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Environmental Policy and Exports in China: An Analysis Based on the Top 10,000 Energy-Consuming Enterprises Program

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Abstract: This study builds a model to theoretically analyze the impact of China's Top 10,000 Energy-Consuming Enterprises Program on the country's manufacturing exports. The results show that the implementation of this Program has not only a cost-increasing effect but also an innovation-promoting effect on manufacturing enterprises' exports. In particular, the actual effect depends on the superimposition of these two effects, which change as the intensity of the Program changes. Using data on industrial enterprises in Sichuan Province, the study applies the sharp regression discontinuity design (SRDD) to identify the causal relationship between the Program's intensity and the export scale of manufacturing enterprises, which turns out to be an inverted U-shaped relationship. Moreover, with a moderate intensity of the Program, the innovation-promoting effect is proved greater than the cost-increasing effect, which leads to an expansion of the enterprises' export scale. The study concludes that the implementation of appropriate environmental control policies does not undermine the export competitiveness of Chinese enterprises, but instead promotes a win-win solution by improving both environmental quality and export performance.

Keywords: carbon reduction; export scale; environmental regulation; SRDD



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1. Introduction

Exports play a vital role in promoting China's economic growth, which has helped China become the second largest economy in the world. Since China's reform and opening up, its export volume has increased nearly 90 times, with an average annual growth rate of about 16% after adjusting for prices. (This number has been computed using data from China Statistical Yearbook.) In 2009, China's exports surpassed Germany, making the country the world's largest exporter. In 2011, its manufacturing exports accounted for more than 10% of the world total. (Please refer to the WTO website: https://stats.wto.org/dashboard/merchandise_en.html (accessed on 1 January 2022)) However, China has paid a huge environmental toll because of its reliance on exports. It became the world's largest carbon dioxide (CO₂) emitter since 2006, with emissions increasing annually by about 6%. In 2021, China's carbon emissions accounted for nearly 45% of the global total [1], far more than those by the United States and the European Union together. According to the National Environmental Analysis of the People's Republic of China jointly released by the Asian Development Bank and Tsinghua University, less than 1% of China's 500 large cities meet WHO air quality standards.

The 19th National Congress of the Communist Party of China stated, for the first time: "we must set up and practice the idea that green water and green hills are golden mountains and silver mountains." As a result, strengthening environmental governance, reducing environmental pollution, and building a "beautiful China" have become the new buzzwords.

As the world's largest energy consumer and CO₂ emitter, China has been committed to reducing emissions and improving environmental quality. The National Climate Change Plan (2014–2020) issued by the State Council in 2009 targeted to reduce, by 2020, CO₂

emissions per unit of GDP by 40–45% compared with 2005 and make non-fossil energy account for more than 15% of primary energy consumption. During the 12th Five-Year Plan (2011–2015), China produced 670 million tons of energy-saving standard coal. In 2015, the CO₂ emission intensity reduction rate was 6.8%, ranking first in the Group of Twenty (G20), compared to the reduction rates of 6.0% and 4.7% in the United Kingdom and the United States, respectively, in the same period (Pricewaterhouse Coopers). At the Joint Announcement on Climate Change with the United States at the APEC summit in November 2014, China vowed to achieve peak carbon emissions by 2030. Being abundant and cheap, coal meets a large part of the energy needs of the fast-growing economy and is the fulcrum of China's energy structure, as well as the main source of carbon emissions. Therefore, to achieve the goal of reducing carbon emissions and improving environmental quality, China needs to reduce coal consumption in manufacturing [2].

Indeed, a strict environmental control policy has been widely feared to restrain export growth and inhibit industrialization, with reasonable theoretical bases. In theory, environmental regulation may impose additional emission reduction and pollution control costs on enterprises, leading to reduced productivity and export competitiveness. However, Porter and Linde [3] point out that strict and appropriate environmental control can stimulate enterprises to develop new production technologies and organizational methods, in turn actually improving productivity and export competitiveness.

In China, would stringent carbon control policies restrain exports and economic growth in exchange for environmental improvement? Or would they improve environmental quality as well as achieve export growth as a win-win solution? Exploring the answer to this could help to clarify not only the theoretical differences between environmental control and export growth, but also the relationship between them. Moreover, the revised environmental policies and the proposed transformation of the mode of economic growth have important practical significance for China [4].

The Chinese government has been promoting conservation in key energy-intensive units in order to improve energy efficiency. During the period of 12th Five-Year plan, the State Council, with other government departments, formulated the Top 10,000 Energy-Consuming Enterprises Program, the most representative and wide-ranging energy conservation policy so far. These enterprises account for more than 60% of the total national energy consumption, and many of these have export businesses. As cheap energy has been an important competitive advantage for exports [5], will the implementation of such a large-scale program constrain China's export growth and hamper China's economic development? This research finds empirical evidence for the implementation of China's carbon emission policy by studying the internal mechanism and boundary conditions of China's export competitiveness at the micro-enterprise level. The research conclusions also provide suggestions for future environmental policies.

This study differs from the extant literature in three aspects. First, it uses the Top 10,000 Energy-Consuming Enterprises Program in 2011 as a case study for the first time. The regression discontinuity method is used to evaluate the impact of environmental regulations on manufacturing enterprises' export growth. Second, the empirical analysis in this study is conducted at the micro enterprise level. Enterprises are direct participants in foreign trade, and their export competitiveness is directly related to China's economic development. Constrained by the availability of enterprise micro data and policy data, most empirical studies on the relationship between environmental regulation and export trade are conducted at the macro level or meso regional and industrial levels, rather than at the relatively weak micro level. Thus, the empirical research in this paper provides a valuable supplement to the literature. Third, the Program divides the national macro energy saving goal into a carbon reduction quota that the micro-level enterprises bear, which is included in the policy of restricting the enterprises' energy use right at the front. Unlike the existing empirical studies, the targets of measuring environmental regulation policies mainly focus on terminal control policy indicators and macro policy indicators. The former brings serious endogenous problems, while the latter is affected by confounding factors.

The rest of this paper is organized as follows. Section 2 presents a brief literature review, Section 3 provides a brief view of the carbon reduction policy, and Section 4 introduces data sources and data processing, which focus on the setting of the econometric model, and the definition and estimation of variables. Section 5 presents the empirical analysis with a series of stability tests. Section 6 derives policy implications and concludes the paper.

2. Literature Review

There are three strands of thought on the impact of environmental regulation on exports: the restraint hypothesis, promotion hypothesis, and uncertainty hypothesis. Under the restraint hypothesis, environmental regulation restrains exports. Neoclassical economic theory holds that environmental regulation internalizes the external pollution faced by enterprises [6], which increases the enterprises' costs, thereby impairing their export competitiveness [7]. Countries with a high environmental regulation level lose the comparative trade advantage of some pollution-intensive industries, while countries with a low environmental regulation level enhance it. This phenomenon contributes to countries with low environmental standards becoming a haven for global pollution industries. Robison [8] found that environmental regulation changed the comparative advantage of American industries; the lower the cost of industrial pollution control, the higher the export tendency. Van Beers and Van den Bergh [9] tested the relationship between environmental regulation and exports in 21 OECD countries based on the gravity model. They found that strict environmental regulation has a significant negative impact on exports. Jug and Mirza [10] modified the gravitational model of Van Beers and Van den Bergh [9], taking into account the endogenous problem of environmental regulation. They found that the impact of environmental regulation on export competitiveness was significantly negative. Using industrial data from the United States and Japan, Cole et al. [11] also found that environmental regulation has a negative impact on the two countries' industrial competitiveness, especially considering the endogenous nature of environmental regulation. Ederington et al. [12] researched the American manufacturing industry and stated that environmental regulation would restrain trade volume, whether it is regarded as an exogenous or endogenous variable. Shi and Xu [13] and Zhang et al. [14] also conducted relevant research based on different data in China. They found that environmental regulation would increase additional costs for enterprises and have a negative impact on enterprises' export choice and export regulation.

Other similar studies based on both developed and developing countries also found that environmental regulation intensity had a significant negative impact on their exports [15–17]. Hering and Poncet [18] conducted an empirical study using China's urban export data and similarly found a negative correlation between environmental regulation and exports.

However, some scholars subscribe to the promotion hypothesis that environmental regulation is conducive to exports. Typically, Porter and Linde [3] found that the increase in production factor price and cost owing to strict environmental regulation could stimulate enterprises to carry out technological innovation that requires process innovation compensation and product innovation compensation. These two kinds of innovation compensation can partly or totally offset the cost increase from environmental regulations, which helps exports. From a dynamic point of view, a reasonably designed environmental regulation can stimulate the regulated enterprises to carry out technological innovation, helping to realize a win-win situation for both environmental improvement and enterprise competitiveness promotion [19]. Nevertheless, some scholars believe that moderate environmental regulation can promote a country's scale of trade [20,21]. Xu [22] used the gravitational model created by Van Beers and Van den Bergh [9] to study 31 countries with a large income gap and found that environmental regulation is beneficial to total exports. Altman [23] explored that environmental regulation would have a positive impact in adding to domestic enterprises' export volume if enterprises have X-inefficiency. Costantini and Mazzanti [24]

and Rubashkina et al. [25] found that environmental regulation had no negative impact on the export competitiveness of the manufacturing industry, but could promote technological innovation and increase trade scale. Yang et al. [26] found that there exists a strong positive correlation between environmental regulation and enterprise innovation, which significantly increases enterprise productivity and leads to an expansion in export trade. Xie et al. [27] investigated that environmental regulation can significantly promote export quality, possibly through two channels, process and product productivity. The empirical research by Brandi et al. [28], Zhu et al. [29], and Ouyang et al. [30] also showed that environmental regulation is the key driving force to promote enterprise exports (especially green exports), that is to say, the Porter Hypothesis is established.

Finally, there is the uncertainty hypothesis, supported by some research, that proposes that environmental regulation had no obvious influence on exports. Tobey [31] used the Heckscher–Ohlin (H-O) model to test the relationship between the strictness of environmental regulation and exports of polluted products, based on multinational cross-sectional data and found that the impact of environmental regulation on exports was not significant. Using data and regulatory variables similar to Van Beers and Van den Bergh [9], Harris et al. [32] found that the impact of environmental regulation intensity on trade was not significant but attributed the conclusion to the incorrect design of the original research model. Harris et al. [32] stated that a statistically logical relationship between environmental regulation and export trade did not necessarily exist, and countries' desire to expand exports by reducing the level of environmental regulation may be frustrating. Arouri et al. [33]'s empirical analysis of Romania reached a similar conclusion that environmental regulation has no significant impact on total export trade. Ouyang et al. [34] and Song et al. [35] also support the statement that the impact of environmental regulation on exports is uncertain.

The inconsistency of empirical results at home and abroad have triggered considerable critical research. Levison and Taylor [15] offer the following reasons for the conclusion that environmental regulatory factors have a significant impact on international trade: unobserved heterogeneity, endogenous variables, and the aggregation bias of macro data. Alpay et al. [36] and Lanoie et al. [37] pointed out that a possible reason why empirical studies on the impact of environmental regulation on exports have not reached a consensus is that the impact of different policy instruments on the measurement of environmental regulation varies greatly. Moreover, it is difficult to obtain reliable data on environmental regulation [38]. There are many variables to measure environmental regulation in national (regional), industry, and enterprise data. Early export studies were mainly based on a country or industry and environmental regulations derived from national or industry data. The analyses of the impact of environmental regulation on export behavior and competitiveness were mostly based on the Heckscher–Ohlin–Vanek (HOV) model or gravity model. However, with the rise of heterogeneous trade theory, export behavior of micro enterprises has become a major research topic. If macro or industry-level data had been used to measure the intensity of environmental regulations for enterprises, the differences in environmental regulation intensity among different enterprises could have been ignored, and biased conclusions drawn. Foreign scholars used the number of days that enterprises deal with environmental protection departments each year, or the number of law enforcement checks made by environmental agencies, to measure the intensity of environmental regulation faced by enterprises [39,40]. However, measurement of environmental regulation involves not only the nature of the policy instruments, but also their implementation. The number of days an enterprise spends dealing with environmental protection departments each year might be random, rather than being a direct effect of strict environmental regulation. Thus, it is impossible to accurately measure the intensity of environmental regulation.

The extant literature, apart from being divergent, mainly evaluates the impact of environmental regulation (policy) on exports from the macro- or meso-industrial level, lacking evidence at the micro enterprises level. This paper argues that the impacts of environmental regulation on enterprise exports are not the inhibition or promotion of a

single mechanism, but a result of the interaction between two mechanisms. According to heterogeneous trade theory, the export competitiveness of enterprises is reflected in their cost (efficiency) advantages [41,42]. The lower the unit cost, the greater the likelihood that enterprises will gain positive profits by removing the fixed export cost [43]. This paper finds that the Program has two impact mechanisms on enterprise export: cost-increasing and innovation-promoting. It can directly increase the cost of enterprises, weaken the competitiveness of enterprises' exports, and reduce the scale of enterprises' exports. The increase in enterprise cost not only includes an increase in energy cost, but also the cost of strengthening energy measurement, maintaining statistics, and other related management work. To simplify the analysis, all these costs are included in the enterprise energy cost. If the carbon reduction target cannot be achieved during the 12th Five-Year Plan period, enterprises are to face a series of government penalties, which implies that the cost constraints of the carbon reduction policy are hard constraints. The Program can also stimulate enterprises to optimize production and innovation, force enterprises to improve efficiency, and promote the expansion of enterprises' export scale. Accordingly, we propose the following two hypotheses.

Hypothesis 1 (H1). *The implementation of the Program has a cost-increasing effect and an innovation-promoting effect on exports from Chinese manufacturing enterprises. The actual effect of the Program on the export scale of enterprises depends on the superimposition of these two effects.*

Hypothesis 2 (H2). *Under moderate intensity, the Program promotes exports from enterprises, while under higher intensity, it restrains the export of enterprises. In other words, as the intensity of the Program goes from low to high, its impact on enterprise exports presents a “first-rising-then-falling” inverted U-shaped relationship.*

3. The Top 10,000 Energy-Consuming Enterprises Program

Under the Comprehensive Work Program for Energy Conservation and Emission Reduction in the 12th Five-Year Plan, the Chinese government formulated the Top 10,000 Energy-Consuming Enterprises Program (T10000P). The Program calls for the selection of key energy using units, mainly industrial enterprises, with a comprehensive energy consumption of more than 10,000 tons of standard coal in 2010 and more than 5000 tons of standard coal per year designated by relevant departments. Relevant departments include the State Council, the Development and Reform Commission, the Ministry of Education, the Ministry of Industry and Information Technology, the Ministry of Finance, the Ministry of Housing and Urban Rural Development, the Ministry of Transport, the Ministry of Commerce, the SASAC of the State Council, the AQSIQ, the National Bureau of Statistics, the CBRC and the National Energy Administration. About 17,000 enterprises are included in this Program during the period of 12th Five-Year Plan (2011–2015), with a total energy consumption of more than 60% of the country's energy consumption. The T10000P requires local energy-saving authorities to decompose the energy-saving target scale of the 10,000 enterprises into a target for each enterprise during the plan period. They are also required to report to the National Development and Reform Commission for record and assessment.

The State Council required that the achievement of energy-saving goals and the implementation of energy-saving measures must be included in the provincial government's assessment system for energy-saving goals. The assessment results of energy-saving targets in different regions to be summarized and published every year and copied to the state-owned assets supervision and administration commission (SASASAC), the China banking regulatory commission (CBRC), and other relevant departments are also wanted. The achievement of energy-saving goals of central enterprises were to be included in their performance appraisal. It was thought to be important to establish a sound accountability system as a part of the comprehensive appraisal of the leading groups and leaders' performance valuation. The CBRC would urge banks and financial institutions to present

more credit support for energy-saving projects under the Program, in accordance with the principles of risk control and business sustainability. Full consideration was to be given to the achievement of the energy-saving goals in enterprise credit rating, credit access, and exit management. Banking and financial institutions would strictly control lending to those enterprises whose energy-saving failed to meet the standards and whose rectification is not effective. Energy-saving supervision institutions at all levels were required to take the following actions to achieve the Program's goals. First, they needed to strengthen energy-saving supervision. Second, they would conduct special supervision of the implementation of an energy conservation management system at the 10,000 enterprises according to law. Third, the assessment and review of energy saving in fixed assets investment projects would be conducted. Fourth, they would implement energy consumption quota standards. Fifth, they would eliminate outdated equipment and implement energy-saving planning. Finally, they would investigate and punish illegal energy-using activities according to law. The institutional-level design of the Program was meant to ensure rigid constraints on enterprise energy consumption decision.

According to the Program's guidelines, an enterprise's inclusion in the 10,000 enterprises list is determined by its carbon use scale in the base period (2010). Enterprises or institutions that use more than 10,000 tons of standard coal is a major condition. The list of the 10,000 enterprises was meant to be dynamic, and enterprises were to be added every year after 2011 according to the criterion of the scale of carbon used exceeding 10,000 tons. However, in light of the changes in this list, the increase has been relatively small. If and when new enterprises enter the list, they come under the government's radar, with clear carbon reduction targets for the entire 12th Five-Year Plan period. In other words, "10,000 tons of standard coal" is a clear discontinuity point to assess if the Program seriously affected the enterprises. This also enables the testing of robustness using a regression discontinuity design (RDD) in the empirical study. The energy consumption scale data in the base period are the premise of the RDD method. So far, no national data on the carbon consumption scale of industrial enterprises have been released. Fortunately, due to the implementation of the program, Sichuan Province reported carbon scale data of some enterprises and institutions during the base period, enabling our study to use a clear RDD test (SRDD) using enterprise data from Sichuan Province.

We select the carbon consumption scale of the enterprise in 2010 uniformly reduced by 10,000 tons as the horizontal axis variable, where the breakpoint 0 means the carbon consumption scale is exactly 10,000 tons. We then select whether it is in the 10,000 enterprises list as the vertical axis variable. If yes, the value is 1, and if not, the value is 0. Based on the sample data of 10,000 enterprises in Sichuan Province, the clear breakpoint mechanism described is shown in Figure 1. It can be seen that there is a clear discontinuity point at 10,000 tons of standard coal, which indicates that the enterprise data from Sichuan Province are valid for testing. Under the clear discontinuity point mechanism, the influence of covariates can be erased. Furthermore, the empirical analysis can add covariates in SRD to ensure the robustness of the conclusion.

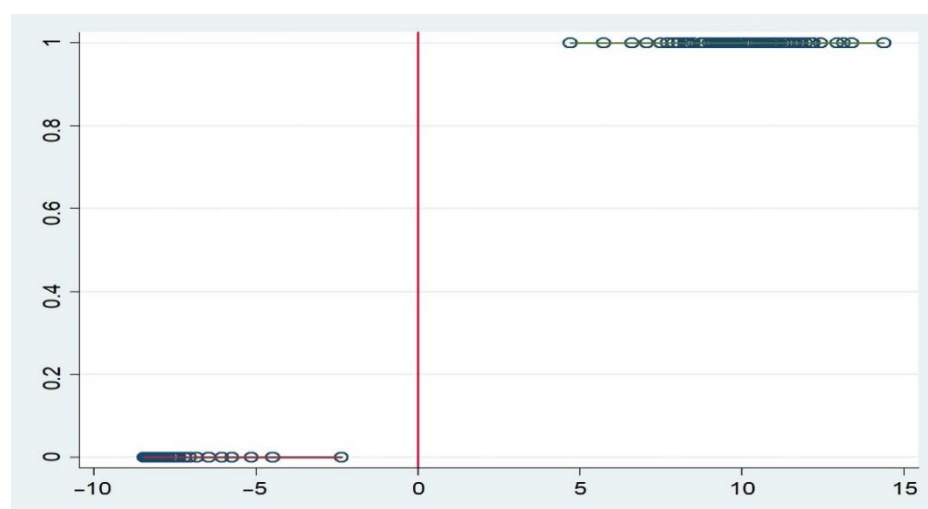


Figure 1. The 10,000 enterprises program and the carbon scale of enterprises in the base period.

4. Empirical Strategy and Data

4.1. Empirical Strategy

It is not easy to scientifically assess the impacts of a carbon reduction policy on entire enterprise exports. The reason is that whether enterprises are influenced by the carbon reduction policy is a non-random event. The biased errors of observable variables, unmeasurable variables, and other missing variables are the key factors that led to the lack of consensus in previous studies. We use the regression discontinuity method to address the three kinds of biased errors.

The regression discontinuity method works as follows. Under the system arrangement of one-size-fits-all, the probability of being treated changes discontinuously when the running variable reaches a certain threshold (discontinuity point), while other factors affecting the result variable do not jump around this threshold. Therefore, the treatment effect can be identified by the difference between the left and right limit values of the running variable threshold.

The policy variable D is referred to as the carbon reduction policy. The jump of the result variable Y at the discontinuity point can be considered as the result of policy variable D if the following conditions are satisfied. The policy variable D entirely depends on a reference variable X (i.e., there exists a discontinuity point mechanism to determine whether individual i is affected by policy D), and other factors Z that may affect the result variable Y are continuous at the discontinuity point. Hence, the causal effect of D on Y can be identified. According to the allocation mechanism of reference variable X around the discontinuity point to individual i , whether it is affected by policy variable D , regression discontinuity can be divided into Sharp Regression Discontinuity Design (SRDD) and Fuzzy Regression Discontinuity Design (FRDD). Whether individual i is affected by policy D depends entirely on whether the value of the reference variable X exceeds the value of the clear discontinuity point, which is, $D = 1 \{X \geq x_0\}$ ($1\{\cdot\}$ is a demonstrative function. If the condition in parentheses is established, it takes 1; otherwise, it takes 0.). The probability that the individual i is affected by policy D is different before and after the value of the fuzzy discontinuity point, which is, $\Pr [D = 1 | X \geq x_0] \neq \Pr [D = 1 | X < x_0]$.

The RDD method constructs a counterfactual analysis framework based on potential results to infer the causal effect of policy D on the outcome variable Y of individual i . In other words, the outcome of individual i independent of policy D is set as Y_{0i} , the result dependent of policy D is set as Y_{1i} , and the treatment effect of policy D is set as $\tau_i = Y_{1i} - Y_{0i}$ for any individual i . In the assessment of policy effectiveness, more attention should be paid to the average treatment effect. If the discontinuity point mechanism satisfies the following three assumptions, the policy treatment effect can be identified based on the discontinuity point information.

Assumption 1. (Discontinuity Point Existence Assumption): Suppose that the limit value of individual i affected by policy exists around discontinuity point x_0 ,

$$P^+ = \lim_{x \rightarrow x_0^+} E[D_i | X = x], \quad P^- = \lim_{x \rightarrow x_0^-} E[D_i | X = x] \quad (1)$$

where $P^+ \neq P^-$. If it is clear discontinuity point, then $P^+ = 1$ and $P^- = 0$.

This assumption implies that whether an individual is affected by the policy (or the probability of the individual being affected) is uniquely determined by the value of the reference variable X (compared with the discontinuity point value).

Assumption 2. (Continuity Assumption): Suppose that the potential outcome variables (Y_{1i} , Y_{0i}) of individual i are continuous functions of reference variable X , and both of them are continuous at discontinuity point x_0 , then,

$$\lim_{\varepsilon \rightarrow 0} E[Y_{ji} | X_i = x_0 + \varepsilon] = \lim_{\varepsilon \rightarrow 0} E[Y_{ji} | X_i = x_0 - \varepsilon] \quad j = 0, 1 \quad (2)$$

Assumption 3. (Local Randomization Assumption): Suppose that whether individual i is affected by policy seems to be allocated randomly around discontinuity point x_0 , then,

$$(Y_{0i}, Y_{1i}) \perp D_1 | X_i \in \delta(x_0) \quad (3)$$

where $\delta > 0$ is any small positive number, and $\delta(x_0) = (x_0 - \delta, x_0 + \delta)$ represents δ neighborhood of x_0 .

Assumption 3 implies that two conditions must be satisfied. First, there should be no significant difference in the main characteristics (covariates) of individuals near discontinuity points to ensure that the identification of causal effects is not affected by the biased errors of measurable variables. Second, individuals are required to be unable to accurately control the reference variables, so that they can enter (or not enter) the policy impact group voluntarily, which can help eliminate the endogenously biased errors caused by unmeasurable variables. In other words, Assumption 3 ensures that whether individual i is affected by policy is allocated randomly around the discontinuity point.

When the above three assumptions are satisfied, the average treatment effect of policy D on individual outcome variable Y can be identified according to the following formula [44]:

$$E[\tau_i | X_i = x_0] = \frac{\mu^+ - \mu^-}{P^+ - P^-}, \quad (4)$$

where τ_i is the treatment effect of individual i , $\mu(x) = E[Y_i | X_i = x]$, and $Y_i = Y_{0i} + \tau_i D_i$. The definition of P^+ and P^- are the same as those in formula (1), and the definitions of μ^+ and μ^- are shown as

$$\mu^+ = \lim_{x \rightarrow x_0^+} \mu(x), \quad \mu^- = \lim_{x \rightarrow x_0^-} \mu(x),$$

In fact, formula (4) corresponds to a Wald estimation, also called a local Wald estimation because it is estimated using data around the discontinuity point. In the case of clear discontinuity points, P^+ and P^- degenerate to 1 and 0, respectively. In addition, the estimation of formula (4) depends heavily on the selection of the neighborhood width (also called bandwidth) of discontinuity point x_0 . The narrower the selected bandwidth is, the smaller the estimation error. Because of the limitation of available samples, a large variance of estimation results. The wider the selected bandwidth is, the larger is the estimation error. However, the variance of estimation can be reduced if more samples are used. Three explanations are provided here accordingly. First, in the case of clear discontinuity points, the estimation error and variance of bandwidth can be weighed, and the optimal bandwidth can be found following Imbens and Kalyanaraman [45]. Second, considering the robustness of the empirical results, the bandwidth size needs to be adjusted to check

whether the estimated results will change significantly. Third, given the bandwidth, the values of reference variables of sample firms have different distances from discontinuity points. The closer the discontinuity points are, the greater the value of samples for accurate inference of treatment effect is. This requires different weights of samples according to their distances from discontinuity points. Generally, there are two kinds of functions used to assign weights: triangular and rectangular kernels. To ensure the robustness of conclusions, this study reports SRDD results under both functions.

4.2. Outcome Variables and Data

According to their availability and completeness, the data of 10,000 enterprises in Sichuan Province are used as sample data on the basis that these cover most industries. The data used in this study are composed of two parts. The first part are the Sichuan Province data in the database of industrial enterprises of a certain scale from 2010 to 2013. The database contains the main characteristic indicators and almost all financial indicators of industrial enterprises of a certain scale. In 2011, the statistical caliber of the database changed. Before 2011, the respondents were industrial enterprises whose main business income was 5 million yuan or more. After 2011, the respondents were industrial enterprises whose main business income was 20 million yuan or more. Therefore, some enterprise samples were not included in the industrial enterprise database any more from 2010 to 2011, due to the change in statistical caliber. However, samples of enterprises with continuous operation from 2010 to 2013 were retained. The core variables of the enterprise in base period (2010) and export information in the future were also retained. When expanding the analysis of the impact of policy lag, the enterprise samples in the data set from 2010–2011, 2010–2012 and 2010–2013, have been retained to avoid heavy sample loss. For the sample data of enterprises, we followed seven inclusion criteria. First, if the export information of enterprises in each period was missing, they were removed. In addition to the zero and positive values, there are many missing values in the export information of enterprises in the database. For missing values, there is no way to judge whether enterprises have no exports, so they can only be deleted. Second, the establishment time of enterprises had to be before 2010, with the month of establishment from January to December; those that were not so were deleted. Third, the gross industrial output value of enterprises cannot be negative or missing. Fourth, the employment scale of enterprises cannot be less than 5 persons. Fifth, the key financial indicators of enterprises (such as total assets, fixed assets, current liabilities, etc.) cannot be negative or missing. Sixth, enterprises' R&D data and subsidies data cannot be negative or missing. Finally, the sales income of enterprises cannot be less than 5 million yuan.

The second part of our data set is the list of the top 10,000 energy-consuming enterprises and the energy-saving target published by the National Development and Reform Commission (NDRC). We used two rules for the sample data. First, according to the 10,000 enterprises list, the 10,000 enterprises and the non-10,000 enterprises in the energy consumption data of enterprises and institutions published by Sichuan Province in 2010 should be first identified. Second, the enterprise data from Sichuan Province in the industrial enterprise database (2010–2013) should be matched with the energy consumption data and the unsuitable samples (mainly non-industrial enterprises and non-institutional samples) eliminated. In total, 1710 samples of enterprises or institutions consuming coal were published in the enterprise data of Sichuan Province in 2010, and 1021 among them were successfully matched.

4.3. Definition and Estimation of Variables

4.3.1. Core Variables

For every enterprise, the scale of energy consumption is closely related to the scale of output. Other conditions being the same, the higher the output, the greater the corresponding energy consumption. The goal of energy conservation and carbon reduction represents different policy intensities for enterprises with different production scales [46].

Accordingly, this study considers an important ratio to measure the intensity of the carbon reduction policy. The numerator is the target scale of the Top 10,000 Energy-Consuming Enterprises Program during the 12th Five-Year Plan period, and the denominator is the production scale of enterprises in the base period. The value of policy intensity basically falls in the region $[0, 1]$. We find only 36 results greater than 1, where tail-shrinking treatment is applied.

The implementation cycle of the Program is the 12th Five-Year Plan period. However, the available manufacturing enterprises data cover only the first three years of this period. There are two concerns about defining the export scale of an enterprise. First, exports are easily affected by the international economic environment, so the export scale shows periodic fluctuation characteristics. In this study, the average value of the three-year export scale (taking natural logarithm value) is taken as the result variable to smooth out the impact of the cycle. Second, to test Assumption 2 in the expansion analysis, this study analyzes three cases: one year, two years, and three years after the Program begins (the logarithms of the export scale of enterprises in 2011, 2012, and 2013 are used (since the export value has many zero values, the formula $\ln(1 + \text{export value})$ is used when the natural logarithm value is taken. As for the control variables, the same method is used to deal with those with zero value when the natural logarithm is taken)). The study also explores whether the impact of the Program on enterprise exports is gradually realized.

4.3.2. Co-Variables

We combine the characteristics of the existing literature and enterprise data to select the appropriate co-variables. At the same time, it affects the enterprises' energy consumption and, in turn, the treatment intensity of the carbon reduction policy, and their exports. The first is total output value, which accurately measures the production scale, and can be obtained directly from the enterprise data. To eliminate the influence of dimension and outliers, a natural logarithm is taken. The second one is capital per capita. The capital density of an enterprise might affect its export and energy consumption at the same time. This variable is estimated by dividing the net balance of fixed assets at the end of the year by the number of employees and then taking the natural logarithm. The third is total factor productivity (TFP) of enterprises, estimated by the LP method. Given the same scale of production, a high TFP of enterprises not only helps to reduce factor input and energy consumption but also promotes exports. The fourth is R&D investment in the base period, used to distinguish the innovation behavior of enterprises. Innovation may not only affect energy consumption and exports, but is also one of the important transmission mechanisms of the carbon reduction policy affecting enterprises' exports. The variable is defined to be within 0–1 according to the R&D cost of the enterprise in the base period. The fifth is enterprise subsidy income, which is estimated by its natural logarithm. On the one hand, as an additional source of income for enterprises, subsidies can offset the cost of the carbon reduction policy and weaken the negative impact of energy consumption regulation. On the other hand, the scale of subsidies reflects the relationship between government and enterprise that affects the intensity of the carbon reduction policy for enterprises. The sixth is financial standing, estimated as the ratio of total liabilities to total assets of an enterprise, or the asset–liability ratio. The seventh is export characteristics of enterprises in the base period. This is defined within 0–1 according to the export delivery value in the base period. Exports have strong inertia, and exports in the base period also reflect the enterprises' scale of production and energy consumption. Additionally, we put a restriction on the age of enterprises, property rights characteristics, and industry characteristics (quadrant code industry dummy variables), among other factors.

5. Results

5.1. Test Analysis

5.1.1. Continuity Test of Co-Variables near Discontinuity Points

To assess regression discontinuity, we need to judge whether it is reasonable to use the discontinuity point mechanism to identify the treatment effect of the carbon reduction policy on the scale of exports. First, it is necessary to assess whether there is a jump in the main covariates near the discontinuity point. If there exists a jump, the jump in the result variables near the discontinuity point cannot be considered as the result of policy variables, but the result of co-variables. Table 1 presents the empirical tests in detail. At the level of 5%, the original assumption that the co-variables jump near the discontinuity point can be rejected completely.

Table 1. Continuity test of co-variables near discontinuity points.

Co-Variables	Wald Coefficient	Standard Deviation	<i>p</i> Value	Result
Total output value	0.008	1.966	0.996	No jump
Capital per capita	0.019	1.163	0.987	No jump
Total factor productivity (TFP)	2.323	2.748	0.398	No jump
Financial standing	0.410	0.719	0.568	No jump
Age of enterprise	7.062	8.752	0.420	No jump
Export scale	0.833	1.690	0.622	No jump
Subsidies	5.423	3.267	0.097	Almost no jump
R&D	3.281	2.079	0.115	No jump

Note: All the reports in the table are the results of continuity test of co-variables near discontinuity points under optimal bandwidth. The results under 1/2 and 2 times optimal bandwidth turned out unchanged; these have not been reported in order to meet article length limits.

5.1.2. Continuity Test of the Density Function of the Reference Variable at the Discontinuity Point

For validity of RDD results, we need to test whether individuals can manipulate their reference variables. Enterprises cannot control whether they enter the state of energy saving and carbon reduction by adjusting the scale of carbon consumption in the base period optionally. In fact, the Program's implementation plan, as formulated by the NDRC, can provide some evidence for the fact that enterprises are unable to manipulate the reference variables. As we know, the Program was officially released at the end of 2011. However, the selection of the 10,000 enterprises was based on the scale of carbon consumption for enterprises in 2010. Therefore, even if enterprises had foreknowledge of the Program, they could not have adjusted the scale of carbon consumption in the previous year to produce self-selection for policy implementation. Whether enterprises can manipulate reference variables depends on specific tests as well. McCrary [47] provides a specific idea for such a test. Whether the density function of the distribution of reference variables is continuous at the discontinuity point is used to check whether an individual can manipulate the reference variables. If there is a clear jump, it means that the individual can manipulate the reference variables to achieve self-selection for policy implementation. Otherwise, it means that the individual cannot manipulate the reference variables, ensuring that the policy is exogenous. We choose the carbon consumption scale of enterprises in 2010 as the horizontal axis variable, and its density function distribution as the vertical axis variable. Based on the data of carbon consumption scale of enterprises in 2010, the results of the density function distribution test are shown in Figure 2. As expected, the density function near the discontinuity point shows very good continuity. This implies that enterprises cannot choose whether to adopt the Program by manipulating the scale of carbon use in the base period.

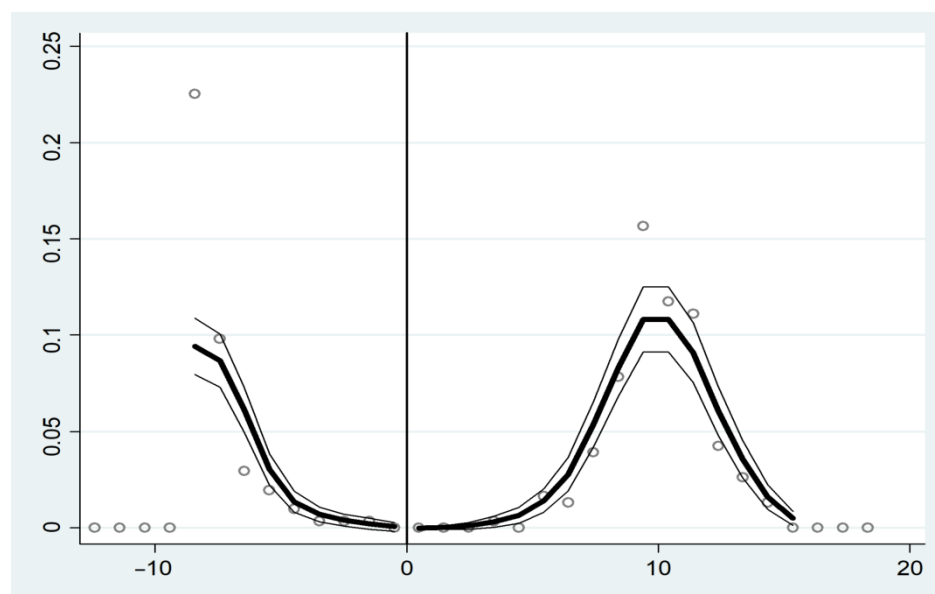


Figure 2. Continuity of the density function of the reference variable at the discontinuity point.

5.2. Baseline Results

To fully test the impact of the intensity of the carbon reduction policy on enterprise exports, SRDD tests were conducted on all samples.

The SRDD test is taken under the following circumstances: triangular nucleus function or rectangular kernel function, controlled or uncontrolled co-variables, the optimal bandwidth or 1/2 optimal bandwidth or 2-fold optimal bandwidth. The results are presented in Table 2. We find a negative correlation between the carbon reduction policy and export scale, indicating that the Program can significantly constrain any increase in the enterprises' export scale.

Table 2. Empirical results of the carbon reduction policy and enterprise exports.

	1	2	3	4
	Triangular Nucleus		Rectangular Kernel	
Local Wald50	−16.7537 *** (−8.40)	−15.613 *** (−4.73)	−21.4051 *** (−4.97)	−20.6105 *** (−8.00)
Local Wald100	−16.220 *** (−5.32)	−18.2274 *** (−3.92)	−15.3881 ** (−2.25)	−14.85024 *** (−4.71)
Local Wald200	−11.1305 *** (−3.31)	−9.2163 ** (−2.33)	−10.9395 *** (−3.02)	−7.1457 *** (−2.79)

Note: The brackets denote Z values. **, *** denote the significance at confidence level of 0.05, and 0.01, respectively. Furthermore, 50, 100, and 200 denote SRDD results at 1/2 optimal bandwidth, optimal bandwidth, and 2-fold optimal bandwidth, respectively. Columns 1 and 3 show SRDD results with uncontrolled co-variables, while columns 2 and 4 show SRDD results with controlled co-variables.

5.3. General Results

To fully test the impact of the intensity of the Program on export heterogeneity of enterprises, enterprises participating in the SRDD test are still grouped by the Program's degree of influence. The ratio of the target scale of the carbon reduction policy to the total output scale of the enterprise in the base period is used to measure the intensity of the policy impact on each of the 10,000 enterprises. On the basis of different quantiles (25, 50, and 75 quantiles) of the intensity of energy conversation and carbon reduction, these 10,000 enterprises are divided into four groups by low to high policy intensity. They also form sub-samples with 120 non-10,000 enterprises. Finally, we conducted SRDD empirical analysis based on these four sub-samples, and the results are presented in Table 3.

Table 3. Intensity of the carbon reduction policy and SRDD empirical results.

		<25th	25th~50th	50th~75th	>75th
Triangular nucleus	Local Wald50	64.49 *** (11.36)	−18.94 *** (−6.39)	−16.88 *** (−8.18)	−15.96 *** (−7.89)
	Local Wald100	8.533 * (1.82)	−14.23 *** (−6.45)	−28.49 *** (−3.76)	−15.46 *** (−4.08)
	Local Wald200	−5.780 (−0.90)	−13.19 *** (−3.53)	−10.19 ** (−1.98)	−14.77 *** (−3.60)
Rectangular kernel	Local Wald50	56.47 *** (8.06)	−18.68 *** (−4.79)	−11.56 *** (−2.77)	−9.438 ** (−2.00)
	Local Wald100	45.89 *** (4.70)	−18.49 *** (−6.39)	−10.18 ** (−2.31)	−10.68 *** (−2.67)
	Local Wald200	−6.440 (−1.05)	−14.49 *** (−3.10)	−11.72 ** (−2.16)	−13.68 *** (−2.99)

Note: The brackets denote Z values. *, **, *** denote the significance at confidence level of 0.1, 0.05, and 0.01, respectively. Furthermore, 50, 100, and 200 denote SRDD results at 1/2 optimal bandwidth, optimal bandwidth, and 2-fold optimal bandwidth, respectively. Columns 1 and 3 show SRDD results with uncontrolled co-variables, while columns 2 and 4 show SRDD results with controlled co-variables.

Several conclusions can be drawn from the empirical results. First, based on the assumption of whether it is under triangular nucleus or rectangular kernel functions with the optimal bandwidth or 1/2 optimal bandwidth, the Program, or the carbon reduction policy, can significantly and effectively promote the export scale of enterprises. Second, if the bandwidth is adjusted to twice the optimal bandwidth, it will be impossible to judge whether the moderately intensive policy has an impact on the export scale. The main reason is that if the bandwidth becomes larger, the local Wald estimation will contain more samples, which reduces the possibility of correctly identifying the treatment effect of the policy. Third, if the policy intensity is extremely strong, regardless of the form of the kernel function and the value of the bandwidth, the Program policy will have a steady negative impact on the export scale of enterprises. Furthermore, if the policy intensity is extremely small, the positive effect of innovation promotion will exceed the negative effect of the cost increase on the export scale, and the total effect on the export scale will be positive. However, if the policy intensity becomes much larger, the positive effect of innovation promotion will hardly exceed the negative effect of the cost increase on the export scale, and the total effect on the export scale will be negative.

6. Conclusions

This study examined the impact of the carbon reduction policy on manufacturing enterprises' exports in Sichuan Province by using the SRDD method, based on the Top 10,000 Energy-Consuming Enterprises Program launched in 2011. The carbon reduction policy has a direct cost increase effect and indirect innovation promotion effect on enterprise exports. The actual effect of the policy on the export scale depends on the superimposition of the two effects. Based on the different sensitivities of the two effects to the intensity of the policy, the following conclusions can be drawn. First, with a moderate regulation intensity, the innovation promotion effect dominates the cost increase effect, leading to a win-win situation in which the Program actually promotes enterprises' export competitiveness. Second, with a higher regulation intensity, the cost increase effect dominates the innovation promotion effect. It shows that the carbon reduction policy has a negative effect on weakening the export competitiveness of enterprises. To some extent, the conclusions of this study reconcile the differences in the existing literature on environment and trade. This study proposes a new understanding from the perspective of the intensity of environmental regulation. It also highlights that the impact of environmental constraints on a country's economic development depend on the intensity of the constraints, whether it is to promote or suppress the export competitiveness of enterprises.

The findings offer three important policy implications. First, environmental regulation policies, including energy conservation and reducing carbon emissions, may not weaken China's export competitiveness. The key issue is to regulate the intensity of regulation appropriately to achieve a win-win of both economic development and environmental optimization. How to regulate the intensity of environmental regulation would, however, require policymakers to conduct in-depth research and evaluation of enterprises and constantly optimize environmental regulation policies by using trial and error and dynamic adjustment. Second, there does exist considerable flexibility for enterprises to cope with the pressure of environmental regulation, provided they are given a certain period of time to grow and adjust. A one-size-fits-all regulation policy is a powerful drug for government to use against environmental deterioration, but it may not be the best choice to obtain a win-win result of simultaneous progress on the economic and environmental fronts. Third, the key to help enterprises overcome the inevitable pain of environmental regulation is to stimulate and encourage R&D and innovation investment. In other words, if all environmental costs are borne by enterprises, they will inevitably restrict their development, as well as the emergence of new ones. If they are borne entirely by government, they might lead to the ineffective use of environmental governance funds. A good middle way is to subsidize enterprises' innovation investment when they are under regulatory pressure, so that they can take responsibility for wisely allocating resources for environmental governance.

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