

# Selection of Environmental Regulation Tools Based on Technological Innovation

Taking the Provincial Panel Data Analysis of Southwest China as an Example

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**Abstract**—Based on the relationship between environmental regulation tools and technological innovation, this paper first clarifies and restates the interaction between environmental regulation and technological innovation, and theoretically points out that appropriate environmental regulation tools are conducive to technological innovation. Then data is used to describe the current technological innovation and the use of environmental regulation tools in Southwest China (Chongqing, Sichuan, Guangxi, Yunnan, Guizhou); the data of Southwest China in 2005-2013 is used, and the impact of different regulation tools on the technological innovation in the Southwest China is empirically analyzed with panel data regression model based on perspectives such as command-control, market-incentive and invisible environmental regulation tools. The empirical results show that market-incentive environmental tools have a significant positive impact on technological innovation in Southwest China, and there is no positive correlation between command-control environmental regulation tools and invisible environmental regulation tools and technological innovation. For such empirical results, it is suggested to accelerate marketization and promote market incentive tools to play a greater role; improve command-control environmental regulation policies, improve their impact on technological innovation; promote public participation, and play the role of invisible environmental regulation tools.

**Keywords**—*technological innovation; environmental regulation tools; panel data regression*

## I. INTRODUCTION

In recent years, China's environmental pollution and ecological imbalances have become increasingly serious, and caused widespread concern. As the prevention and control of pollution is listed as one of the three uphill battles in China, exploring how to carry out effective pollution prevention has become an increasingly important issue of academic concern. Effective pollution prevention and control emphasizes more on reducing pollution through technological innovation. At the same time, the effects of pollution prevention and control have also shown fairly significant regional imbalances. Although China's industrial pollution control performance has improved rapidly, many studies have recognized that the industrial pollution control performance in the Southwest

China is much lower than that in other regions of the East. Under the background of obvious regional imbalances in China's environmental regulation and technological innovation, it is particularly important to carry out long-term pollution prevention measures in the Southwest China. In this context, this paper explores the selection of environmental regulation tools to achieve "effective pollution prevention" based on the relationship between environmental regulation and technological innovation. In order to answer this question, it is necessary to effectively evaluate the environmental regulation means and tools in the past. In the second part, the paper firstly expounds the relationship between environmental regulation and innovation; in the third part, the paper describes the status quo of environmental regulation and technological innovation in the Southwest China; in the fourth part, the paper empirically tests the effectiveness of current environmental regulation tools in the Southwest China, and proposes the selection of environmental regulation tools for the Southwest China.

## II. LITERATURE REVIEW

The impact of environmental regulation on technological innovation has always been a hot topic in academic circles. In general, environmental regulation has a positive compensation effect and a negative offset effect on technology innovation theoretically. Some studies believe that environmental regulation has a negative offset effect on technological innovation. Environmental regulation will affect the resource allocation of enterprises, and force enterprises to invest more funds in non-production parts such as clean environment, increase production costs of enterprises, form extrusion of R&D investment of enterprises, and reduce innovation ability of enterprises. Some other studies believe that environmental regulation has a positive compensation effect on technological innovation and promotes the emergence of technological innovation. The reason for the positive compensation effect is that environmental regulation increases the cost of environmental pollution, and leads technological innovation to develop towards clean energy, thus guiding enterprise innovation to develop towards technologies of reducing pollution.

Theoretical analysis shows that environmental regulation has two opposite effects on technological innovation. The dual benefit of environmental regulation and technological innovation is also concerned, that is, how to properly guide environmental regulation to gain a positive total effect of environmental regulation on technological innovation; at this point, the positive compensation effect is greater than the negative extrusion effect. Economist Porter first elaborated and investigated the impact of environmental regulation on technological innovation and environmental quality from the enterprise level. Subsequent studies sum it up as "the Porter-hypothesis". Porter believes that the rational design and utilization of environmental regulation tools can guide regulated enterprises to optimize resource allocation and promote technological innovation and R&D, so that the benefits brought by technological innovation can offset the negative impact brought by the cost of environmental regulation, and ultimately improve enterprise productivity and product competitiveness. Subsequent studies further improve "the Porter-hypothesis" from the perspective of local market failure, and provide a reasonable explanation for the introduction of environmental regulation policies. Studies have indicated that corporate decision-making behavior is controlled by its managers, but managers cannot always make all-rational decisions for various reasons (for example, corporate managers are not willing to bear the risk of R&D transformation as risk averters, or lead to bounded rationality of economic men due to the incomplete market information); as a result, under environmental regulations, enterprises have insufficient R&D on clean energy. Appropriate environmental regulations will help to improve local market failures, promote to increase investment in clean energy R&D, and promote technological innovation.

Although it is theoretically possible to draw the necessity of the introduction of environmental regulation policies, theoretical analysis also emphasizes that unreasonable environmental regulation may cause compensation effects to be greater than offset effects, and result in negative impacts of environmental regulation on technological innovation. This further emphasizes the importance of regional evaluation of the effectiveness of environmental regulation policies. A large number of empirical studies have evaluated the effectiveness of government's environmental regulation. Domestic and foreign scholars have carried out rich empirical studies based on different regions, and have found that three different relationships between environmental regulation and technological innovation exist simultaneously: 1. Environmental regulations in some regions inhibit the technological innovation capability of enterprises to some extent (at this point, compensation effect is less than the offset effect), for example, Denison (1981), Jiang Ke, Lu Xianxiang (2011), Wang Peng, and Guo Yongqin (2013) studied the environmental regulations of the United States, all Chinese provinces and central China, respectively, and found that these regions have formed excessive environmental regulations. 2. Environmental regulation in some regions can significantly promote technological innovation (at this point, the offset effect is greater than the compensation effect), for example, Berman and Bui (2001) and Ma Hailiang et al (2013) studied the air regulation in Los

Angeles and the economic environment regulation of the Yangtze River Delta, respectively, and found that the positive effect of environmental regulation through technological innovation exceed the negative effect caused by the increase in costs. 3. The impact of environmental regulation on technological innovation is uncertain (the offset effect is equivalent to the compensation effect). For example, the empirical research by Shen Neng and Liu Fengchao (2011) proves that there are regional differences in the promotion of technological innovation by environmental regulation. "The Porter-hypothesis" has received good support in the more developed eastern regions, while it's hard to get support in the lesser-developed central and western regions, which empirically verifies the existence of thresholds for environmental regulation and technological innovation.

At the same time, in recent years, more and more studies have emphasized the effective evaluation of current environmental regulation policies from the perspective of environmental regulation tools. Foreign researchers Weitzman (1974), Magat (1978), and Milliman & Prince (1989) have all found market-based economic incentive environmental regulation tools (such as sewage charges or tradable permits) and market-based economic penalty tools (such as taxation, etc.), which is can better stimulate the development of pollution control technologies than command-control regulation tools that stipulate a fixed amount of pollutants. Domestic studies have also increasingly emphasized separate inspection of command-control environmental regulation tools for different environmental tools, market-incentive environmental regulation tools and informal environmental regulation represented by environmental information disclosure (Wang Ling, 2012; Jia Ruiyue, Wei Jiuchang, Zhao Dingtao, et al., 2013; Yuan Yijun, Liu, 2013;). These studies have found that the role of different environmental regulation tools in technological innovation does have significant differences.

The previous research review suggests that the effects of environmental regulation on technological innovation have significant differences in regions and environmental regulation tools. In order to achieve a win-win situation of environmental regulation and technological innovation in the Southwest China, it is necessary to effectively evaluate the effects of different environmental regulations based on an in-depth understanding of environmental regulation tools in the Southwest China. Finally, appropriate environmental regulation tools are adopted, so that the compensation effect is greater than the offset effect, and the environmental regulation in the Southwest China promotes technological innovation.

### III. BASIC FACTS OF ENVIRONMENTAL REGULATION AND TECHNOLOGICAL INNOVATION IN SOUTHWEST CHINA

#### A. *Status Quo of Environmental Regulation in Southwest China*

There are many kinds of environmental regulation tools. Based on analysis, this paper divides the environmental regulation tools in Southwest China into three categories:

administrative command control, market incentive and invisible environmental regulations. Among them, command control and market incentive are formal environmental

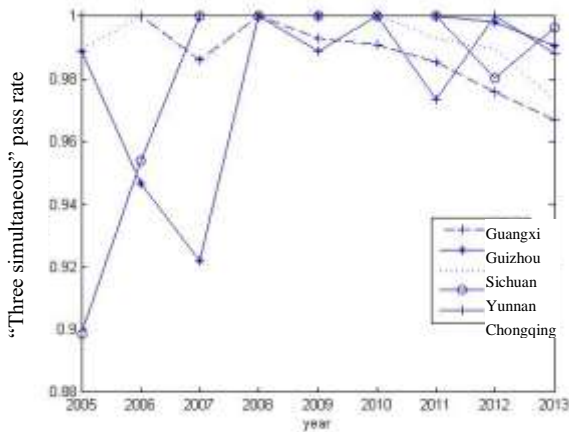


Fig. 1. Variation chart of time series of command-control environmental regulation tools in Southwest China.

1) *Status quo of Command-controlled environmental regulation tools (CER) in Southwest China:* Command-control environmental regulation means that legislative or administrative part directly intervenes in the emission behaviors in production and life according to relevant laws, regulations and technical standards. Command-control regulation tools can achieve rapid and measurable effects, and are effective in solving urgent environmental problems, but lack incentives for emission entities. The "three simultaneous" system is China's first environmental regulation system, which was first stipulated in the Provisions on the Protection and Improvement of the Environment in 1973. It requires that the pollution control facilities for development and construction projects must be designed, constructed and put into production simultaneously with the main project, which is a powerful means for China to improve the environmental barriers and prevent new sources of pollution.

This paper takes the "three simultaneous" implementation pass rate of each province in China as the command-control environmental regulation index, and the index data are all from the China Environment Yearbook (2006-2014). It can be seen from Figure 1 that the Southwest China has always adopted strict administrative control, and the pass rate of the "three simultaneous" is above 90% all year round; Yunnan and Chongqing can often guarantee a 100% pass rate of "three simultaneous"; it indicates that the command control regulations of Southwest China strictly enforce the environmental regulations.

2) *Status quo of market incentive regulation tools (MER) in Southwest China:* Market-based incentive environmental regulations mainly regulate or influence the emission behavior of market entities through tools such as price, tax, fees subsidy and credit. Domestic academic circles usually regard sewage charges as the most useful tool in

regulations, and public supervision is regarded as invisible environmental regulation.

environmental regulation. This paper measures the intensity of market incentive regulations in the Southwest China based on per capita sewage charges. The sewage charges in the southwestern provinces in 2005-2013 are from China Environment Yearbook (2006-2014). According to the situation of sewage charges, the gap in the Southwest China is not large, and the sewage charges in Sichuan Province have still increased steadily; on the contrary, the sewage charges in Guangxi Province dropped from a relatively high level in 2005 and 2006 to a relatively low level. This indicates that the fierce market-based policies still have ample room to play in the Southwest China.

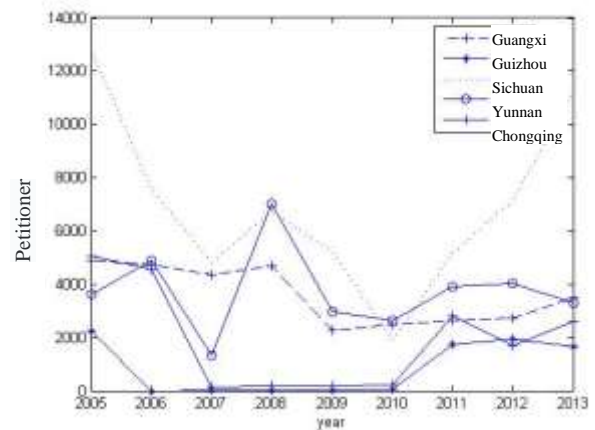


Fig. 2. Variation chart of time series of market-incentive environmental regulation tools in Southwest China.

3) *Invisible environmental regulation (IER):* The public can supervise and exert pressure on the entities of environmental destruction, and they also make an important force to promote the correct formulation and effective implementation of environmental policies, therefore becoming an important force in environmental regulation. Considering the availability of data, this paper selects the environmental petitions of various provinces and regions in China as indicators to measure the degree of public environmental participation. The indicator data come from the China Environment Yearbook (2006-2014). The number of petitioners in Sichuan has always been in a leading position, followed by Yunnan and Chongqing. The invisible environmental regulations in Guizhou and Guangxi are the worst. Even in some years, there were only ten petitions. However, the overall time series shows certain U-shaped characteristics, which indicates that as an invisible environmental regulation, the public participation has certain volatility in these provinces, and that the public have actively participated in environmental regulation activities. This is a slightly favorable signal, indicating that more and more people are starting to join in the supervision of

environmental regulation as an invisible regulatory force. On the whole, it can be seen that Sichuan, Chongqing and Yunnan that have stricter market regulations are also at the forefront of innovation activities.

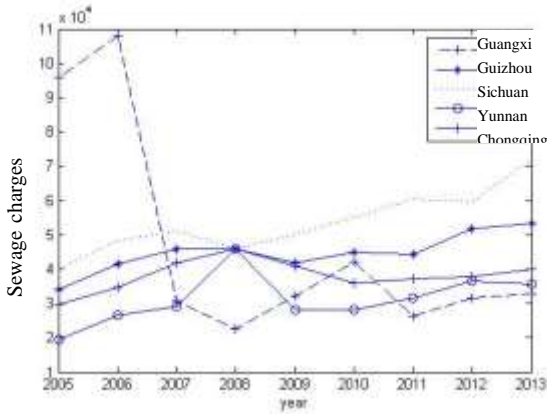


Fig. 3. Variation chart of time series of invisible environmental regulation tools in Southwest China.

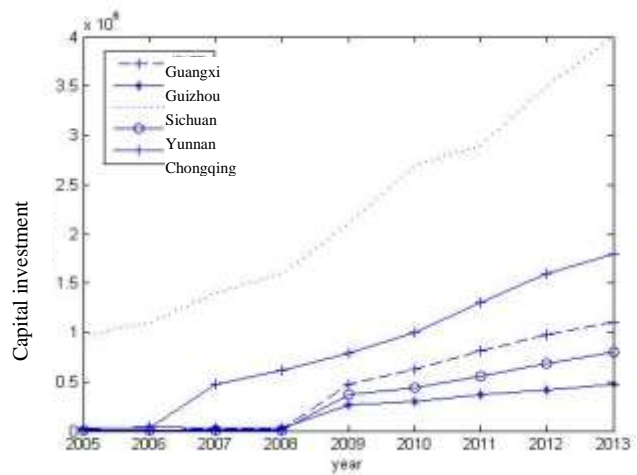
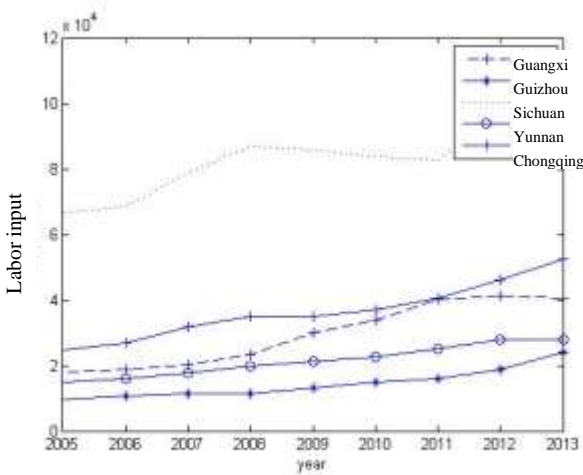


Fig. 4. Variation chart of time series of technological innovation output in Southwest China.

2) *Southwest China*: The amount of patent authorization can objectively reflect the original innovation capabilities and comprehensive scientific & technological capabilities of a region; besides, among various research and development, the patent data is comprehensive and available. This paper selects patents as the measurement index of technological innovation output. At the beginning, the gap among the five provinces in Southwest China was not large; however, Sichuan continued to maintain a high patent growth rate, and it was far ahead of other provinces by 2013; the development of innovation activities in Guangxi and Guizhou was seriously lagging behind, Yunnan remained basically stable low-speed growth, and Chongqing also started to improve rapidly from 2008.

B. Status Quo of Technological Innovation in the Southwest China

1) *Measurement of investment in technological innovation*: The investment in technological innovation mainly includes two indicators: capital investment K and labor input L in technological innovation activities. Capital investment is measured by the internal expenditure from the research and experimental development funds of research and development institutions, and labor input is measured by the full-time equivalent of research and development personnel.

It can be seen from the figure that Sichuan's capital investment and labor input are far ahead of other provinces, which partly explains that one of Sichuan's high growth driver is from its investment; Chongqing is second only to Sichuan, and the three provinces began to rapidly increase their capital investment in 2009.

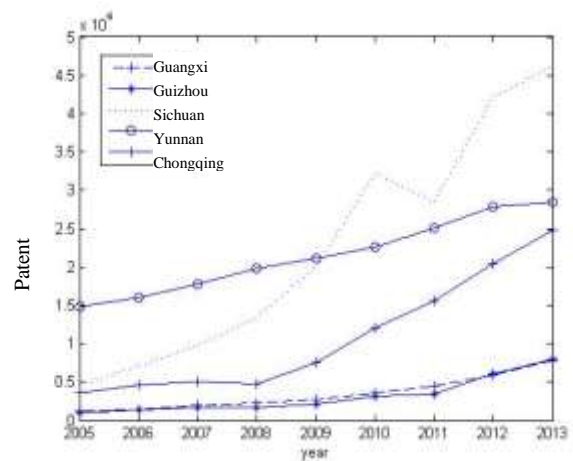


Fig. 5. Variation chart of time series of technological innovation output in Southwest China



**IV. EMPIRICAL ANALYSIS OF ENVIRONMENTAL CONTROL TOOLS AND TECHNOLOGICAL INNOVATION**

This part evaluates the effectiveness of environmental regulation tools. A panel data regression model for the relevant data of the five southwestern provinces (Sichuan, Guangxi, Guizhou, Yunnan, Chongqing) is established as follows.

$$\text{patents} = f(L, k, CER, MER, IER)$$

TABLE I. REPORT ON THE REGRESSION RESULTS OF ENVIRONMENTAL REGULATION TOOLS AND TECHNOLOGICAL INNOVATION

Patents	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
L	28755.76	9165.757	3.14	0.004	10128.7 47382.82
K	-1152.161	1398.153	-0.82	0.416	-3993.551 1689.228
CER	-32303.87	52308.14	-0.62	0.541	-138606.8 73999.05
MER	-130.6581	918.3733	-0.14	0.888	-1997.017 1735.701
IER	.1438616	.0730725	1.97	0.057	-.0046396 .2923627
_cons	-275292.8	77978.79	-3.53	0.001	-433764.8 -116820.9

<sup>a</sup>. F test that all u<sub>i</sub>=0: F(4, 34) = 13.04 Prob > F = 0.0000

The empirical results indicate that in Southwest China, the labor input in innovation investment is significant within 0.01, and the increase in labor input will significantly increase the scientific and technological innovation achievements; however, the effect of capital investment on scientific and technological innovation is not statistically significant, and the reason may lie in the excessively extensive capital investment, ignoring the introduction of technical talents. On the other hand, in terms of the use of environmental regulation tools, the market incentive regulation tools represented by sewage charges have played a significant positive role, which indicates that it is very necessary for the backward areas in Southwest China to vigorously strengthen marketization and implement market-incentive environmental regulation tools; however, administrative measures and invisible environmental regulation with spontaneous public participation do not play a significant positive role. Combined with the previous analysis, the possible reason is that Southwest China has carried out strict “three qualification” administrative measures, but such strict administrative measures have not led to an increase in innovation activities; at the same time, public participation is seriously inadequate, and invisible environmental regulation has not yet played a significant role.

**V. CONCLUSION**

Based on the empirical research regression results, it can be seen that it is very necessary for the backward areas in Southwest China to vigorously strengthen marketization and implement market-incentive environmental regulation tools; however, administrative measures and invisible environmental regulation with spontaneous public participation do not play a significant positive role. This means that Southwest China should use appropriate environmental regulation tools to promote technological innovation, and improve the environmental regulation tools in Southwest China based on the evaluation results of the environmental regulation tools’ effect on technological innovations. Specifically, the following measures should be

Where patents represent innovation output variables, L and K represent innovation input variables, and CER, MER, and IER represent command-control environmental regulation tools, market incentive environmental regulation tools and invisible environmental regulation tools, respectively. A fixed effect model is selected in the hausman test of the panel data regression results of this paper, and the report results are shown in "Table I".

taken: accelerating the process of marketization, creating a good environment for the effective implementation of market-incentive environmental regulation tools; improving the command-control environmental regulation policy; improving the public awareness of environmental protection in the western region and giving play to invisible environmental regulation. In addition, continuing to increase investment in technological innovation is also an option.

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