Impact of energy-saving and carbon reduction policy on the upgrading of export product quality—Empirical analysis based on the PSM-DID method

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Abstract. In view of the dual background of high-quality economic transformation and low-carbon economy, this paper treats energy-saving and carbon reduction policy for key energy users as a quasi-natural experiment, and empirically investigates the causality and internal mechanism of the front-end control environmental regulation on the export product quality of manufacturing firms. Utilizing the propensity score matching plus difference-in-differences (PSM-DID) method, and based on the export panel data of manufacturing firms, this research provides more in-depth and robust evidence that the policy has led to a significant improvement in export product quality among regulated firms. Furthermore, it is revealed that technological innovation is the driving factor and the positive effect is more pronounced for processing trade firms. The conclusions enrich the evidence for the Strong version of Porter hypothesis, clarifying that the front-end control environmental regulation based on key energy users in developing countries can achieve the double dividend of environmental protection and quality upgrading, thus provide policy implications accordingly.

1. Introduction
With the incessant depth of the economic reform and open up, China has become the world’s largest exporter. However, the long-term overstepping strategy of industrialization has led to serious negative consequences for ecological pollution and energy shortage, as well as the drawback of “big but not strong” in export. In 2011, the State Council promulgated the “Top-10000 enterprises energy-saving and carbon reduction program” (Top-10000 program hereafter), which aimed at promoting the reduction of coal consumption by more than 10,000 key energy users, making it the most extensive and representative energy-saving policy in China. It is of vital practical significance to clarify whether strict energy-saving and carbon reduction policy can coordinate the “3E” system, that is, the balance of environment, energy and economy, and promote the upgrading of export quality of manufacturing enterprises.

Based on the database of the Annual Survey of Industrial Firms (ASIF), the China Customs Transaction Database (CCTD) and the directory of Top-10000 program enterprises, we treat the Top-10000 program as a quasi-natural experiment, and utilize propensity score matching plus difference-in-differences (PSM-DID) method to examine the causal link of front-end control environmental regulation on the quality of export product. Furthermore, we examine the transmission mechanism of innovation and the moderating role of trade patterns.

Our findings contribute to the literature in two ways. First, we innovatively shed light on the effect of environmental regulation on the upgrading of export product quality and its driving mechanism.
previous studies tend to focus on the scale of exports, we make up for this limitation and expand the scope of application of the Porter Hypothesis (PH)\cite{1}. Second, we add new empirical evidence to the effect of the front-end governance policy tool with enterprises as the regulatory object, and exploit a quasi-natural experiment to avoid the endogenous problems and aggregation deviations, so as to provide more reliable and in-depth conclusions\cite{2, 3}.

2. Related literature and theoretical analysis

The research on environmental regulation and export competitiveness has always been controversial\cite{2, 4, 5}. The PH challenges the traditional static competition paradigm advocated by neoclassical economics\cite{6}, and holds that strictly and rationally designed environmental regulation tools can force enterprises to innovate, offset the cost of environmental compliance, and achieve a win-win pattern of improving ecological quality and enterprise efficiency\cite{7}.

Since the development of the new-new trade theory, quality has become the focus of enterprise heterogeneity, which is regarded as a key factor in measuring export transformation and upgrading\cite{8}. According to the PH, we believe that from a dynamic perspective of “innovation offsets effect”, environmental regulation will promote technological innovation of enterprises and become a new opportunity to promote the upgrading of export quality.

Specifically, the Top-10000 program disassembles the macro energy-saving target into specific carbon reduction quota of enterprises. It requires enterprises to improve energy-saving management system, optimize production process and improve products, which makes enterprises face severe environmental compliance costs and forces enterprises to make technological innovation. Under the increasing regulation intensity and the enhancement of environmental protection awareness in the international community, enterprises pursuing sustainable operation and maximizing profits will generate driving force for technological innovation, so as to gain the favor of the international market, win the first-mover advantages, which is conducive to the upgrading of export product quality.

3. Data description

3.1. Measurement of variables

3.1.1. Treatment variables and control variables. We use dummy variable to measure the Top-10000 program, it equals 1 if the firm is on the list of the program and 0 otherwise. We also introduce a series of potential factors that affect export as control variables, including firm age, capital density, financial status, ownership (state-owned enterprise - SOE), financial constraints and industry concentration (Herfindahl Hirschman index - HHI)\cite{9, 10}.

3.1.2. Outcome variable. Export product quality: Drawing on the post-mortem method of reasoning\cite{11, 12}, we construct the measurement equation to obtain the variable of quality:

\[
\text{quality}_{ifg} = \ln \lambda_{ifg} = \frac{\tilde{q}_{ifg}}{\sigma - 1} = \frac{\ln q_{ifg} - \ln q_{ifgt}}{\sigma - 1} \tag{1}
\]

where \(\text{quality}_{ifg}\) represents the quality of product \(g\) exported by firm \(i\) to country \(f\) in year \(t\), and \(\tilde{q}_{ifg} = (\sigma - 1)\ln \lambda_{ifg}\) is a random disturbance term which contains the quality of the export product.

Further, we include the GDP of each province to measure the scale of domestic market demand in formula (1) to control for the influence of product differentiation\cite{13}. To address the endogeneity bias caused possibly by the correlation between product quality and price\cite{14, 15}, we take the average price of the product \(g\) exported by firm \(i\) to other countries as the instrumental variable of the price of the product \(g\) exported by firm \(i\) to country \(f\), and obtain the following equation:

\[
\text{quality}_{it} = \frac{\text{value}_{ifg}}{\sum_{g} \text{value}_{ifg}} r \text{quality}_{ifg} \tag{2}
\]

where \(\text{value}_{ifg}\) represents the value of the product \(g\) exported by the firm \(i\) to the country \(f\) in
year $t$, and $\Delta$ represents the collection of products exported by firm $i$ to all countries in year $t$.

3.2. Data source

Accounting for export product quality is based on the CCTD, compiled by China’s General Customs Administration and provides detailed product trade data. The second database is the ASIF, containing the financial data of firms. Both of ASIF and CCTD are during 2007-2013 in this research. Thirdly, the list of firms issued by the government. After cleaning the ASIF and CCTD and merging, we then match them with the firm list of the Top-10000 program. We eliminated the firms that entered the program in 2012 and 2013 to avoid interfering with the evaluation. After extensive search and matching, 1630 firms are finally obtained, which further constituted large-scale unbalanced panel data.

4. Empirical strategy

4.1. Econometric model

4.1.1. Difference-in-Differences model (DID). In order to examine the impact of the Top-10000 program on the export product quality, we establish the following benchmark function based on DID model which is a widely using method for evaluating policy effect:

$$Quality_{it} = \alpha_0 + \alpha_1 Time_{it} + \alpha_2 Program_{i} + \delta Controls_{it} + \mu_t + \eta_i + \epsilon_{it}$$ (3)

where $i$ and $t$ represent the firm and year respectively, $Quality_{it}$ is the export product quality. $Time_{it}$ equals 1 for each year after 2010 and 0 otherwise. $Program_{i}$ equals 1 if the firm is on the policy list and 0 otherwise. The coefficient of $Time_{it} \times Program_{i}$ is a standard DID estimator. Also, we involve the control variables $Controls_{it}$, time fixed effect $\mu_t$, firm fixed effect $\eta_i$, and error term $\epsilon_{it}$.

4.1.2. Propensity Score Matching (PSM). Due to the choice of firms to implement the energy-saving and carbon reduction policy is not random but related to the energy usage, it might lead to self-selection bias and cause the “differential deviation” of the DID method. Whereas the PSM method is suitable for non-random data, we can effectively solve the problem by matching the processing group and the control group, ensuring the findings are more reasonable.

Based on the literature and the characteristics of firm data, we select a series of covariates including industrial output value, capital density, financial status, employment level and R&D investment. Moreover, we control for firm age and property rights (SOE). To ensure optimal matching, we use the caliper method and logit regression to calculate the propensity score.

4.2. Main results

Through balance test, we can examine the effectiveness of covariate selection and PSM method. The results in Table 1 show that before PSM the mean values of the covariates of the processing group and control group are significantly different. After the matching, the distribution of the variables between the two groups becomes balanced with no significant differences. Therefore, the common trend assumption is satisfied which indicates that the PSM-DID method is appropriate.

| Variable       | Sample                  | Mean | Deviation | Deviation reduction | T-test | p-value |
|----------------|-------------------------|------|-----------|---------------------|--------|---------|
|                |                         | Treatment group | Control group |                   |        |         |
| Employment     | Before matching         | 7.0516 | 5.4543 | -140.1             | -99.8  | -0.05   | 0.960   |
|                | After matching          | 7.0516 | 7.0548 | -0.3               | 98.8   | 0.960   |
| Capital density| Before matching         | 4.284 | 2.9549 | -94.3              | -25.35 | 0.000   |
|                | After matching          | 4.284 | 4.2686 | 1.1                | 98.8   | 0.21    | 0.830   |
| Financial status| Before matching      | -0.9625 | -1.17693 | 12.6               | 3.13   | 0.002   |
|                | After matching          | -0.9625 | -0.8956 | -1.0              | -0.24  | 0.812   |
| Output         | Before matching         | 13.695 | 11.287 | 173.7              | 49.08  | 0.000   |
After matching

| Variable | Export product quality |
|----------|-----------------------|
| SOE      |                       |
| Before matching | 0.06848 | 0.02328 | 21.7 | 7.97 | 0.000 |
| After matching | 0.06848 | 0.06156 | 3.3 | 84.7 | 0.55 | 0.581 |
| R&D      |                       |
| Before matching | 0.00703 | 0.00414 | 15.5 | 4.64 | 0.000 |
| After matching | 0.00703 | 0.0067 | 1.8 | 88.5 | 0.35 | 0.729 |
| Age      |                       |
| Before matching | 12.849 | 7.7832 | 42.1 | 18.33 | 0.000 |
| After matching | 12.849 | 12.463 | 3.2 | 92.4 | 0.47 | 0.637 |

Then, we estimate the reference equation (3) and the benchmark regression result is presented in Table 2. After controlling the firm fixed effect, time fixed effect and a series of control variables, the impact coefficient of energy-saving and carbon reduction on the quality of export product is 0.007 and is significant at the 5% level, indicating that Top-10000 program has a significantly positive influence on export product quality.

### Table 2. The effect of Top-10000 program on export product quality

| Variable                     | Export product quality |
|------------------------------|------------------------|
| $time_i \times program_j$   | 0.007**                |
| Age                          | -0.004***              |
| Capital density              | 0.001***               |
| Financial status             | -0.004**               |
| SOE                          | 0.004                  |
| Finance constraints          | 0.156***               |
| Marketization                | 0.002                  |
| HHI                          | -1.700***              |
| Constant                     | 0.249***               |
| Observations                 | 112,134                |
| R-squared                    | 0.755                  |
| Year FE                      | YES                    |
| Firm FE                      | YES                    |

Note: Robust standard errors in parentheses are clustered at the city level. Significance: *** p<0.01, ** p<0.05, * p<0.1 (the same below)

### 4.3. Robustness checks

#### 4.3.1. Placebo test with randomization of the treatment

We randomly generate a list of Top-10000 program firms out of the total sample and assume that they are regulated, and conduct the random assignment 500 times-regressed by equation (3). As is shown in Figure 1, the estimated coefficients are centered around zero and distributed obey the normal distribution, and most of estimates’ p-values are larger than 0.1. Meanwhile, our true estimate is clear outlier. Therefore, it provides further support that our estimate is unlikely to be driven by missing variables.
4.3.2. Controlling for regional linear time trend. To control the different export trends that may exist in different regions over time, we add a region-year fixed effect in our baseline equation (3). Estimation results are presented in Table 3, column (1). We continue to find that the estimated coefficient of \( t_i \times program_j \) is significantly positive, with the magnitude being even large compared to Table 2, indicating that our estimate is not affected by the aggregate trends.

4.3.3. Robustness with respect to influential outlier. One concern for identification is that outliers might lead to bias of the estimate. To address this problem, we winsorize 1% for all continuous variables and re-estimate the reference equation (3). As shown in column (2) of Table 3, the key coefficient remains positive and statistically significant, implying the robustness of our finding.

| Variable            | (1)     | (2)     |
|---------------------|---------|---------|
| \( t_i \times program_j \) | 0.008** | 0.007** |
|                     | (0.004) | (0.004) |
| Constant            | 0.245***| 0.251***|
|                     | (0.016) | (0.014) |
| Controls            | YES     | YES     |
| Observations        | 112,134 | 112,134 |
| R-squared           | 0.756   | 0.762   |
| Year FE             | YES     | YES     |
| Firm FE             | YES     | YES     |
| Region-Year FE      | YES     | NO      |

5. Further analysis

5.1. Mechanism
To explore the potential mechanism from the perspective of “innovation offsets effect”, we analyse the treatment effect on firm’s technological innovation. We select total factor productivity (TFP) as proxy
indicator which can reflect the changes in the technological level and represent the adjustment results of production activities. Specifically, we use semiparametric method (referred to as OP method) to measure\cite{18}, and use the fixed-effect estimation method (referred to as FE method) and labor productivity as robust tests. The results are presented in Table 4, column (1)-(3) which consistently support that the Top-10000 program can significantly stimulate technological innovation and thereby drive export quality upgrading.

Table 4. Further analysis results

| Variable          | (1)        | (2)        | (3)        | (4)        | (5)        |
|-------------------|------------|------------|------------|------------|------------|
|                   | Innovative Offsets Effect | Heterogeneous Effect | TFP_OP | TFP_FE | TFP_Labor | Processing trade | General trade |
| \( time_i \times program_i \) | 0.177*** | 0.144*** | 0.198*** | 0.012** | 0.005 |
|                   | (0.035)   | (0.033)   | (0.037)   | (0.005)   | (0.005)   |
| Constant          | 5.754***  | 7.544***  | 4.635***  | 0.223***  | 0.261***  |
|                   | (0.320)   | (0.342)   | (0.309)   | (0.025)   | (0.015)   |
| Controls          | YES       | YES       | YES       | YES       | YES       |
| Observations      | 112,134   | 112,134   | 112,134   | 23,834    | 88,300    |
| R-squared         | 0.811     | 0.869     | 0.834     | 0.753     | 0.739     |
| Year FE           | YES       | YES       | YES       | YES       | YES       |
| Firm FE           | YES       | YES       | YES       | YES       | YES       |

5.2. Heterogeneous effect

Differences in trade patterns are critical to the development mode and tariff policy of firms\cite{19}. Processing trade firms have more natural external connection, which facilitates the acquisition of innovative technologies and process optimization resources, and accelerates the improvement of product quality. However, the general trade firms have higher fixed capital investment and are more independent in the manufacturing process, making it difficult to achieve short-term renovation. As shown in Table 4 column (4)-(5), the policy has significantly promoted the quality of processing trade firms to a greater extent, while the general trade firms have not been significantly affected, which is consistent with the theoretical analysis.

6. Conclusions and recommendations

Based on the data of ASIF and CCTD, this paper utilizes the Top-10000 enterprises energy-saving and carbon reduction program to construct a quasi-natural experiment, and uses the PSM-DID method to empirically investigate the impact of front-end control environmental regulation on the quality of export product. The main conclusions are as follows:

1. Energy-saving and carbon reduction policy can significantly promote the quality upgrading of export product of manufacturing enterprises. The findings are consistent across a series of robustness tests, and contribute to existing debate over the strong version of PH in the context of developing country.

2. Further mechanism tests shed light on that the policy can effectively stimulate the technological innovation of enterprises, and make up for the production cost of environmental negative externality internalization through “innovation offsets effect”, so as to realize the win-win situation.

3. Heterogeneity analysis shows that energy-saving and carbon reduction can effectively improve the export quality of processing trade enterprises to a greater extent, but it has no obvious effect on the general trade enterprise group in the short term.

According to the above findings, we put forward the following policy implications:

First, government should improve front-end restraint environmental regulation, set appropriate mandatory energy-saving restraint targets or raise clean production standards. Additionally, pay attention to making good use of the energy-saving target accountability system, linking the effect of environmental protection implementation with the performance appraisal of officials.

Second, it is necessary to strengthen the differentiation and flexibility of policy design, and fully consider the carrying capacity of enterprises with different characteristics to formulate effective
assessment targets. In addition, government needs to establish the supporting system, make full use of the financial subsidies and talent cultivation to encourage enterprises to give full play to the “learning by doing” effect.

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