

Assessment of the Impact of China's Carbon Emissions Trading Pilot Policy on the Export Product Quality

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Abstract. To achieve the "dual carbon" goals, China has established a carbon emissions trading market to reduce corporate carbon emissions through market mechanisms. The effect of China's carbon trading pilot programme on export product quality is examined in this study. The analysis employs the quasi-natural experiment provided by this policy, focusing on the quality of exported goods. From 2009 to 2016, panel data from 31 provinces and municipalities created a difference-in-differences (DID) model. This model allows for a comprehensive examination of the impact at the city, industry, and destination country levels. The results show that the quality of exported goods is much improved by the adoption of the carbon trading pilot programme. Additionally, the examination of heterogeneity shows that the influence of the policy is greatest in central cities, with less noticeable effects in the eastern and western areas. The report offers suggestions for advancing carbon trading policies at its conclusion, including the adoption of customized strategies that take into account the distinctive qualities of certain geographic areas. These recommendations are intended to maximise the effectiveness of the carbon trading system and support China's broader environmental and economic objectives.

Keywords: Carbon emissions trading mechanism, difference-in-differences method, export product quality, city heterogeneity.

1. Introduction

China's overseas commerce has expanded rapidly since the reform and opening up. From 16.77 billion yuan in 1978 to 42.07 trillion yuan in 2022, the country's goods trade exports have maintained their lead in the world economy. After joining the World Trade Organization, China's overall import and export figures experienced an average annual growth rate of 12.2%, with foreign trade contributing approximately 20% annually to economic growth. This rapid development has significantly bolstered China's economic expansion. However, with the shift of labor-intensive industries to Southeast Asia and the diminishing demographic dividend, China's foreign trade model faces new challenges, leading to significant changes in its economic structure and production.

Regarding the growing worldwide occurrence of climate change, China, being a prominent source of carbon dioxide emissions, has a huge need to curtail emissions. China has explicitly proposed the "30·60" dual carbon targets. Reducing carbon emissions by 2030 and becoming carbon neutral by 2060 are the objectives. China has been conducting carbon emission trading pilots in eight provinces and cities since 2013, with the national carbon market launch taking place in 2021, in an effort to encourage green and low-carbon development. The carbon trading market is a crucial mechanism for pricing greenhouse gas emissions and aims to achieve a harmonious balance between economic and environmental benefits by setting carbon emission caps in crucial industries.

Although the Chinese government prioritized improving export rules and optimizing the content and quality of export goods in the "14th Five-Year Plan," concerns remain over the possible effects of carbon trading legislation on the development of high-quality commerce. This is a result of China's previous export growth strategy, which was marked by poor innovation, high pollution, and high energy consumption. The existing studies on this topic can be broadly divided into two categories: How carbon emission trading mechanisms affect the industrial economy and how environmental regulation impacts export trade.

According to the data that is now available, carbon trading policies can stimulate industrial restructuring, low-carbon energy transitions, and the development of high-quality manufacturing [1]. The carbon trading market has facilitated technological advancement and optimized energy consumption structures, thereby realizing the "Porter Hypothesis" [2]. This has enhanced the competitiveness of green innovative industries in foreign trade [3]. In the context of the renewable energy sector, the implementation of carbon trading policies has been observed to stimulate technological advancement, enhance productivity, and diminish the reliance on conventional energy sources [4].

While a substantial body of literature examines the influence of environmental regulation on export volume, there is a paucity of research investigating its impact on export product quality. Researchers frequently employ the demand inference method to estimate export product quality [5]. Empirical evidence indicates that carbon trading pilot policies play a significant role in the export trade volumes in pilot regions [6]. The intensity of "carbon reduction" policies exhibits an inverted-U relationship with the export scale of manufacturing enterprises. Moderate policy intensity enhances innovation effects that outweigh cost increases, thereby expanding export scales [7].

In summary, a great deal of study has been done on the economic effects of carbon trading schemes and how they relate to export commerce. Still, most researchers concentrate more on export quantity than quality. Furthermore, research on carbon trading and export product quality predominantly considers microenterprise perspectives, with a lack of city-level analysis. This study investigates the geographical heterogeneity of export product quality across cities and empirically evaluates the effect of the carbon emission trading market on export product quality. It is based on theoretical analysis and uses the difference-in-differences (DID) model.

This research adds three new insights into the body of knowledge about the effects of environmental rules on the quality of export products. Firstly, it looks at how carbon trading schemes affect export product quality, which expands on previous studies. Secondly, the article addresses how the carbon trading market has affected various cities in different ways. Thirdly, the study enriches the methodological toolkit by employing mediation effects and interaction terms in the basic DID model regression.

2. Theoretical Foundation and Research Hypotheses

The Porter Hypothesis postulates that rigorous yet well-structured environmental regulations can stimulate innovation within firms, resulting in enhanced product quality [8]. In the context of the carbon emission trading mechanism, firms facing constraints on their carbon quotas are likely to allocate their limited production factors towards the production of higher-quality, higher value-added products. This enables them to optimise their product mix and transition from low-end to high-end export products.

However, it should be noted that there are significant variations in the economic structure and industrial layout of different regions in China. To provide an example, the eastern area is typified by a preponderance of high-tech companies and the service sector, whereas the centre region is more dependent on energy-intensive and heavy industries. Because different regions have different industrial structures, the effects of carbon trading schemes vary significantly across them [9]. Furthermore, the efficacy of policy implementation and the efficiency of governance also have an impact on the outcomes of such policies. Some regional governments have demonstrated greater proactivity and efficiency in the implementation of policies, resulting in more effective carbon emission reductions [10].

Based on the facts presented above, the study proposes that export product quality can be improved through the use of carbon trading pilot programmes, having effects that are diverse in space.

3. Research Design

3.1. Baseline Regression Model

To evaluate how the carbon market affects the quality of export products, a DID model is developed using the carbon emissions trading market pilot programme as a quasi-natural experiment. The following is how the baseline regression model is created:

$$\text{Quality}_{it} = \alpha_0 + \alpha_1 \text{treat}_i \times \text{post}_t + \alpha_2 \text{Contorls} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Where i and t represent cities and years, respectively. The dependent variable Quality represents the export quality of city i in t year; $\text{treat}_i \times \text{post}_t$ denotes the direct effect of the policy, with treat_i as a province dummy variable and post_t as a year dummy variable. Contorls is a set of control variables; λ_i and λ_t are city fixed effects and time fixed effects, respectively. In addition, ε_{it} represents the random disturbance term.

3.2. Variable Selection and Descriptive Statistics

3.2.1. Main dependent variable

The quality of export goods is the study's dependent variable. Following the measurement approach of existing research, this study adopts the demand estimation method of Khandelwal et al. [5]. The export products quality is estimated using the parameters of "city-HS2-digit code product-export destination country-year". The measurement model is as follows:

$$\ln q_{ijmt} + \sigma \ln p_{ijmt} = v_{mt} + v_j + \phi_{ijmt} \quad (2)$$

Where q_{ijmt} represents the export volume of product j from city i to country m in year t ; p_{ijmt} represents the corresponding export price. v_{mt} represents the combined fixed effects of "export destination country-year", and v_j represents product fixed effects. In equation (2), the random disturbance term $\phi_{ijmt} = (\sigma - 1) \ln \lambda_{ijmt}$, contains the export product quality λ_{ijmt} that needs to be estimated. Direct OLS estimation of this equation may overlook the reverse causality between price p_{ijmt} and quality λ_{ijmt} . To address this, the classic approach of using the average export price of product j from city i to destinations other than country m in the same year as an instrumental variable, as suggested by Bingzhan Shi and Wenbo Shao, is adopted [11]. A two-stage least squares (2SLS) estimation is then performed based on this approach:

$$\text{qua}_{ijmt} = \ln \hat{\lambda}_{ijmt} = \frac{\hat{\phi}_{ijmt}}{(\sigma - 1)} = \frac{\ln q_{ijmt} - \ln \bar{q}_{ijmt}}{(\sigma - 1)} \quad (3)$$

Thus, $\ln \hat{\lambda}_{ijmt}$ represents the estimated export product quality at the "city-product-export destination-time" level. To facilitate cross-period and cross-sectional comparisons, $\ln \hat{\lambda}_{ijmt}$ is standardized following the method of Bingzhan Shi and Wenbo Shao [11]. The standardization process is as follows:

$$\text{Qua}_{ijt} = \frac{\ln \hat{\lambda}_{ijt} - \min \ln \hat{\lambda}_{ijt}}{\max \ln \hat{\lambda}_{ijt} - \min \ln \hat{\lambda}_{ijt}} \quad (4)$$

Where, Qua_{ijt} represents the standardized product quality; $\max \ln \hat{\lambda}_{ijt}$ and $\min \ln \hat{\lambda}_{ijt}$ indicate the highest and lowest possible product quality for a given export good. Referring to the method of Xiaoping Li et al., the city-level export product quality is calculated as follows [12].

$$\text{Quality}_{it} = \sum \text{Qua}_{it} = \sum \left(\frac{\text{value}_{ijt}}{\sum_{ijt \in \Omega} \text{value}_{ijt}} \right) \times \text{Qua}_{ijt} \quad (5)$$

Where, Quality_{it} symbolises the calibre of goods exported from a city.; Ω denotes a set at the city level; value_{ijt} indicates the quantity of export. The standardized quality of export goods is converted

to the city level using export amount as a weight, aggregating the product qualities of various enterprises at the city level to obtain the final city-level export product quality.

3.2.2. Control variables

The level of economic advancement: Calculated using the logarithm of per capita GDP (pergdp), total export amount (export), and proportion of industrial structure (structure) in each region [13]. Technological Human Capital: Logarithm of per capita expenditure on science and technology (persci), logarithm of per capita road area (perroad), average logarithm of urban employee wages. Local Fiscal Level (fiscal): Measured by the logarithm of local fiscal revenue divided by GDP in each region [13]. The level of financial development (finance): The measurement is calculated by using the logarithm of financial institutions' annual loan balance ratio to GDP in each region [14]. The statistical description of each variable is shown in Table 1.

3.2.3. Descriptive statistic

Table 1. Descriptive statistic

VARIABLES	N	mean	sd	min	max
did	2,091	0.0163	0.127	0	1
quality	2,091	0.735	0.0741	0.320	1
structure	2,091	4.465	0.0950	3.914	4.605
pergdp	2,091	10.49	0.619	4.595	12.58
persci	2,091	3.259	1.593	-1.875	8.706
fiscal	2,091	0.0745	0.0272	0.0222	0.220
finance	2,091	2.132	0.986	0.588	8.777
perroad	2,091	15.82	6.761	1.370	60.07
export	2,091	4.041	2.053	-4.900	9.835
wage	2,090	10.60	0.313	9.493	11.72

4. Empirical Analysis

4.1. Baseline Regression Results

Table 2 displays the baseline regression findings for the carbon trading programme. The regression of the baseline model is displayed in Column (1) without any control variables, and the regression results with control variables included are displayed in Column (2). The final empirical findings are shown in column (4) with the addition of both control variables and fixed effects. Column (3) shows the regression results without control variables but with additional two-way fixed effects. The impact of legislation pertaining to carbon emissions on the mean quality of exported goods is consistently large across all models. This resilience implies that, even under different combinations of control variables and fixed effects, the influence of carbon emission policies on the average quality of export products is constant.

Table 2. Baseline regression results

	(1)	(2)	(3)	(4)
VARIABLES	quality	quality	quality	quality
did	0.0656*** (0.00910)	0.0812*** (0.00821)	0.0365*** (0.0121)	0.0405*** (0.0120)
structure		0.124** (0.0507)		0.0953 (0.0966)
lnpergdp		-9.50e-05 (0.0100)		-0.000935 (0.00610)
persci		-0.00201 (0.00343)		-0.000668 (0.00334)
fiscal		-0.710*** (0.142)		-0.404*** (0.142)
finance		-0.00672* (0.00373)		-0.00157 (0.00321)
perroad		0.00106** (0.000441)		-0.000287 (0.000512)
export		0.0111*** (0.00209)		0.00239 (0.00361)
wage		-0.00700 (0.0111)		-0.0261 (0.0231)
Time fixed effect	N	N	Y	Y
Urban fixed effect	N	N	Y	Y
Constant	0.734*** (0.00359)	0.266 (0.227)	0.734*** (0.000196)	0.626 (0.473)
Observations	2,091	2,090	2,091	2,090
R ²	0.013	0.172	0.658	0.661

Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Table 2 displays a strong main effect for the "did" variable, which continues to have a statistically significant effect at the 1% level even after controlling for other variables and fixed effects. This emphasizes how important the "did" variable is to the model. The "did" variable significantly positively affects export commerce at the 1% level, according to the model's inclusion of control variables and fixed effects. This implies that exports in the pilot zones are significantly benefited by the carbon trading pilot policy. The average treatment effect in pilot regions during the pilot period is 0.0405 higher than in other cases, thus confirming hypothesis one.

The quality of exported goods is positively impacted by improvements in economic structure and infrastructure, as can be shown in relation to the control variables. In column (2), the variables "perroad" and "structure" demonstrate a significant effect on "quality," with a 5% level of significance. However, after incorporating fixed effects (columns 3 and 4), the significance of these variables diminishes as fixed effects absorb specific impacts from unobserved regional or temporal factors.

At the 1% level of significance, it is discovered that the variables "fiscal" and "export" significantly improve "quality" in columns (2) and (4), respectively. One may argue that areas with greater fiscal levels would place financial strain on producers, which could lower the calibre of goods exported. Conversely, a rise in export volume might improve the calibre of goods exported.

4.2. Robustness Checks

The treatment and control groups must exhibit comparable patterns in order for the DID (Difference-in-Differences) paradigm to be effective. This implies that prior to the implementation of the carbon emission trading system, export trade patterns in the pilot and non-pilot areas need to be comparable. Any disparities in export trade growth between pilot and non-pilot regions following the adoption of the programme might be attributed, rather than to the carbon trading policy itself, to

pre-existing diverging patterns in the lack of parallel developments. To ensure the validity of the experimental findings, this study examines the developmental patterns of the "treatment" and "control" groups before and after the adoption of the policy from two different angles.

4.2.1. Dynamic effects test

The theoretical framework of the dynamic effects test involves cross-multiplying dummy variables with pre- and post-policy implementation years and regressing the dependent variable on these interaction terms and control variables. If the coefficients of the interaction terms are not statistically significant during the four years before to policy implementation but become so after policy implementation, then the difference-in-differences (DID) model meets the parallel trends assumption. To estimate the interaction terms prior to the start of the carbon pricing programme, this research takes 2013 as the base year before implementation. The findings of the dynamic effects regression analysis examining how China's export trade is affected by the carbon trading programme are shown in Table 3.

Tabel 3. Dynamic effects test

VARIABLES	quality
pre5	0.003 (0.016)
pre4	0.004 (0.016)
pre3	0.009 (0.016)
pre2	0.010 (0.017)
current	0.034* (0.020)
post1	0.049*** (0.019)
post2	0.050** (0.020)
post3	0.082** (0.039)
Constant	0.978*** (0.184)
Observations	2,090
R ²	0.662

There were no discernible differences between pilot and non-pilot regions in the three years prior to the carbon trading policy's introduction, as Table 3 demonstrates. This indicates that the variable coefficients for those three years are not statistically significant. This supports the assumption of "parallel trends." Conversely, the carbon trading pilot policy's execution greatly boosted China's export commerce, as shown by the interaction terms' coefficients for the three years that followed its implementation being substantial at the 1% or 5% level.

4.2.2. Placebo test

This study further corroborates the randomness of policy implementation in low-carbon pilot regions through the use of a placebo test. The fundamental premise of this experiment is to alter the timing of policy implementation in order to ascertain whether a policy effect can still be generated. If the regression coefficient is found to be significant, it may be concluded that other policies or random factors may have caused changes in export trade in different regions. In the event that the regression coefficient is not significant, this indicates that the assumed policy implementation time is unable to produce the corresponding effect, thereby confirming the reliability of the policy effect in

the baseline regression. Consequently, this study tests the policy implementation time by assuming it was implemented in 2011. Table 4 presents the results of the investigation.

Table 4. Placebo test

VARIABLES	quality
did2011	0.0129 (0.00979)
structure	0.0960 (0.0712)
lnpergdp	0.000221 (0.00805)
persci	-0.000458 (0.00233)
fiscal	-0.370*** (0.113)
finance	-0.00157 (0.00326)
perroad	-0.000377 (0.000456)
export	0.00226 (0.00228)
wage	-0.0264 (0.0173)
Constant	0.612* (0.323)
Observations	2,090
R ²	0.659

Table 4 shows that the regression findings do not reach statistical significance when the implementation date of the carbon pricing scheme is advanced by two years. This proves the robustness of the baseline regression results by showing that random factors or other policies are not linked to the growth in export commerce.

4.3. Robustness Checks

To properly analyse the various effects of the carbon pricing system on export commerce, this study divides cities into eastern, western, and central sectors. The grouped regression findings are shown in Table 5.

Table 5. Robustness checks

VARIABLES	(1)	(2)	(3)
	East	West	Middle
did	0.0187 (0.0128)	0.104 (0.0686)	0.0374*** (0.0137)
structure	-0.240* (0.131)	0.281 (0.173)	0.177* (0.105)
lnpergdp	0.00936 (0.0118)	0.00807 (0.0140)	-0.00178 (0.0231)
persci	-0.00981*** (0.00284)	0.0123** (0.00558)	5.14e-05 (0.00409)
fiscal	-0.120 (0.139)	-0.128 (0.306)	-0.694*** (0.182)
finance	-0.00276 (0.00389)	-0.00646 (0.0107)	-0.00251 (0.00465)
perroad	-0.000259 (0.000576)	0.000198 (0.000920)	0.000458 (0.000880)
export	-0.00703 (0.00553)	0.00783* (0.00414)	0.00219 (0.00392)
wage	0.0144 (0.0234)	-0.0879* (0.0460)	0.0158 (0.0258)
Constant	1.674*** (0.521)	0.286 (0.796)	-0.162 (0.475)
Observations	769	567	754
R ²	0.731	0.649	0.635

Table 5 reveals a notable disparity in the number of samples collected in central and eastern region cities compared to those in western region cities. Owing to their physical and economic advantages, cities in the central and eastern areas are more likely than those in the western region to take part in the global division of labour.

The results of columns (1) and (2) indicate that there is no statistically significant association between the export product quality in cities in the eastern and western regions and the carbon trading regime. With a coefficient of 0.0374, the regression findings for the cities in the central region are shown in Column (3) and are 1% level statistically significant. This implies that central region cities' exported goods are of higher quality as a result of the carbon trading pilot program's execution.

One potential explanation is that central region cities tend to prioritize energy-intensive and heavy industries, such as those in Wuhan and Zhengzhou, which are largely dominated by manufacturing and heavy industries with considerable carbon emissions. Therefore, it stands to reason that notable emission reductions are more likely to be seen in these regions under the carbon emission trading scheme. Moreover, policy efficacy is significantly impacted by the effectiveness of governance and the strength of policy implementation. For example, provinces in central China, such as Hubei and Hunan, demonstrate greater enthusiasm and effectiveness in policy implementation. This may be driven by local government's desire to enhance local competitiveness or obtain policy incentives from the central government. It can be posited that elevated levels of environmental pollution may give rise to more rigorous policy enforcement and an increased necessity for governance. Hebei cities and the midstream Yangtze River basin, for instance, are heavily polluted, which makes the carbon emission pricing scheme less effective there.

5. Conclusion

The influence of China's adoption of carbon pricing laws on the volume of export trade in seven pilot zones since 2011 was thoroughly examined in this study. Utilising data from 31 provinces and

cities and a differences-in-differences (DID) model, it was possible to identify the substantial beneficial impacts of carbon trading pilot programmes on export commerce, with a focus on central areas. This was attributed to the concentration of energy-intensive and heavy industries in these regions, as well as the effective policy enforcement by local governments.

These results underline how important it is to improve green development policies and grow the domestic carbon trading industry. Given the results, it is suggested that the national carbon trading market be developed further in order to increase liquidity and variety of participation. This should involve the creation of financial markets for carbon. It is also recommended that policy adjustments be made to take account of regional economic conditions and resource endowments. In particular, it is of the utmost importance to provide increased support for the development of carbon markets in central regions. This will facilitate the demonstration of the effectiveness of such markets and encourage a greater number of participants in carbon trading markets.

However, it should be noted that the study is subject to certain inherent limitations. Due to data limitations, the analysis is constrained to policy effects up until 2016, which precludes an assessment of the current market dynamics and sustainability. Future research should investigate the regional and sectoral variations in response to carbon trading policies, evaluate the long-term sustainability and scalability of carbon markets, and develop nuanced environmental policy measures to advance national export trade transformation and upgrade. In conclusion, this study offers crucial theoretical support and insights for optimizing carbon market policies and promoting sustainable economic development in the future.

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