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Will Environmental Regulation Narrow the Gap in Regional Economic Growth?

Based on the Perspective of Resource Endowment Differences

Yuping Shang, Shanghai University of Finance and Economics, China
Shengnan Wu, Shanghai University of Finance and Economics, China
Fachuan Zheng, Shandong University of Finance and Economics, China

ABSTRACT

Empirical studies have shown that China's Air Pollution Prevention and Control Law (APPCL2000), as an environmental regulation, has significantly alleviated the air pollution problem and improved the TFP of air polluting enterprises. However, few scholars have studied the regional heterogeneity of this policy. To study this issue, this manuscript introduces the "Hu Line" from the perspective of regional resource endowment differences and divides China into a resource advantaged area (A area) and a resource disadvantaged area (B area). Subsequently, this manuscript uses the triple difference model and big data of Chinese industrial enterprises to verify. The results show that under environmental regulations, the TFP of air polluting enterprises in B area has increased more than in A area, and the rapid decline in the proportion of low-efficiency air polluting enterprises in B area is the main mechanism. It shows that environmental regulation is beneficial to narrow the gap of regional economic growth and realize economic catch-up in resource-disadvantaged areas.

KEYWORDS

Environmental Regulation, Hu Line, Resource Endowment Differences, Total Factor Productivity, Triple Difference Model

1. INTRODUCTION

As is known to all, since the reform and opening up in 1978, China has achieved rapid economic development relying on resource endowments and labor advantages (Cui et al., 2021). However, the resource-intensive economic development pattern caused high emissions and serious pollution problems (Wang et al., 2020). According to the "BP World Energy Statistics Yearbook 2020", as of 2019, the economic growth of China is still driven by energy, accounting for more than 3/4 of the global net growth. At the same time, China's carbon emissions caused by energy consumption have increased by 0.5%, and environmental governance is facing huge challenges (Cheng et al., 2020). To achieve the goal of sustainable economic development, the Chinese government has intensively adopted a variety of environmental regulation policies. A large number of studies have proved that the environmental regulation is an important mean for the government to control environmental pollution, which can also increase the total factor productivity (TFP) of enterprises. And therefore,

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the Chinese government has continuously strengthened the environmental regulations to achieve sustainable economic development as soon as possible. However, some people have voiced opposition from the perspective of balanced regional development. They claimed that China has a vast territory and there are obvious regional disparities, so the environmental regulations should be adapted to local conditions. For example, advantageous areas with good foundation for economic development and a high concentration of production factors can well avoid the problem of increased production costs for enterprises when facing environmental regulations. However, disadvantaged areas with poor economic development foundation and low concentration of production factors are unable to cope with the external pressure brought by environmental regulations, which means that the production cost of enterprises is rising and the production efficiency is declining. In this case, the gap of regional economic growth will continue to grow. From agglomeration economy perspective, the agglomeration economic effect is an important driving force for improving the TFP of enterprises. In the context of national unified environmental regulation, the agglomeration effect of advantageous areas shows three mechanisms, which are “sharing”, “matching” and “learning”. In the face of the same external shocks, they can maintain lower production costs, especially help polluting enterprises resist shocks. Zhao et al. (2019) believed that the pollution reduction has spatial economies of scale, and agglomeration can reduce the costs of pollution control and management. Therefore, under the national unified standard of environmental regulations, enterprises in advantageous areas may show higher TFP, which will widen the TFP gap between enterprises in different areas. Some people proposed to implement loose environmental regulation in disadvantaged areas to alleviate the regional diaparty. To test this advice, this paper examined the regional heterogeneity of environmental regulations on the TFP of enterprises under the framework of agglomeration economics. It is of great significance for developing countries to better balance regional development while making use of environmental regulations to “force” enterprises to develop. In particular, China is currently focusing on large-scale industrial transfer. A large number of high-polluting and low-efficiency industries has gradually shifted from advantageous eastern coastal areas to inland disadvantaged areas. Whether inland areas should implement loose environmental regulations and accept low-efficiency and high-polluting enterprises has always been a hot topic.

Based on existing literature, traditional classical economic theories and early empirical studies indicated that strict environmental regulations increased the costs of pollution control and reduced the competitiveness and productivity of firms. For example, Gray (1987) studied 450 manufacturing data from 1958 to 1978 and found that the Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA) in the US had significantly reduced the enterprises’ productivity. This conclusion explained 30% of the decline in US manufacturing productivity in the 1970s. Jorgenson & Wilcoxen (1990) found that the costs of controlling emissions in the US from 1973 to 1985 exceeded 10% of the government’s total costs of purchasing goods and services, resulting in a 19.1% decrease in the gross national product. Based on the research of Gray (1987), Barbera & Mcconnell (1990) replaced the measurement method of environmental regulation and proposed that the impact of the environmental regulations on TFP explained 10%-30% of the decrease in manufacturing productivity in the US in the 1970s, using the data of five high-pollution industries (such as papermaking and chemical industry). However, the “Porter effect” systematically explained the “win-win” relationship between environmental protection and economic growth, which attracted widespread attention. Porter & Linde (1995) highlighted that the environmental regulations actually imposed the pressure of innovation on enterprises, which was conducive to the technological improvement of enterprises. Moreover, the innovation effect exceeded the cost effect, thereby improving the productivity and competitiveness of enterprises. Berman & Bui (2001) compared the productivity difference between refineries with and without the environmental regulation during 1987-1992 by using the double difference (DID) method. They found that the productivity of refineries without the environmental regulation decreased while that of refineries with environmental regulation rose sharply. Lanoie et al. (2008) also verified the positive effect of the environmental regulation by empirically studying the relationship between the environmental regulation and TFP in Quebec's manufacturing industry. Hamamoto (2011) took a new program launched in Japan to improve the energy efficiency of household appliances and automobiles as a natural experiment to analyze its impact on the R&D behavior of enterprises. It was found that the introduction of this program significantly increased the R&D expenditure of household appliances enterprises by 9.5%.

Concurrently, the research on the "emission reduction effect" and "growth effect" of China's environmental regulation policies has also attracted extensive attention in academic field. Qi et al. (2015) and Qi et al. (2016) evaluated the "win-win" effect of the environmental regulation through structural equation method and DID method, respectively. Additionally, Li & Weng (2014), Qi et al. (2016), and Xu & Qi (2017) confirmed the existence of the "growth effect" of the environmental regulation based on China's provincial data and industrial enterprise data. However, Xu & Qi (2017) found that China's environmental regulations reduced the productivity of enterprises by reducing innovation ability, increasing intermediate costs and weakening financing constraints. It is obvious that whether the environmental regulations improve the TFP of enterprises or not has always been one of the core propositions in the field of environmental economics. Furthermore, from regional heterogeneity perspective, there is still no literature specifically discussing the regional heterogeneity of environmental regulation on TFP and its influencing mechanism, but only preliminary consideration of regional heterogeneity phenomenon. Cai & Ye (2020) evaluated the impact of environmental regulations on TFP based on the natural experiment of China's New Environmental Protection Law (NEPL). They found that NEPL had a significant hindering effect on enterprise TFP, and the market competitiveness and higher government efficiency were beneficial to alleviate the negative impact of NEPL. Peng et al. (2021) explored four choices of Dual Target Enterprise Environmental Behaviors (DTCEB) for heavy polluting enterprises, namely alienating, conservative, contradictory and intimate environmental behaviors. The results of regional heterogeneity indicated that the eastern region should strengthen public participation, the central region should increase incentive tax rate preference, and the western region should strengthen legislation. The above studies have preliminarily proved that there is regional heterogeneity in the impact of environmental regulation on TFP, but the detailed empirical analysis and mechanism test need to be further worked out.

From the perspective of agglomeration economics, some scholars concluded that pollution reduction exhibited spatial scale effect and the agglomeration effect could reduce the governance and management costs of pollution reduction (Zhao et al., 2019; Wang & Wheeler, 2005; Qi et al., 2016). The gathering of a large number of enterprises is conducive to the exchange of knowledge and skills among workers, which can promote the enterprise productivity (Ciccone & Hall, 1996). In addition, agglomeration facilitated the imitation of technology and knowledge among enterprises, which is good for improving enterprise productivity (Yamamura & Shin, 2007; Tveteras & Battese, 2006). Li & Chen (2013) pointed out that APPCL2000 alleviated the air pollution problem and significantly improved the TFP of air pollution-intensive industries. It can be found that when studying the impact of environmental regulations on enterprise TFP, it is necessary to focus on air pollution-intensive enterprises, rather than the entire industry. The research of Cailou et al. (2021), Hu et al. (2021), and Lin et al. (2021) also confirmed that it was of great importance to select polluting enterprises as samples in the study of environmental regulations. However, based on the existing literature, few scholars have studied the heterogeneity effect of the policy on the TFP of air pollution-intensive enterprises in different regions and its impact mechanism (Zhang et al., 2020). Considering different endowments in different regions, we introduces the "Hu Line" and divides China into a resource-advantage area (A area) and a resource-disadvantage area (B area) (Hsieh & Klenow, 2009). Owing to differences in natural resource endowments, B area is at an unfavorable position in terms of population agglomeration and economic growth. Referring to the previous research, we still regard APPCL2000 as a quasi-natural experiment in environmental regulation (Zhang et al., 2020), and use TFP (Hsieh & Klenow, 2009) as a proxy variable of economic growth. Subsequently, we use the big data of Chinese industrial enterprises and the triple difference model (DDD) to test the regional heterogeneity of APPCL2000 on the TFP of air polluting enterprises. Finally, under the framework of agglomeration economics, we prove that environmental regulations are conducive to narrowing the regional disparties and realizing economic catch-up in disadvantaged areas, and we refute the idea that environmental regulations in disadvantaged areas should be relaxed.

The main contributions of this paper are as follows. (1) We evaluate the regional heterogeneity of environmental regulation to TFP from the perspective of resource endowment, and answer the question of whether environmental regulation needs unified standards or local conditions through detailed theoretical and empirical models. (2) We take the APPCL2000 and the “Hu line” as quasi-natural experiments to effectively overcome the endogenous problem of the environmental regulation variables and resource endowment variables in the existing literature. (3) In terms of agglomeration economics and resource allocation efficiency, theoretical hypotheses are proposed, and the quantile regression methods are used to empirical test. The results show that the rapid decline in the share of polluting enterprises in disadvantaged areas is the main mechanism of the regional heterogeneity of the impact of environmental regulations on the TFP of polluting enterprises.

The paper is structured as follows. The next section focuses on theoretical mechanism and research hypothesis. Section 3 describes the quasi-natural experimental. Afterwards, we introduce the measurement model, data sources, and parallel trend. Subsequently, the empirical results are presented. In section 6, we describe the results of the mechanism. In the penultimate section, we further discuss the heterogeneity analysis results. The last section concludes the paper.

2. THEORETICAL MECHANISM AND RESEARCH HYPOTHESIS

Environment is a typical public good, so its consumption is non-competitive and non-exclusive theoretically (Shan & Wang, 2019). Enterprises will have problems with excessive environmental consumption without government supervision. Therefore, it is necessary for the government to implement environmental regulations to intervene in the production activities of enterprises, which could improve resource utilization efficiency and reduce pollution emissions. At present, relevant studies have preliminarily confirmed that environmental regulations can bring double benefits of “emission reduction effect” and “growth effect”. However, the government still encounters many practical problems when implementing environmental regulations. For environmental regulations in different regions, should we adopt unified standards or adapt measures to local conditions? This question has not been studied. For example, advantageous areas with a good foundation in economic development and a high concentration of production factors can well avoid the problem of increased production costs for enterprises when facing environmental regulations. However, disadvantaged areas with poor economic development foundation and low concentration of production factors are unable to cope with the external pressure brought by environmental regulations, which shows that the production cost of enterprises is rising and the production efficiency is declining. If things go on like this, it will widen the gap in regional economic growth.

From the perspective of agglomeration economics theory, scholars who support this view believe that relative to the scattered distribution of production resources, the concentration of them has agglomeration characteristics such as economies of scale and increasing returns to scale. Agglomeration can effectively save the production cost of enterprises and promote the centralized use of energy through mechanisms such as sharing, matching, and learning, which is conducive to improving the efficiency of resource utilization and thereby improving enterprise TFP. Kamal-Chaoui & Robert (2009) and Glaeser & Kahn (2008) all showed that increasing the urban economic density was beneficial to saving the production cost of enterprises. Glaser (2011) pointed out that cities with a high degree of agglomeration were more energy-efficient and environmentally friendly than areas with low economic density. The concentrated, high-density production and living methods can effectively reduce commuting time, promote knowledge spillover, and help improve enterprises TFP. As shown in Figure 1, according to the “Hu line” proposed by Mr. Hu Huanyong (Hu, 1935), China is divided into a resource advantage area (A area) and a resource disadvantage area (B area). Due to differences in natural resources, B area is at a disadvantage in terms of population agglomeration and economic growth[1]. After the implementation of the APPCL2000, the production costs of enterprises rose rapidly. However, A area exhibited lower production costs than B area, especially in polluting industries. As stated by Wang & Wheeler (2005), the environmental regulation was manifested as the increase of sewage charge rate and enterprises costs, but there was scale effect in pollution control. Furthermore, Lu & Feng (2014) explained the spatial scale effect of pollution reduction from the perspective of "core-periphery", and they found the agglomeration can reduce the governance and management costs of pollution reduction. In addition, Qi et al. (2016) mentioned that the effect of the environmental regulation was affected by factors such as the regional institutional environment and the degree of marketization. Therefore, we infer that the pollution reduction can display spatial scale effect, and the agglomeration can reduce the costs of enterprise.

On the contrary, another view holds that under the combined effect of environmental regulation and agglomeration, the economic growth gap in different regions may not be widen. The influence of environmental regulations on the regional heterogeneity of enterprise TFP depends on multiple forces. The growth effect of environmental regulation depends on the resource allocation effect. Environmental regulations can inhibit the entry of low-efficiency polluting companies or force them to withdraw, thereby improving the regional industrial structure and enterprise competitiveness. Sadeghzadeh (2014) and Andersen (2018) proposed that the environmental regulation could promote the transfer of production resources from low-productivity to high-productivity enterprises, effectively increasing industry productivity and promoting the efficiency of resource allocation among enterprises. Greenstone et al. (2012) and Konishi & Tarui (2015) also posited that the main mechanism of impact of the environmental regulation on enterprise productivity was the reconfiguration of production factors. Moreover, the theoretical and empirical results of Wang et al. (2019) both showed that the high-productivity enterprises produced more, while the low-productivity polluting enterprises exited the market under the environmental regulation. This effect was more obvious in the Midwest, but they have not explained this regional heterogeneity further. And therefore, we speculate that strict environmental regulations will inhibit the entry of low-efficiency polluting enterprises or force them to withdraw, thereby promoting the TFP. This mechanism can be more obvious in resource disadvantaged area and economically backward areas. In addition, due to the agglomeration effect, under the unified national environmental regulations, areas with inferior resources need to pay higher marginal pollution costs than those with superior resources, which will further inhibit the entry or exit of low-efficiency polluting enterprises. Therefore, under the framework of agglomeration economic effect and resource allocation effect, environmental regulation may not widen the gap of regional economic growth in different areas.

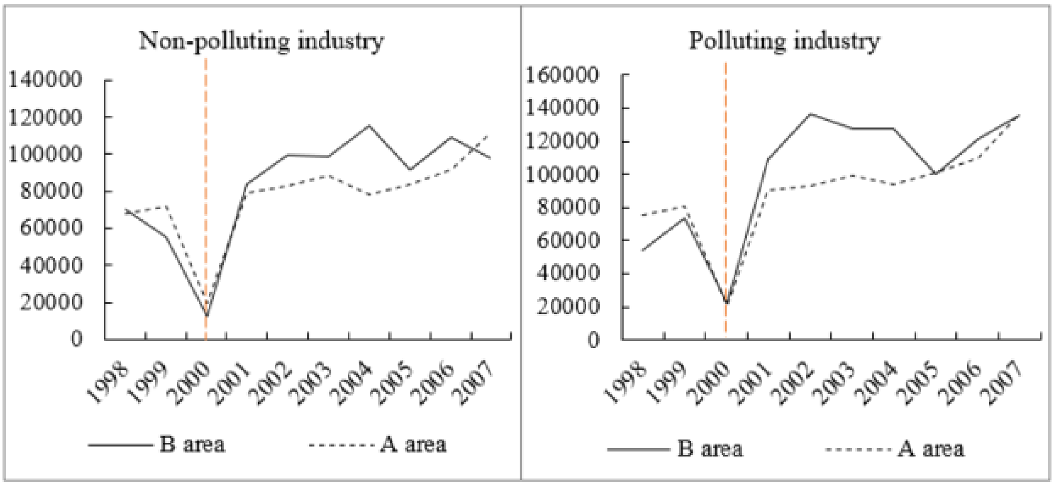
In summary, we propose two opposite hypotheses: Hypothesis 1 and 2, to be tested empirically:

Hypothesis 1: Maintaining unified environmental regulation standards will widen the gap of regional economic growth.

Hypothesis 2: Maintaining uniform environmental regulation standards will narrow regional economic growth disparty.

Note: the enterprises' production costs are measured by the sum of the enterprises' wage costs, total liabilities, management costs, and input of intermediate products.

Figure 1. The average production costs of enterprise



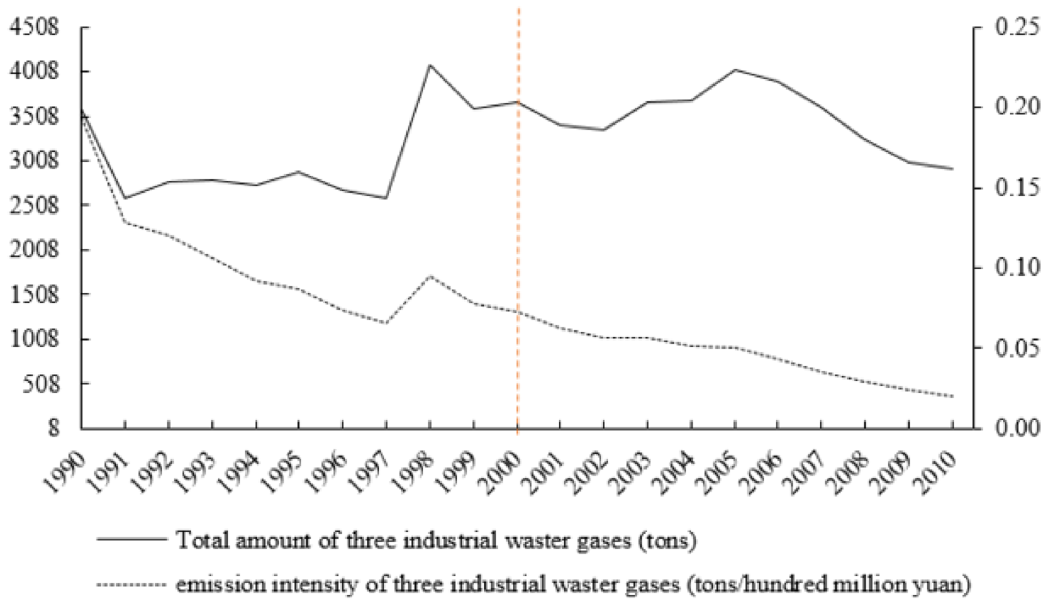
3. THE FACT OF QUASI-NATURAL EXPERIMENT

3.1. The Revision of China APPCL2000

China enacted the Air Pollution Prevention and Control Law in 1987 to protect the environment and promote sustainable economic development. So far, it has experienced three revisions in 1995, 2000, and 2015, which are referred to as APPCL1995, APPCL2000, and APPCL2015 in turn. Owing to the short effective time of the APPCL2015 and insufficient data, we focus on the APPCL2000, which is regarded as a quasi-natural experiment and a proxy variable of environmental regulation. Compared with the APPCL1995, the number of regulations in the APPCL2000 has increased from 50 to 66, and more specific provisions are made on executive subject, prohibited acts, and legal responsibilities. In terms of prohibited acts, the APPCL2000 has added a chapter "Prevention and Control of Waste Gas, Dust, and Odor Pollution", requiring enterprises to take protective measures when discharging waste pollutant gases such as dust, smoke and dust into the atmosphere. Moreover, the APPCL2000 has added penalties such as fines, production bans, and closures. For example, "Enterprises that adopt equipment prohibited from production, sale, import or use, or adopt processes prohibited from use, shall be ordered by the competent authorities of the city at the prefecture level and above to make corrections. If the circumstances are serious, the competent authorities shall report to the people's government at the same level to order the suspension of business in accordance with the authority prescribed by the State Council." The State Environmental Protection Administration revised a series of supporting policies and management regulations in 2000 on the basis of the APPCL2000, such as the National Ambient Air Quality Standard and the Comprehensive Emission Standard of Air Pollutants. Figure 2 shows the trend of three types of industrial waste gas (sulfur dioxide, soot, dust) emissions and emission intensity from 1990 to 2010 in China. It can be observed that the year 2000 is at a turning point. The industrial waste gas emissions dropped significantly, and emissions intensity of industrial waste gas also maintained a steady downward trend from 2001 to 2002, indicating that the APPCL2000 has achieved a significant emission reduction effect.

Note: Industrial waste gas emission intensity refers to the proportion of the amount of industrial waste gases to the base period (1990) real GDP.

Figure 2. Trends of total industrial waste gases emission and emission intensity



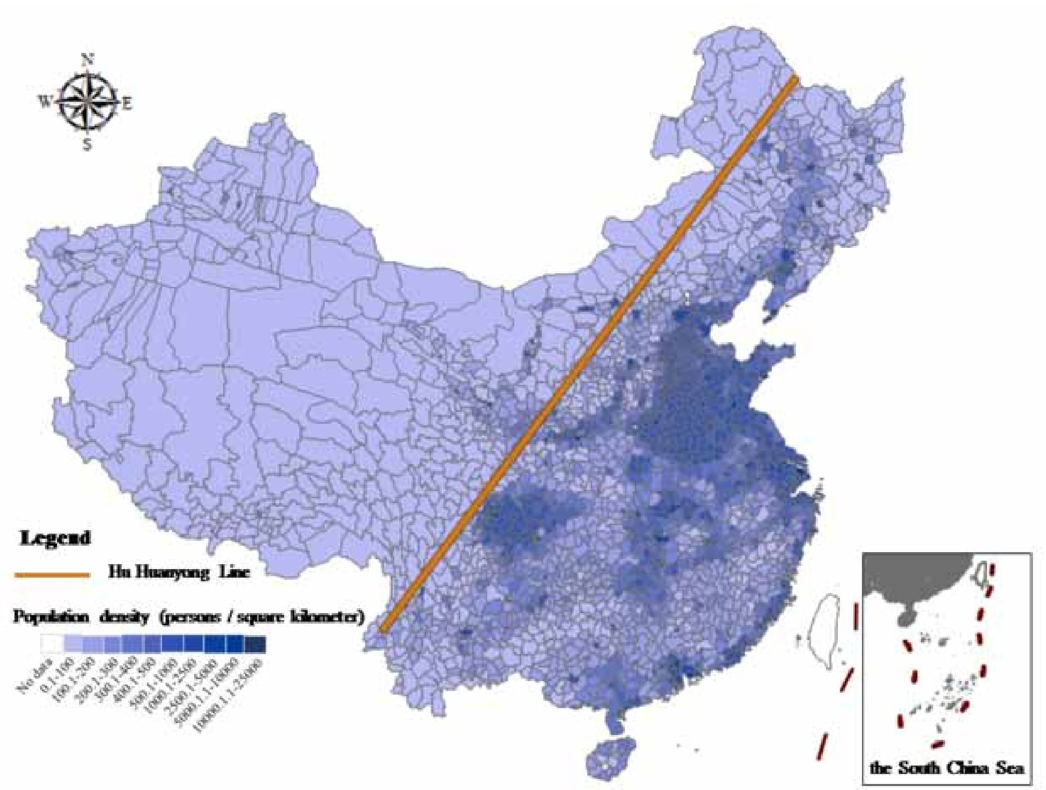
3.2. The “Hu line”

Since ancient times, it seems that China’s southeast have fewer land and more people, and northwest China has more people and fewer land. However, no one can provide strong evidence for this vague understanding. Hu (1935) first proposed the Aihui-Tengchong population geographic boundary (later called the “Hu line”) based on the population distribution map and population density map in 1935. China was divided into two regions according to the “Hu line”. The southeast area was four million square kilometers, accounting for about 36% of the country’s total area, and the northwest area was seven million square kilometers, accounting for about 64%. On the contrary, the population of the southeast was 440 million, accounting for 96% of the total population, and that of the northwest was 18 million, accounting for only 4%. This set of data clearly exhibited the pattern of uneven population distribution in China, and the “Hu line” has been always considered as an ecological line describing this phenomenon from then on. Because the “Hu line” is the boundary of an area suitable for human survival, the southeast of the line is dominated by plains, water networks, and hills, which are rich in natural resources and suitable for human survival and economic development. The northwest of the line is dominated by grasslands, deserts and snow-covered plateaus. The lack of natural resources becomes obstacles for human survival and economic development, so its main function is ecological restoration and protection. This paper verifies the “Hu line” based on county-level data from the 2000 census, as shown in Figure 3. It is worth emphasizing that the “Hu line” still exists nowadays. The population of the southeast is 1.17 billion, accounting for 94% of the total population, and the population of the northwest is 80.62 million, accounting for only 6% according to our calculations. Therefore, we take the “Hu line” as the geographical division standard, and divide China into the northwest and southeast areas. The northwest area of the “Hu line” is a resource disadvantaged area, and the southeast is a resource advantage area.

3.3. Polluting and Non-Polluting Industries

The environmental regulation is considered to have a major impact on the increase of production costs of enterprises in polluting industries, but a relatively small impact on the production costs of

Figure 3. The "Hu line" based on county-level data from the 2000 census



enterprises in non-polluting industry. Hence, when studying the effect of environmental regulation on the TFP of enterprises, it is necessary to introduce dummy variables of "polluting industries". We classify polluting and non-polluting industries based on SO2, smoke, and dust emissions[2]. We regard the industries whose waste gas emissions per unit output value exceed the average level of all industries in 2000 as polluting industries, while the others are non-polluting industries. As a result, food manufacturing industry (industry code: 14), beverage manufacturing industry (15), tobacco products industry (16), paper and paper products industry (22), petroleum processing, coking and nuclear fuel processing industries (25), chemical raw materials and chemical products manufacturing industry (26), non-metallic mineral products industry (31), ferrous metal smelting and rolling processing industry (32), non-ferrous metal smelting and rolling processing industry (33) are polluting industries, and the others are non-polluting industries. The polluting industries are treated as the experimental group and non-polluting industries as the control group.

4. METHODOLOGY AND DATA

Based on the theoretical mechanism and quasi-natural experiments, we use the data of Chinese industrial enterprises from 1998 to 2007 and the panel data of 286 prefecture-level cities from 1998 to 2007 for empirical test. Specifically, it is divided into three steps. First, we treat the APPCL2000 as a quasi-natural experiment, and assess the difference in the impact of environmental regulation on the TFP of enterprises on both sides of the "Hu line" through the DDD method. This is the test of hypothesis 1 and 2. Second, the mechanism of the regional heterogeneity of the impact of environmental regulations on TFP is explained through the data of enterprises, new enterprises and net increase enterprises in each prefecture-level city. Finally, we further discuss the heterogeneity, considering factors such as enterprise size, ownership, and age.

4.1. Model Specification

The policy evaluation articles usually adopt a DID model to evaluate the difference between the effects of the experimental and non-experimental samples before and after the implementation of the policy, which can eliminate the unobservable confounding factors that do not change with time. Presently, the frontier research of international environmental economics has introduced triple difference (DDD) based on dual difference, that is, time, region and industry are put into the same model, which can effectively solve the problem that the hypothesis of parallel trend of DID model is not valid. Based on the DDD model of Snyder et al. (2003) and Cai et al. (2016), we introduce industry pollution variables to evaluate the difference in the impact of the environmental regulation on the TFP of polluting enterprises on both sides of the "Hu line". The following regression models are set:

$$tfp_{ijrt} = \beta_0 + \beta_1 post_t \times geography_r \times pollution_j + \beta_2 post_t \times geography_r + \beta_3 post_t \times pollution_j + \beta_4 geography_r \times pollution_j + \rho X_{it} + \delta_r \times time + \gamma_j \times time + \varphi_r \times \mu_j + \varepsilon_{ijrt} \quad (1)$$

where *i, j, r*, and *t* represent the enterprise, industry, region, and year respectively. The interpreted variable (*tfp)* represents the TFP of an enterprise. This paper uses the OP method of Olley & Pakes (1996) to estimate the *tfp*. In addition, we also take the LP method of Levinsohn & Petrin (2003) to estimate the *tfp* to keep the results robust. The core explanatory variable (*post*×*geography*×*pollution)* represents the difference in the impact of the APPCL2000 on TFP of polluting enterprises on both sides of the "Hu line". The variable (*post)* represents a dummy variable of the APPCL2000 implementation time. If the implementation time of the APPCL2000 is after 2000 (excluding 2000), it takes a value of 1; otherwise, it has a value of 0. The variable (*geogrephy)* represents a dummy variable of enterprise location. If an enterprise is located in the northwest of the "Hu line", it takes a value of 1; otherwise, it has a value of 0. The variable (*pollution)* represents a dummy variable of industry attributes. If an enterprise belongs the polluting industry, it takes a value of 1; otherwise, it has a value of 0. This paper also controls other characteristic indicators that may affect TFP, represented by *X*, including whether the enterprise receives financial support (*cons*), whether the enterprise receives subsidies (*sub*), whether the enterprise is an innovative enterprise (*inn*), and whether the enterprise is a state-owned enterprise (*dummy_state*), whether the enterprise is a foreign-funded enterprise (*dummy_for*), and whether the enterprise is located in Hong Kong, Macau, or Taiwan (*dummy_HMT*). In addition, the model also introduces three variables: $\delta_r \times time$, $\gamma_j \times time$, and $\varphi_r \times \mu_j$ to control regional time trends, industry time trends, and regional differences in industries.

4.2. Data Source

This paper uses the data of Chinese industrial enterprises from 1998 to 2007. The data includes the enterprise's name, industry code, year, date of establishment, total assets, number of employees, ownership and the city where the enterprise is located. We first delete the observations with statistical errors before the empirical study. Then, we delete non-manufacturing enterprises. Finally, we unify the industry code to the standard of 2002. Table 1 shows the results of descriptive statistics. The mean value of the variable (*post*) is 0.925, indicating that 92.5% of the sample data belong to post-implementation of the APPCL2000. The mean value of the variable (*geography*) is 0.01, indicating that only 1% of the sample data belong to the cities on the northwest side of the "Hu line". It is also consistent with the concept of the "Hu line". The mean value of the variable (*pollution*) is 0.263, indicating that 26.3% of the sample data represent the polluting enterprises.

Table 1. Descriptive statistical results

Variable	Symbol	Mean	Sd	Min	Max
total factor productivity (OP method)	*tfp_op*	2.422	0.785	-6.380	7.696
total factor productivity (LP method)	*tfp_lp*	6.614	1.013	-1.967	10.947
dummy variable of APPCL2000 implementation time	*post*	0.925	0.263	0	1
dummy variable of enterprise location	*geogrephy*	0.010	0.099	0	1
dummy variable of industry attribute	*pollution*	0.263	0.440	0	1
whether the enterprise receives financial support	*cons*	0.685	0.464	0	1
whether the enterprise receives subsidies	*sub*	0.166	0.372	0	1
whether the enterprise is an innovative enterprise	*inn*	0.100	0.300	0	1
whether the enterprise is a state-owned enterprise	*dummy_state*	0.057	0.231	0	1
whether the enterprise is a foreign-funded enterprise	*dummy_for*	0.072	0.258	0	1
whether the enterprise is located in Hong Kong, Macau, or Taiwan	*dummy_HMT*	0.064	0.245	0	1

4.3. Parallel Trend

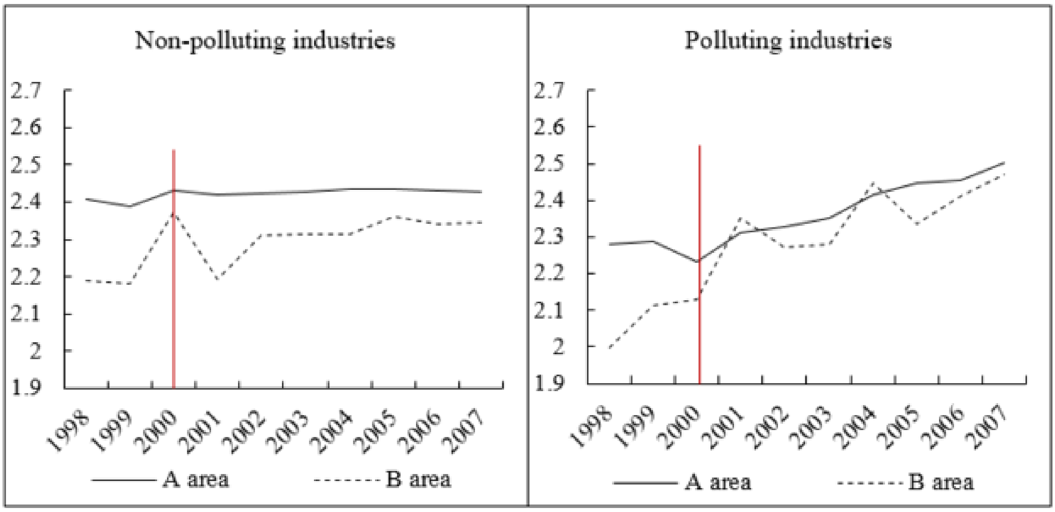
Before using the DID or DDD method to assess the impact of a policy, there are strict prerequisites, that is, the experimental and the control group must have a common time trend before the policy is implemented, which is the "parallel trend" test. In the DDD model of this paper, the "parallel trend" test means that before the APPCL2000, the polluting enterprises on both sides of the "Hu line" had consistent time trends in TFP. However, they should display different trends after the APPCL2000. Figure 4 shows the result of the parallel trend test. The horizontal axis represents the year, and the vertical axis represents the average TFP of enterprises at the prefecture-level. The year 2000 is the demarcation point for policy implementation, in which 1998-2000 is before policy implementation, and 2001-2007 is after. As shown in the left of Figure 4, the changes of TFP in cities on both sides of the "Hu line" show parallel trends in non-polluting industries. Whether it is before or after the APPCL2000, the TFP of cities on the southeast of the "Hu line" in non-polluting industry is higher than that of cities on the northwest. However, in the pollution industry shown on the right of Figure 4, the TFP of cities on both sides of the "Hu line" before the APPCL2000 exhibits parallel trends. After the APPCL2000, the TFP of cities on both sides of the "Hu line" shows an increasing trend, and the gap is getting smaller. Therefore, the parallel trend hypothesis of the DDD has been verified. Figure 4 further reveals that the policy effect of the APPCL2000 was most obvious in the first year (2001), and declined in subsequent years. In addition, it can be observed that the APPCL2000 not only improves the TFP of polluting enterprises, but also narrows the TFP gap between cities on both sides of the "Hu line" in the long term.

5. EMPIRICAL RESULTS

5.1. Benchmark Regression Results

Table 2 reports the regression results of the APPCL2000 on the TFP (OP method) of polluting enterprises on both sides of the "Hu line" based on the setting of formula (1). In columns (1)-(8), we add *year*region* effect, *year*industry* effect, and *region*industry* effect to control regional time trends, industry time trends, and regional differences in industries. Concurrently, all regressions are clustered at the city-level to adjust standard errors. Columns (1)-(4) are regression results without control variables, and columns (5)-(6) are results with them. The DID variable *post*pollution* fails

Figure 4. Trend of the TFP before and after the implementation of the APPCL2000



to pass the significance level of 10% according to column (8), indicating that the APPCL2000 has no significant effect on TFP of polluting enterprises. The probable reason is that the effect of the policy is non-linear. Furthermore, the coefficient of the DDD variable *geography*post*pollution* is 0.2218, and it is significantly positive at the significance level of 5%. It shows that the APPCL2000 has a more significant positive effect on the TFP of polluting enterprises on the northwest side of the “Hu line”. Precisely, The APPCL2000 increased the TFP of polluting enterprises on the northwest side of the “Hu line” by 0.2218 relative to the southeast side, which verified hypothesis 2. It is worth pointing out that maintain uniform standards for environmental regulations is more conducive to narrowing the productivity gap between regions across the country. Moreover, the results of the control variables are consistent with theoretical expectations. Owing to space limitations, the empirical analysis will not report the regression results of the control variables.

5.2. Robustness Test

5.2.1. Re-examination of the TFP Based on LP Method

This paper also examines the impact of the APPCL2000 on TFP (LP method) of polluting enterprises on both sides of the “Hu line” to further test the robustness of the empirical results. Table 3 shows the result. Taking column (8) as an example, the DID variable *post*pollution* is significantly positive at the significance level of 1%, which indicates that the APPCL2000 has a significant effect on TFP of polluting enterprises. Furthermore, the coefficient of the DDD variable *geography*post*pollution* is 0.6418, and it is significantly positive at the significance level of 1%. It shows that the APPCL2000 has a more significant positive effect on the TFP of polluting enterprises on the northwest side of the “Hu line”, which is consistent with the benchmark result.

5.2.2 Re-Examination of Delineated Areas Based on Population Density

The results may be biased, considering the large gap in the sample size of enterprises on both sides of the “Hu line”. To this end, we further take the 2000 census data to calculate the “population density” of prefecture-level cities. One approach is to define areas where the population density of prefecture-level cities exceeds the median of all cities as agglomeration areas, while the others are defined as B area. Another approach is to define areas where the population density of prefecture-level cities exceeds the average of all cities as agglomeration areas, and the other are B area. Table 4 reports

Table 2. Benchmark regression results

Explained variable	*tfp_op*							
model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*geography*post*pollution*	0.3794*** (4.5727)	0.3853*** (4.6924)	0.3808*** (4.6124)	0.3836*** (4.6535)	0.2255** (2.3556)	0.2217** (2.2977)	0.2267** (2.3734)	0.2218** (2.2969)
*post*geography*	-0.0944** (-2.4432)	-0.0979** (-2.5123)	-0.0959** (-2.4960)	-0.0988** (-2.5199)	-0.0378 (-0.9003)	-0.0341 (-0.7893)	-0.0390 (-0.9317)	-0.0341 (-0.7891)
*geography*pollution*	-0.3223*** (-4.6140)	-0.3289*** (-4.7635)	-0.3240*** (-4.6657)	-0.3273*** (-4.7312)	-0.1987** (-2.5829)	-0.1943** (-2.5030)	-0.2001*** (-2.6088)	-0.1944** (-2.4999)
*post*pollution*	0.0047 (0.4639)	0.0024 (0.2499)	0.0048 (0.4670)	0.0048 (0.4664)	0.0081 (0.8271)	0.0083 (0.9215)	0.0081 (0.8237)	0.0081 (0.8270)
cons					-0.0605*** (-5.5910)	-0.0607*** (-5.3412)	-0.0604*** (-5.5752)	-0.0608*** (-5.3799)
sub					0.0264** (2.5326)	0.0268** (2.4615)	0.0263** (2.5099)	0.0269** (2.4625)
inn					0.0807*** (3.7930)	0.0801*** (3.7250)	0.0807*** (3.7895)	0.0802*** (3.7722)
dummy_state					-0.2848*** (-11.7461)	-0.2847*** (-11.7427)	-0.2848*** (-11.7590)	-0.2847*** (-11.7300)
dummy_for					0.1532*** (5.6113)	0.1538*** (5.4260)	0.1531*** (5.6011)	0.1538*** (5.4268)
dummy_HMT					-0.0073 (-0.2340)	-0.0072 (-0.2291)	-0.0075 (-0.2389)	-0.0072 (-0.2297)
Constant	2.4313*** (177.2422)	2.4377*** (265.3759)	2.4307*** (177.8786)	2.4291*** (178.5245)	2.4648*** (171.2407)	2.4660*** (249.1445)	2.4639*** (169.9146)	2.4667*** (174.9716)
*Year*Region*	Y	Y	N	Y	Y	Y	N	Y
*Year*Industry*	Y	N	Y	Y	Y	N	Y	Y
*Region*Industry*	N	Y	Y	Y	N	Y	Y	Y
Observations	315,275	315,275	315,275	315,275	315,275	315,275	315,275	315,275
R-squared	0.0004	0.0003	0.0004	0.0004	0.012	0.012	0.012	0.012
F	6.383	6.706	6.551	5.870	93.07	92.79	93.22	86.31

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level).

the corresponding regression results. Except for the DDD coefficient *geography*post*pollution* in columns (2) and (4) that fails to pass the significance level of 10%, the remaining columns are all significantly positive at the significance level of 1%. The coefficient of *geography*post*pollution* in column (3) is 0.0717, and column (7) is 0.0739, indicating that the APPCL2000 has a more significant positive effect on the TFP of polluting enterprises in cities with low population density. Hypothesis 2 is verified again.

6. MECHANISM ANALYSIS

We speculate that the regional heterogeneity of the nationally unified environmental regulation on the TFP of enterprises is mainly determined by the entry and exit of low-efficiency polluting enterprises based on resource allocation effect. There is no agglomeration effect of the environmental regulation in B area, which is manifested by higher production costs. Therefore, the entry and exit of low-efficiency polluting enterprises are inhibited, which reduces the share of polluting enterprises in B area, and thus improves the TFP of enterprises in the region. It can be described as a survival of the

Table 3. Re-examination of the TFP based on LP method

Explained variable	tfp_lp							
model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*geography*post*pollution*	0.7157*** (4.3935)	0.7939*** (4.5660)	0.6990*** (4.3577)	0.7802*** (4.4853)	0.5857*** (3.8934)	0.6492*** (4.0370)	0.5692*** (3.8602)	0.6418*** (3.9848)
post geography*	-0.1611 (-1.1386)	-0.2228 (-1.4117)	-0.1440 (-1.0497)	-0.2296 (-1.4427)	-0.0843 (-0.6287)	-0.1374 (-0.9187)	-0.0676 (-0.5215)	-0.1416 (-0.9415)
*geography *pollution*	-0.6315*** (-6.4277)	-0.7212*** (-6.3255)	-0.6132*** (-6.4463)	-0.7079*** (-6.2102)	-0.5415*** (-5.4350)	-0.6144*** (-5.3814)	-0.5233*** (-5.4451)	-0.6072*** (-5.3146)
*post*pollution*	0.1826*** (7.3484)	0.1639*** (6.2938)	0.1831*** (7.3107)	0.1830*** (7.4230)	0.1979*** (7.5564)	0.1868*** (7.0016)	0.1985*** (7.5104)	0.1981*** (7.6350)
Constant	6.4001*** (108.8892)	6.4346*** (100.3968)	6.4136*** (110.7458)	6.3662*** (98.1821)	6.1430*** (109.5760)	6.1552*** (97.3591)	6.1560*** (112.9761)	6.1132*** (93.4285)
Control variables	N	N	N	N	Y	Y	Y	Y
*Year*Region*	Y	Y	N	Y	Y	Y	N	Y
*Year*Industry*	Y	N	Y	Y	Y	N	Y	Y
*Region*Industry*	N	Y	Y	Y	N	Y	Y	Y
Observations	301502	301502	301502	301502	301502	301502	301502	301502
R-squared	0.011	0.011	0.010	0.012	0.074	0.074	0.073	0.075
F	32.29	27.05	32.40	26.68	69.74	71.03	69.30	66.31

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include cons, sub, inn, dummy_state, dummy_for, and dummy_HMT.

Table 4. Re-Examination of Delineated Areas Based on Population Density

Explained variable	Grouped by median population density in 2000				Grouped by mean population density in 2000			
	tfp_op	tfp_lp	tfp_op	tfp_lp	tfp_op	tfp_lp	tfp_op	tfp_lp
model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*geography*post*pollution*	0.1399*** (3.4542)	0.1634 (1.5598)	0.0717* (1.7968)	0.1258 (1.2592)	0.1359*** (3.9388)	0.3009*** (3.0699)	0.0739** (2.1717)	0.2813*** (2.8550)
*post*pollution*	0.0068 (0.5914)	0.2044*** (6.9251)	0.0078 (0.7024)	0.2157*** (6.9713)	0.0126 (0.9215)	0.1906*** (6.8203)	0.0115 (0.8661)	0.1953*** (7.0904)
*geography*pollution*	-0.1534*** (-3.6988)	-0.3148*** (-3.8044)	-0.0708* (-1.7909)	-0.2591*** (-3.2598)	-0.1618*** (-4.9920)	-0.3498*** (-5.0734)	-0.0851*** (-2.8040)	-0.2992*** (-4.4165)
*geography*post*	-0.0001 (-0.0117)	0.1950*** (2.6545)	-0.0055 (-0.4342)	0.1945** (2.5915)	0.0085 (0.9141)	0.0894 (1.0479)	0.0027 (0.2592)	0.0761 (0.8121)
Constant	2.4317*** (180.4853)	6.3739*** (103.7122)	2.4677*** (176.1905)	6.1174*** (98.3008)	2.4307*** (169.6315)	6.3613*** (100.8136)	2.4672*** (167.4665)	6.1092*** (99.4797)
Control variables	N	N	Y	Y	N	N	Y	Y
*Year*Region*	Y	Y	Y	Y	Y	Y	Y	Y
*Year*Industry*	Y	Y	Y	Y	Y	Y	Y	Y
*Region*Industry*	Y	Y	Y	Y	Y	Y	Y	Y
Observations	315275	301502	315275	301502	315275	301502	315275	301502
R-squared	0.0004	0.016	0.012	0.078	0.001	0.014	0.012	0.076
F	3.484	41.61	87.06	77.69	5.867	46.74	88.02	78.54

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include cons, sub, inn, dummy_state, dummy_for, and dummy_HMT.

fittest mechanism. To this end, we take the DID method to test from the perspective of prefecture-level cities. The following regression models are set:

$$firm_{rt} = \alpha_0 + \alpha_1 post_t \times geography_r + \alpha_2 post_t + \alpha_3 geography_r + \rho Z_{rt} + \delta_r + \gamma_t + \varepsilon_{rt} \quad (2)$$

where *r* and *t* represent the region and year, respectively. The interpreted variable (*firm)* represents the number of polluting enterprises in each prefecture-level city. In addition, there are two explained variables. The variable (*newfirm*) and the variable (*firm_add*) represent the number of new and net increase of polluting enterprises at the prefecture-level, respectively. Concurrently, the sample data are divided into five equal parts according to TFP (*tfp*), which are *min*-20^{th},20^{th}-40^{th},40^{th}-60^{th},60^{th}-80^{th},80^{th}-*max*. The definitions of variables (*post*, *geogrephy*) are consistent with formula (1). We also control a series of prefecture-level variables (*Z*) related to the number of enterprises. In detail, the industrial structure (*industrial*) is measured by the sum of the proportions of the secondary and tertiary industries. The investment rate (*investment*) is measured by the ratio of fixed asset investment to the GDP. The level of agglomeration (*agglomeration*) is measured by the population density of the municipal district. The human capital (*humancapital*) is measured by the average years of education[3]. The consumption (*consumption*) is measured by the ratio of the retail sales of social consumer goods to the GDP. The degree of openness (*opening*) is measured by the ratio of foreign direct investment to GDP. The fiscal capacity of the government (*fiscal*) is measured by the ratio of government budget revenue to budget expenditure. The economic development (*pergdp*) is measured by the deflated GDP per capita.

6.1. The APPCL2000 and the Number of Polluting Enterprises

Table 5 reports the results of the APPCL2000 on the number of polluting enterprises on both sides of the "Hu line". The sample data are divided into five equal parts according to the TFP (*tfp*), which are *min*-20^{th},20^{th}-40^{th},40^{th}-60^{th},60^{th}-80^{th},80^{th}-*max*. In columns (1)-(5), the coefficient of *geography*post* in the *min*-20^{th} equal division is 0.7994, and is significant at the significance level of 1%. The coefficient in the 20^{th}-40^{th} equal division is similar. Furthermore, the absolute value of the coefficient in the 40^{th}-60^{th} and 60^{th}-80^{th} equal division is smaller, and is significant at the level of 10% and 5%, respectively. However, the coefficient in the 80^{th}-*max* equal division is not significant statistically. It is verified that the APPCL2000 reduces the share of low-efficiency polluting enterprises in B area, which is further reflected in the relative improvement of the TFP.

6.2. The APPCL2000 and the Entry of Polluting Enterprises

Subsequently, we further examine the entry effect of polluting enterprise. Table 6 reports the regression results of the APPCL2000 on the number of new increase of polluting enterprises on both sides of the "Hu line". In columns (1)-(2), the coefficient of *geography*post* in the *min*-20^{th} and 20^{th}-40^{th} equal division is -0.7506 and -0.6748, and are both significant at the level of 1%. However, the absolute value of the coefficients in the 40^{th}-60^{th}, 60^{th}-80^{th} and 80^{th}-*max* equal division are smaller, and the significance is weak. Thus, we conclude that the APPCL2000 is not conducive to the entry of low-efficiency polluting enterprises in B area, thus improving the TFP of B area.

6.3. The APPCL2000 and the Exit of Polluting Enterprises

Finally, we introduce the "net increased number" indicator, which is measured by the number of enterprises entering minus the number of leaving to verify the exit effect of enterprises. The results of the APPCL2000 on the number of net increase of polluting enterprises on both sides of the "Hu line" are reported in columns (6)-(10) of Table 6. In columns (8)-(10), the coefficients of *geography*post* in the 40^{th}-60^{th}, 60^{th}-80^{th} and 80^{th}-*max* equal division are not statistically significant, indicating that

Table 5. APPCL2000 and the number of polluting enterprises

Explained variable	*firm*				
group	*min-20th*	*20th-40th*	*40th-60th*	*60th-80th*	*80th-max*
model	(1)	(2)	(3)	(4)	(5)
*geography*post*	-0.7994*** (-4.9546)	-0.6445*** (-3.4875)	-0.2727* (-1.8087)	-0.4955** (-2.0797)	-0.4220 (-1.3837)
geography	0.7877*** (3.3755)	0.5567** (2.3400)	0.2413 (1.2161)	0.3127 (1.1197)	0.1551 (0.4291)
o.post	-	-	-	-	-
industrial	0.0238*** (2.7054)	0.0291*** (3.4181)	0.0248** (2.4833)	0.0532*** (5.9921)	0.0660*** (5.5216)
investment	0.2055 (1.4379)	0.3078*** (2.7294)	0.4643 (1.4692)	0.2632 (1.1584)	0.4412 (1.3329)
agglomeration	-0.0002*** (-3.0849)	-0.0001* (-1.7266)	-0.0000 (-0.1710)	-0.0001 (-1.2045)	0.0000 (0.2940)
humancapital	-0.0056 (-0.5658)	-0.0211** (-2.0887)	-0.0105 (-1.1517)	-0.0449*** (-3.4815)	-0.0337** (-2.5586)
consumption	0.5922 (1.1650)	1.0590** (2.2551)	1.2730*** (2.7140)	0.1487 (0.4197)	0.1518 (0.3127)
opening	-0.7134 (-1.2164)	0.6014 (0.6693)	-0.7194 (-0.6745)	0.0770 (0.0920)	0.1710 (0.1500)
fiscal	-0.0263 (-0.1300)	-0.2992 (-1.1965)	0.2741 (1.2146)	0.2450 (1.3506)	-0.3419 (-1.3504)
pergdp	0.0000*** (3.6456)	0.0001*** (5.0354)	0.0000** (2.4903)	0.0000*** (2.6864)	0.0000** (2.2026)
Constant	-0.4767 (-0.5739)	-0.8202 (-1.0465)	-1.2495 (-1.3893)	-2.3552*** (-2.9913)	-3.4812*** (-3.2838)
*Year*Region*	*Y*	*Y*	*Y*	*Y*	*Y*
*Year*Industry*	*Y*	*Y*	*Y*	*Y*	*Y*
*Region*Industry*	*Y*	*Y*	*Y*	*Y*	*Y*
Observations	1,640	1,534	1,539	1,478	1,396
R-squared	0.784	0.797	0.805	0.808	0.798
F	6.640	5.934	3.013	6.635	4.796

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level).

the APPCL2000 has a negative effect only on the net growth of low-efficiency polluting enterprises in the non-agglomerated area.

To sum up, we propose that the rapid decline in the proportion of low-efficiency air polluting enterprises in B area is the main mechanism for the relative increase in TFP of polluting non-agglomerated in non-agglomeration areas.

Table 6. APPCL2000 and the number of new and net increase polluting enterprises

Explained Variable	*new_firm*					*firm_add*				
group	*min-20th*	*40th*	*60th*	*80th*	*80th-max*	*min-20th*	*40th*	*60th*	*80th*	*80th-max*
model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
*geography*post*	-0.7506*** (-4.0879)	-0.6748*** (-3.2435)	-0.3246* (-1.6663)	-0.4824** (-2.1948)	-0.5709* (-1.9510)	-0.5807*** (-2.9248)	-0.6586** (-2.5731)	-0.1993 (-1.0887)	-0.2711 (-1.1519)	-0.1033 (-0.3596)
geography	0.3605 (1.3942)	0.6396** (2.4335)	0.7605*** (3.7110)	0.4058* (1.7075)	0.7259** (2.2474)	0.4707 (1.5846)	0.9804*** (3.1838)	0.3964 (1.5123)	0.4768 (1.4756)	0.5777* (1.7237)
o.post	-	-	-	-	-	-	-	-	-	-
Constant	-0.0227 (-0.0237)	-1.1727 (-1.2529)	-1.8167* (-1.7397)	-2.9908*** (-3.2507)	-0.9548 (-0.7536)	-1.6719 (-1.6022)	-1.6724 (-1.4806)	-3.1743* (-1.9362)	-3.2799*** (-2.8021)	0.7591 (0.4241)
Control variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Year*Region*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Year*Industry*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Region*Industry*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,339	1,272	1,230	1,184	1,144	851	839	805	807	711
R-squared	0.711	0.732	0.746	0.749	0.741	0.605	0.641	0.658	0.663	0.672
F	5.027	3.398	3.877	5.577	4.260	3.211	2.419	2.536	2.376	3.192

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include industrial, investment, agglomeration, humancapital, consumption, opening, fiscal, pergdp.

7. HETEROGENEITY ANALYSIS

7.1. Heterogeneity of Enterprise Size

Furthermore, we examine the heterogeneity in the impact of the APPCL2000 on the TFP of polluting enterprises of different sizes on both sides of the "Hu line". The sample data are divided into five groups according to the number of employees (enterprise size), which are (0, 100], (100, 300], (300, 500), (500, 1000), [1000, ∞). The regression results are shown in Table 7. It can be found that the coefficients of *geography*post*pollution* are not statistically significant in the sample group with enterprise size less than 500. However, the coefficient is significantly positive at the level of 5% when the enterprise size is greater than 500. It can be observed that the APPCL2000 improves the TFP of large-scale polluting enterprises on the northwest side of the "Hu line", rather than small ones. The possible reason is that the government is unable to investigate all enterprises in the process of environmental regulation. Instead, they can only focus on the typical enterprises, which may lead to the effect of "grasping the big while letting go of the small".

7.2. Heterogeneity of Enterprise Ownership

To examine the heterogeneity in the impact of the APPCL2000 on the TFP of polluting enterprises of different ownerships on both sides of the "Hu line", we divide the sample data into four parts according to the enterprise ownership, which are state-owned enterprise, collective enterprise, private enterprise, and foreign-funded enterprise (or Hong Kong, Macao, Taiwan enterprise). Table 8 shows the regression results. It can be observed that the coefficient of *geography*post*pollution* is not significant in the sample group of private enterprises. However, the coefficient is significantly negative at the level of 1% in the group of foreign-funded enterprises, and is significantly positive in the group

Table 7. Heterogeneity of enterprise size

Explained Variable	*tfp_op*				
enterprise size	(0,100]	(100,300]	(300,500]	(500,1000)	[1000, ∞)
model	(1)	(2)	(3)	(4)	(5)
*geography*post*pollution*	0.0503 (0.4701)	0.1622 (1.4843)	0.3067 (1.6305)	0.6185** (2.1882)	0.4372** (2.2961)
*geography*post*	0.0397 (0.5140)	-0.0476 (-0.9732)	-0.1853*** (-2.9932)	-0.2850*** (-2.6457)	-0.2080* (-1.8824)
geography pollution*	0.0037 (0.0595)	-0.1966*** (-2.6361)	-0.3920*** (-2.6641)	-0.4197** (-1.9979)	-0.3120 (-1.5974)
*post*pollution*	0.0070 (0.6264)	0.0028 (0.2023)	-0.0029 (-0.1569)	-0.0384* (-1.9376)	-0.0344 (-1.5528)
Constant	2.8393*** (13.8340)	2.0702*** (16.3789)	1.5878*** (7.8626)	1.9853*** (8.6267)	2.3620*** (9.3477)
Control variables	*Y*	*Y*	*Y*	*Y*	*Y*
*Year * Region*	*Y*	*Y*	*Y*	*Y*	*Y*
*Year * Industry*	*Y*	*Y*	*Y*	*Y*	*Y*
*Region * Industry*	*Y*	*Y*	*Y*	*Y*	*Y*
Observations	136570	113894	29656	21979	13176
R-squared	0.010	0.013	0.029	0.043	0.049
F	20.89	30.06	22.53	27.60	15.26

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include cons, sub, inn, dummy_state, dummy_for, and dummy_HMT.

of state-owned enterprises and collective enterprises. It is worth pointing out that the APPCL2000 improves the TFP of the state-owned and collective polluting enterprises on the northwest side of the "Hu line", while it has a negative effect on the TFP of foreign-funded enterprises.

7.3. Heterogeneity of Enterprise Age

Generally speaking, it takes time to scale up and improve the technology, so the "growth effect" is not immediate for new enterprises. We further studied the time when polluting enterprises on the northwest side of the "Hu line" were affected by the APPCL2000. The sample data are divided into three parts according to the enterprise age, which are (0, 3], (3, 5], and [5, ∞). The regression results are shown in Table 9. Except for the sample group whose enterprise age is less than three, the coefficients of *geography*post*pollution* are significantly positive. In summary, it will take up to three years for a new enterprise to adapt to the environmental regulation and achieve the growth effect.

Table 8. Heterogeneity of enterprise age

Explained variable	*tfp_op*		
enterprise age	(0, 3]	(3, 5]	[5, ∞)
model	(1)	(2)	(3)
*geography*post*pollution*	0.1118 (0.5293)	0.3933*** (3.6785)	0.1950* (1.9605)
*geography*post*	-0.0894 (-0.8630)	-0.1075 (-1.4130)	-0.0416 (-0.8229)
geography pollution*	0.0703 (0.4329)	-0.3347*** (-3.6417)	-0.2425** (-2.5304)
*post*pollution*	-0.0048 (-0.3708)	0.0128 (0.9574)	0.0051 (0.4893)
Constant	2.1017*** (14.8571)	2.6334*** (15.8108)	2.2965*** (17.9333)
Control variables	*Y*	*Y*	*Y*
*Year * Region*	*Y*	*Y*	*Y*
*Year * Industry*	*Y*	*Y*	*Y*
*Region * Industry*	*Y*	*Y*	*Y*
Observations	63,016	84,338	167,921
R-squared	0.011	0.007	0.020
F	12.54	16.05	52.40

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include cons, sub, inn, dummy_state, dummy_for, and dummy_HMT.

8. CONCLUSIONS

The environmental regulation is an inevitable choice to deal with global environmental issues, and an important measure to realize the transformation of economic development for all countries in the world. However, various factors must be considered comprehensively before the implementation of environmental regulation policy. Especially for China, which has a vast territory and complex national conditions, the regional heterogeneity must be considered in the implementation of policies. In this context, this paper explains the regional heterogeneity of environmental regulation on enterprise TFP from the perspective of resource endowment differences. Based on the DDD model and DID model, we use the data of Chinese industrial enterprises to verify the theoretical hypothesis. The research conclusions are as follows. First, the exogenous impact of environmental regulations will significantly enhance the TFP of polluting enterprises in resource disadvantaged area, which will improve the relative competitiveness of polluting enterprises in resource disadvantaged area and promote coordinated regional development. Second, under the unified national standard of environmental regulations, resource disadvantaged regions manifest themselves as higher entry costs. The "survival of the fittest" mechanism will restrain the number of low-efficiency polluting enterprises, including the entry and the net entry of low-efficiency polluting enterprises. This means that APPCL2000 will reduce the share of low-efficiency polluting enterprises in resource disadvantaged area, which is the main mechanism for environmental regulation to affect the regional heterogeneity of polluting enterprises' TFP. Finally, the relative improvement of the APPCL2000 on the TFP of polluting enterprises in resource disadvantaged area only exists in enterprises that employ more than 500 people, or have been established for more than three years, or are state-controlled or collectively controlled.

Table 9. Heterogeneity of enterprise ownership

Explained Variable	*tfp_op*			
enterprise ownership	State-owned enterprise	collective enterprise	private enterprise	foreign-funded enterprise
model	(1)	(2)	(3)	(4)
*geography*post*pollution*	0.2809** (2.4309)	1.2078* (1.9483)	-0.0219 (-0.2077)	-0.4442*** (-2.9548)
*geography*post*	-0.1915*** (-2.9129)	-0.1985** (-2.3930)	-0.0394 (-0.3581)	0.0797 (0.5585)
geography pollution*	-0.1198 (-1.3282)	-1.0083 (-1.6211)		
*post*pollution*	-0.0267 (-1.2873)	0.0210 (1.1206)	0.0241* (1.7370)	0.1366*** (5.1393)
Constant	2.0849*** (10.1434)	2.0875*** (8.0951)	2.4972*** (10.7613)	1.5302*** (2.6231)
Control variables	*Y*	*Y*	*Y*	*Y*
*Year * Region*	*Y*	*Y*	*Y*	*Y*
*Year * Industry*	*Y*	*Y*	*Y*	*Y*
*Region * Industry*	*Y*	*Y*	*Y*	*Y*
Observations	24,085	12,616	94,994	19,070
R-squared	0.045	0.018	0.009	0.031
F	35.14	10.03	6.185	17.02

Note: (1) ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively. (2) T-statistics in parentheses, and adopt a more robust standard error algorithm (clustering to individual level). (3) Control variables include cons, sub, inn, dummy_state, dummy_for, and dummy_HMT.

In summary, it can be established that the implementation of a nationally unified environmental regulation can inhibit the entry of low-efficiency polluting enterprises into resource disadvantaged area, and reduce the share of those enterprises in the area, thereby improving the TFP. It is pointed out that the environmental regulation is beneficial to narrow the regional diparty in the long run. The conclusion of this paper just refutes the view that China should relax the environmental regulation in resource disadvantaged area. Furthermore, it is worth emphasizing that it is necessary to strengthen the screening effect of environmental regulations on low-productivity polluting enterprises and optimize the allocation of resources during the implementation of environmental regulations. In particular, China is in the context of large-scale industrial transfers. The transfer destinations are often areas with poor economic foundations and insufficient resources, and they can only be forced to accept low-efficiency and high-polluting enterprises. If the government strictly control the environmental regulation of the places where industries are transferred, and strengthen the screening effect of environmental regulation on the entry of low-productivity polluting enterprises, it will not only help reduce pollution and increase enterprise TFP, but also help the economic catch-up in this type of region. Additionally, based on the results of heterogeneity analysis, we suggest that it is effective to introduce large-scale enterprises in resource disadvantaged area. The development of large-scale enterprises can help new enterprises reduce the cost of adaptation and contribute to improve the TFP of enterprises.

Under the framework of agglomeration economic effect and resource allocation effect, this paper investigates the regional heterogeneity of environmental regulation on enterprise TFP from the perspective of resource endowment. However, owing to the limitations of data, this paper can be improved and deepened in many aspects. On the one hand, the samples selected in this paper are relatively old, and new policies and data need to be selected for in-depth testing in the future. On the other hand, regional heterogeneity is not only manifested as resource advantaged area and resource disadvantaged area, but there are other heterogeneity issues deserve further study.

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ENDNOTES

1. Please refer to Section 3 for the classification standard of cities on both sides of the "Hu Line".
2. The data comes from the "Industrial Waste Gas Emissions and Treatment Status" in the "China Environmental Yearbook" in 2000. Among them, the industry code in the Chinese industrial enterprise data is the industry code standard of 2002, but the industry code corresponding to the 2000 "China Environmental Yearbook" is the industry code standard of 1998, so we unified it to the industry code of 2002.
3. The calculation formula is: average years of education = (number of students in institutions of higher learning *16+ number of students in senior middle school *12+ number of students in general middle school *9+ number of students in primary school *6)/(number of students in institutions of higher learning + number of students in senior middle school + number of students in general middle school + number of students in primary school)

Yuping Shang, Ph.D., has long been engaged in the research of environmental regulation and regional economy. She is a candidate in Shanghai University of Finance and Economics, who has published many papers in SCI/SSCI journals, such as Habitat International, Science of the Total Environment, Journal of Transport Geography, and Socio-economic Planning Sciences, etc. The h-index is 6, total citations are 85.

Shengnan Wu is a doctoral candidate at Shanghai University of Finance and Economics. She has published many academic papers and presided over a number of projects. Her research interests are in the area of urban and regional economy.

Fachuan Zheng is a lecturer in the school of Finance and taxation of Shandong University of Finance and economics. He obtained his Ph.D degree in economics from Wuhan University, who has long been engaged in environmental and economic performance research. He has published many papers in journals and presided over a number of topics such as the youth program of Humanities and social sciences of the Ministry of education of China.