans, the central government clearly set the total pollution control target for the next five years. Under the guidance of the CPC Central Committee's ecological and environmental protection policy, the intensity of environmental regulation has been continuously improved. However, for China in the period of economic transition, the formulation of environmental regulations should be adapted to economic development, and the goal should be to promote green technology innovation and achieve high-quality growth. Technological innovation is a key link to achieve the "win-win" goal of environmental governance and economic growth.

Since the porter hypothesis was put forward in 1991, the relationship between environmental regulation and technological innovation has been a hot issue in the academic circle. Scholars have conducted a series of tests on the idea that environmental regulation can promote technological innovation. The empirical research conclusions can be summarized into two categories: (1) The Porter hypothesis is not valid. From the perspective of enterprise cost, strict environmental regulations will increase the environmental protection cost of enterprises and squeeze out the funds used by enterprises for technological innovation to improve productivity (Jorgenson & Wilcoxen, 1990; *Leonard, 1998).* ② 'Porter hypothesis' is established. Most scholars believe that environmental regulation does not

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necessarily lead to the reduction of production efficiency, and appropriate environmental regulation can stimulate enterprises to carry out technological innovation through "innovation compensation" effect. *Weitzman (1974), Montero (2002), Villegas-Palacio & Coria (2010) and Xu Shicun et al. (2012) studied that emission tax and tradable emission permits have a significant positive effect on enterprises' technological innovation. Jaffe & Palme (1997), Frondel et al. (2007), Jia Jun et al. (2014) and Wang Fengzheng et al. (2015) found that the greater the intensity of government environmental regulation is, the more beneficial it is to promote enterprise technological innovation.* At present, most domestic studies on environmental regulation are also focused on formal environmental regulation. This paper will provide some empirical evidence for "Porter hypothesis" based on China's experience.

2. Policy background

Generally speaking, environmental regulations can be divided into formal environmental regulations led by the government and informal environmental regulations that rely on the participation of the public and social organizations (Li Xin, Cao Jianhua, 2018).Formal environmental regulations can be divided into command-and-control environmental regulations and market-based incentive environmental regulations (Zhang Man, 2005) according to the different constraints on economic subjects' pollutant discharge behavior. The command-and-control environmental regulation mainly refers to the laws and regulations formulated by legislative organs or administrative departments to restrict economic subjects' pollutant discharge behavior, which is characterized by compulsion. Market-based incentive environmental regulation refers to the policy tools designed by the government to operate with the help of market mechanism, such as tradable pollutant discharge permit and deposit return, which is characterized by using the characteristics of economic behavior of market subjects to guide them to protect the environment. Compared with the traditional formal environmental regulation, the informal environmental regulation has become an important supplement to the formal environmental regulation because of its characteristics of spontaneity, sociality and non-compulsion, and it is a force that can not be ignored outside the government system to supervise the behavior of economic subjects. *The research results of Blackman and Bannister (1998) show that community environmental pressure formed by local organizations is positively correlated with economic actors' efforts to improve technological innovation ability, even though adopting green technology will increase costs.* The concept of informal environmental regulation was first proposed by Pargal and Wheeler (1995). It refers to the negotiation or negotiation between the public, media and social groups and polluting enterprises to reduce pollution and protect the environment. They include complaints and charges from residents, protests between people and polluting enterprises, pressure from public opinion, boycotting products of polluting enterprises, etc. (Su Xin, Shengshi Zhou, 2019).Environmental attention of both ordinary people (the public environmental protection demands) or the transparency of social public opinion to the disclosure of environmental pollution (environment information disclosure), are virtually to the government and pollutant discharging enterprises has brought great pressure, the pressure is turned into a stream of influence more and more "informal" environmental regulation (Yuan Xu, 2014).At present, the Chinese government mainly uses formal environmental regulations to restrain economic entities' pollutant discharge behavior. Among them, command-and-control environmental regulations include environmental Protection Law of the People's Republic of China and other relevant laws, environmental impact assessment system and "three simultaneous" system in the new five systems and the old three systems (Yumin Zhao, Fangming Zhu and Lilong He, 2009);Market-based incentive environmental regulations include sewage charges (1991), credit incentives (1996), total SO2 emission control and emission trading policies (2002), etc.

3. Mechanism discussion

In theory, appropriate environmental regulation will stimulate enterprises to carry out technological innovation, thereby reducing costs, improving product quality, and offsetting the increase of environmental protection costs caused by environmental regulation, which is likely to improve the international competitiveness of domestic enterprises. It can be concluded that environmental regulation mainly affects the technological innovation level through affecting marginal cost, resource reallocation and green subsidy:

First, marginal cost. Cost pressure of pollution control is the main driving factor for enterprises to carry out technological innovation (Pingping Liu, 2016).When enterprises choose pollution emission level, they mainly consider two factors: marginal pollution cost reduction and expected marginal

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pollution penalty level (Fugui Li, Xiong Bing, 2005).To improve the intensity of environmental regulation, the government raises the expected marginal pollution penalty level of enterprises by means of sewage charges and sewage permits, internalizes the externalities into the production costs of enterprises, and tries to keep the cost of enterprises consistent with the social cost, so as to finally achieve the purpose of restricting enterprises' pollutant discharge behavior. For enterprises with profit maximization as the objective function, there are usually two ways to reduce the cost of environmental protection: one is to improve pollution control technology and strive to control the discharge of pollutants within a reasonable range to meet the requirements of environmental regulation; The second is to improve productivity and speed up technological innovation so as to increase resource utilization efficiency, reduce product costs and expand profit margins, thus offsetting the costs of environmental governance. In either way belong to technical innovation behavior, the promotion of technological innovation is to promote the whole society, that is to say, high intensity of environmental regulation can trigger the ‘innovation’ effect of polluting enterprises, make the environmental regulation effect in the economic growth by ‘short-term losses’ to ‘long-term returns’ (tong-bin zhang, 2017).

Second, resource reallocation. From a deeper perspective, formal environmental regulations promote the improvement of technological innovation level by influencing the reallocation of resources. Appropriate environmental regulations can "force" industrial structure to adjust and upgrade (Zhong MAO, 2015).Because the marginal cost of environmental protection is different in different industries, when the government continuously improves the intensity of environmental regulation to the "inflection point" level, resource-intensive, pollution-intensive enterprises and poorly managed small enterprises cannot bear the rising cost of pollution control, and will reduce the scale of production until they exit the market. Environmentally friendly enterprises and enterprises with high production efficiency bear less pollution control pressure and have the advantage of "green development". Industrial structure in the region tends to be optimized and market concentration degree increases (Zhang Cheng et al., 2011).Formal environmental regulations eliminate backward capacity and transfer excess capacity, so that factors of production flow from previous enterprises to environment-friendly and high-productivity enterprises, which alleviates the problem of resource mismatch caused by distorted subsidy policies (Han Chao et al., 2017), reallocating resources and improving the efficiency of resource use. The remaining competitive enterprises tend to pay more attention to improving productivity and expanding profit space through technological innovation.

Third, government subsidies. When the government improves the intensity of environmental regulation, it tends to give some preference to fiscal and industrial policies to provide support for enterprises' technological innovation by means of capital investment and talent introduction (Fuxin Jiang et al., 2013).In order to achieve environmental protection and change the past "pollution first, treatment later" extensive development mode, the government will formulate more stringent environmental regulations. As mentioned above, strict environmental regulations will increase the environmental protection cost of enterprises to a certain extent, and some enterprises with high pollution and high energy consumption or small scale will therefore face higher environmental protection pressure. Due to the lack of green innovation funds, some enterprises may choose to move to areas with low environmental target constraints, reduce production scale or even withdraw from the market, which is contrary to the original implementation purpose of environmental regulations, resulting in "distortion" of environmental regulation policies. In order to achieve sustainable and healthy economic development and environmentally friendly and green growth, the government will provide support for technological innovation from various aspects including human resources and capital. Since the system reform in 1985, the Chinese government has attached great importance to the investment in scientific and technological innovation. With the in-depth promotion of the strategies of "rejuvenating the country through science and education", "independent innovation" and "innovation-driven", the government has gradually increased its support for technological innovation. According to statistics, government spending on science and technology grew rapidly from 5.2 billion yuan in 1978 to 838.36 billion yuan in 2017, a considerable proportion of which was used to subsidize enterprises for technological innovation. To some extent, government subsidies reduce the financial pressure of enterprises' technological innovation, which is conducive to the improvement of the technological innovation level of the whole society (Pingfang Zhu and Weimin Xu, 2003;Xuezheng Qin et al., 2012).To sum up, this paper argues that environmental regulation promotes technological innovation by influencing marginal cost, resource reallocation and green subsidies.

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4. Research and analysis

4.1. Samples and variables

The sample used in this paper is panel data of 31 provinces and cities in China from 2015 to 2017. The proportion of energy conservation and environmental protection expenditure and patent data come from China Statistical Yearbook, China Statistical Yearbook of Science and Technology and related public websites. Based on the practice of Guo Jin (2019), this paper measures the intensity of environmental regulation by taking the proportion of local energy conservation and environmental protection expenditure in general public budget expenditure. In addition, the number of patent grants is selected to measure regional technological innovation level. Patent index can better measure the r&d strength and original innovation ability of a region, and is often used to measure the level of regional technological innovation in current studies. Patents include invention, utility model and appearance design patents, among which invention patent can better reflect the quality of regional patents (Fengchao Liu, Xiongfeng Pan, 2006).

4.2. Research and analysis

In 2017, the proportion of energy conservation and environmental protection spending in China's general public budget (data for Hong Kong, Macao and Taiwan are not available) shows that Beijing and Hebei have the highest proportion of energy conservation and environmental protection spending, followed by Heilongjiang, Ningxia, Chongqing and Qinghai. Due to the particularity of Beijing's administrative status, more attention is paid to environmental problems, and the expenditure on energy conservation and environmental protection is usually higher. As an area with a high concentration of heavy industry, Hebei province has a serious environmental pollution problem and needs more investment in environmental protection. Therefore, energy saving and environmental protection expenditure accounts for a high proportion in the government's general public budget expenditure. In addition, Heilongjiang, Ningxia, Chongqing and Qinghai are regions with special geographical characteristics and relatively fragile ecological environment. Therefore, the local government pays high attention to the environment and spends a lot on ecological maintenance, energy conservation and environmental protection. From the change of the proportion of energy conservation and environmental protection expenditure in general public budget expenditure in each region from 2015 to 2017 (data from Hong Kong, Macao and Taiwan are missing), it is easy to see that the eastern and central regions generally show a positive growth trend, and the growth is more obvious in the eastern regions, especially Beijing, Tianjin and Shanghai. Eastern and central regions, especially coastal areas is the area that our country economic development level is higher, and the high speed development of economy is often at the expense of the environment of the sacrifice, everywhere to realize "first pollution, then control the path of" is hard to walk through, pay more attention to the green environmental protection technology to realize the economic sustainable development, energy conservation, environmental protection expenditure scale expands unceasingly, therefore, It reflects the continuous improvement of the intensity of environmental regulation.

In terms of the number of patents granted per capita in each region in 2017, it can be seen that Beijing has the highest level of technological innovation, followed by the Yangtze River Delta and Guangdong. These regions have a higher level of economic development, more concentrated innovation factors, and people have higher requirements for quality of life. Therefore, environmental regulation has a significant role in promoting technological innovation. In addition, from the perspective of invention patents, Beijing, Yangtze River Delta and Guangdong have more invention patents granted per capita, which is consistent with the above analysis. More intuitive to reflect the regional patent authorization number three composition, around three per capita in 2017 patent authorization number composition, it can be seen that invention patents authorization of eastern coastal developed areas is significantly higher than the Midwest, especially in places such as Beijing, Shanghai, liaoning invention patent grant accounts for more than 30%, embodies the high level of technological innovation, From the change of patent authorization per capita from 2015 to 2016, it is not difficult to find that the eastern region not only has a large base but also maintains a good positive growth trend, reflecting the continuous improvement of technological innovation level. Based on the above analysis, this paper believes that appropriate environmental regulation can help improve the level of technological innovation to a certain extent, which is consistent with the theoretical mechanism analysis mentioned above.

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5. Conclusions and policy implications

In order to avoid falling into the vicious circle of "economic growth-environmental deterioration", strengthening environmental regulation, carrying out green innovation and transforming extensive economic development mode have become the internal requirements for achieving high-quality economic development. In order to speed up the environmental protection work, we should give full play to the restraint effect of various environmental regulation means on pollution behavior. Based on the analysis of provincial level data, this paper concludes that: (1) appropriate environmental regulation can improve the level of technological innovation, which supports the porter hypothesis;(2) Environmental regulation is to encourage enterprises to adopt cleaner technologies by increasing the expected punishment level of enterprises, reallocating social resources, and providing green subsidies for high-tech industries and new energy industries, so as to improve the technological innovation level of the whole society. The research conclusions of this paper contain strong policy implications. In order to achieve a win-win situation between "environmental protection" and "technological innovation", the following policy recommendations are put forward:

At the current stage, we can appropriately increase the intensity of environmental regulations such as fiscal expenditure for energy conservation and environmental protection. The research of this paper finds that the fiscal expenditure of environmental protection has a certain promoting effect on technological innovation, which is the same as the conclusion of most domestic studies. At the same time, the statistical data also found that the proportion of energy conservation and environmental protection expenditure in the general public budget expenditure in most provinces of China is relatively low, reflecting the overall low intensity of environmental regulation. Therefore, it is necessary to gradually increase the proportion of fiscal expenditure on energy conservation and environmental protection in general public budget expenditure, and timely increase the intensity of environmental regulation, so as to realize the internalization of external costs of polluting enterprises and promote green technology innovation.

While strengthening environmental regulations, emphasis should be placed on the implementation of regulatory measures. Governments at all levels play an important role in the implementation of environmental regulation policies. On the whole, the implementation of environmental regulation policies in China has achieved certain results, but there are also "formality", covering up the pollution behavior of enterprises that contribute a lot to local finance, leading to the "distortion" of environmental regulation policies. Therefore, governments at all levels should pay attention to the practical promotion of environmental protection while formulating environmental policies in line with local conditions, and governments at higher levels should properly supervise the implementation of policies at lower levels to build a complete environmental protection system.

Increase government spending on science and technology to provide financial support for enterprise innovation. The above analysis shows that strict informal and formal environmental regulations will squeeze the funds used by enterprises for technological innovation to a certain extent. In order to coordinate with the smooth implementation of environmental policies, it is necessary for the government to vigorously support enterprises to carry out green innovation through fiscal policies and industrial policies. Since the reform and opening up, the proportion of science and technology investment in China's financial expenditure has been increasing, but there is still a certain gap compared with developed countries. In order to improve the level of technological innovation, the government can provide green subsidies and tax reductions for enterprises' R&D activities, and shorten the period for enterprises to realize "innovation compensation". At the same time, differentiation policy should be implemented, and fiscal subsidies and preferential policies should be appropriately inclined to key industries, high-tech industries and large enterprises with higher production level, so as to give full play to the scale effect of technological innovation of large enterprises.

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