Energy Economics 120 (2023) 106630

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

The impact of export VAT rebate reduction on firms' pollution emissions: Evidence from Chinese enterprises

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ARTICLE INFO

JEL classification:
D22
F13
Q53
Q56

Keywords:
Export VAT rebate reduction
Firms' environmental performance
Technique effect
Scale effect

ABSTRACT

This study investigates firm-level environmental responses to China's export value-added tax (VAT) rebate reduction policy launched in 2007 that aims to reduce exports in high-polluted and high-energy-consumption sectors. First, we combine firm-level export information from the Customs dataset and the list of policy-targeted products to identify firms affected by export VAT rebate reduction policy. Then, we employ a difference-in-differences strategy to examine changes in the affected and unaffected firms' sulfur dioxide and chemical oxygen demand emissions before and after policy implementation. Empirical analysis reveals that the export rebate reduction policy increases firms' pollution emission intensities and decreases their total outputs, leading to a negative but less significant effect on total pollution emissions. Tests to explore the mechanism reveal that firms' financial constraints become tighter if affected by the export VAT rebate reduction, as evidenced by reduced revenues, profits, and total factor productivity. This further translates into lowered purchases of environment-friendly technologies and a worse capacity to adopt clean production practices, which accounts for increased pollutant emission intensities following the export VAT rebate reduction policy.

1. Introduction

Export expansion has played a substantial role in China's economic growth in the past two decades since its entry into the World Trade Organization (WTO) in 2001. Owing to its less strict environmental regulations compared to developed countries, China's exports in pollution-intensive sectors rose significantly in the early 2000s, shaping China into a "pollution haven" (Sun et al., 2017).[1] Export-induced pollution negatively influences health outcomes and increases mortality (Bombardini and Li, 2020; Wang et al., 2017). To tackle these growing environmental challenges, more stringent environmental policies have been enforced since the beginning of the 11th Five-Year Plan in 2006. Additionally, to reduce export-induced pollutant emissions, an unprecedented large-scale reduction in the export value-added tax (VAT) rebate was launched in June 2007 that targets exports of highly polluting, energy-consuming, and resource-based products. Although the economic consequences of the policy have been thoroughly studied (Zhang, 2019; Braakmann et al., 2020; Garred, 2018), little is known regarding whether the export VAT rebate reduction policy has achieved its goal of curbing pollutant emissions. This study uses the export VAT rebate reduction policy as a quasi-natural experiment to examine how this trade policy tool could affect firms' environmental outcomes.

Export VAT rebate is a policy that refunds value-added and consumption taxes paid in domestic production for products declared for exports. This is a standard international practice that lowers the cost of exports and effectively avoids international double taxation. The WTO Agreement on Subsidies and Countervailing Measures (Article 1.1) allows members to provide export rebates as long as the rebate amount does not exceed the full extent of the levied duties. Thus, the export VAT rebate reduction policy leads to incomplete rebates and the cancelation of rebates, which, in practice, serve as an export tax that would discourage exports (Sharma, 2020). If reduced exports cannot be filled by domestic demands, firms' total outputs would fall. Total pollutant emissions would fall as well if rebate reductions exert no influence on pollution emission intensity. However, pollution emission intensity is closely related to firms' capability to improve productivity levels, invest

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[1] According to the BACI trade dataset, China's exports in paper products, which are the major emitters of chemical oxygen demand (COD), and iron and steel, which are the main emitters of sulfur dioxide (SO_2), have risen by >300% and 540%, respectively, from 2000 to 2007.

https://doi.org/10.1016/j.eneco.2023.106630
Received 29 August 2022; Received in revised form 28 January 2023; Accepted 7 March 2023
Available online 15 March 2023
0140-9883/

in environment-protection equipment, and engage in green innovations. These activities are directly affected by firms' financial performance, which would deteriorate because of decreased exports caused by the export VAT rebate reduction. Thus, we expect to see an increase in pollution intensity following the export VAT rebate reduction policy, which indicates unintended worsened environmental performance induced by trade policy.

To test this hypothesis, we use the export VAT rebate reduction policy as a quasi-natural experiment and conduct a difference-in-differences (DiD) analysis for causal inference. We perform an empirical analysis by first identifying the firms in the treated and control groups. As VAT rebates are set for each product while pollution information is collected at the firm level, we use the Customs database that contains transaction-level trade information to construct the treatment variable. Firms whose major exporting products in the pre-policy period are targeted by the rebate reduction policy, are considered as treated firms. Before analyzing the environmental outcomes, we study the export responses to the policy. The empirical analysis shows that firms with high policy exposure export fewer dirty products, suggesting a direct impact of export rebate reduction on export structure, which supports the environmental concerns of the policy (Eisenbarth, 2017).

We then merge this information with the Annual Survey of Industrial Firms (ASIF) and the Annual Environmental Survey of Polluting Firms (AESPF) to study environmental outcomes for the rebate reduction policy. We find that the export VAT rebate reduction policy reduces firms' total emissions of chemical oxygen demand (COD) and sulfur dioxide (SO_2), but the effect is more significant for COD and less significant for SO_2. To further unpack the underlying forces that reshape firms' environmental performance in response to rebate reduction, we follow Martin (2011) and decompose firms' total emissions into emission per output (pollution emission intensity) and overall output to examine the within-firm technique and scale effects on pollution emissions. We find that the policy exerts opposite scale and technique effects. While the treated firms' emission intensities increase, total outputs decrease following the policy. These two effects mitigate each other and consequently result in a less significant impact on total pollution emissions, suggesting that export rebate reduction encourages firms to produce less with more energy. The baseline results still hold for alternative pollutants and under numerous robustness checks. We also employ an event-study analysis to check the identifying assumptions and depict the dynamic impact of the policy.

Later, we disentangle the underlying mechanisms leading to baseline results and find that export VAT rebate reduction significantly worsens treated firms' financial and production indicators, including revenue, profits, and total factor productivity (TFP) relative to non-treated firms. Faced with rebate-reduction-induced shrinkage in export sales and worsened financial status, affected firms are forced to prioritize production investment over environmental investment (Andersen, 2017). To substantiate the financing channel argument, we further run a Difference-in-difference-in-differences (DDD) regression by interacting policy shock with a city's local credit supply and find that rebate cuts exert smaller impact on emission intensities for firms located in regions with better credit access. We further examine firms' environment-related investment following this policy. We find that affected firms reduce their imports of environment-protection equipment more, which leads to decreased energy efficiency and increased pollution intensity. However, the effect on green innovation is less pronounced.

Our study contributes to the literature from three perspectives. First, we complement existing studies on the environmental consequences of trade liberalization and trade policies by examining the impact of an understudied trade policy adjustment. In contrast to environmental policies that could directly affect firms' adoption of green technology or pollution emissions,[2] trade and economic policies are more likely to indirectly affect firms' environmental performance by reshaping their financial and production performances. Cherniwchan (2017) examines the environmental consequences of NAFTA on the US firms and found that emissions of PM10 and SO_2 decreased following NAFTA. This is mainly owing to increased access to dirty inputs and trade-induced technological upgrade. Exploiting the trade liberalization episode in Mexico, Gutiérrez and Teshima (2018) find that import competition induces firms to increase energy efficiency through technological upgradation. Brandi et al. (2020) show that environmental provisions in Preferential Trade Agreements can reduce dirty exports from developing countries. Yang and Hong (2021) use China's accession to the WTO as a quasi-natural experiment and find that a reduction in trade policy uncertainty decreases firms' energy intensity by promoting innovation and technical progress. Unlike existing studies, which mainly focus on the relationship between trade liberalization and the environment, this study investigates the impact of an understudied trade policy, the export tax rebate, on firm-level pollutant emissions. Our findings show that, in addition to the direct negative effect on dirty exports, the reduction in export tax rebates increases firms' pollution intensity and reduces their size, indicating the unintended negative impact of this trade policy.

Our study also complements the literature on evaluating the trade and economic consequences of VAT adjustments by documenting its unintended environmental consequences using a micro dataset. Several studies have evaluated the impact of VAT rebates on exports. Garred (2018) finds that a one percentage point increase in export tax decreases export value by 5.10% using product-level data. Concerning firm-level export performance outcomes, Chandra and Long (2013) provide firm-level evidence of the substantial positive impact of China's VAT rebates on exports. Braakmann et al. (2020) further show that the trade-promoting effect of VAT rebates works mainly through the extensive margin of exports. Similar results were found using data from developed countries, such as Nicholson (2013). In addition to export performance, other prominent microeconomic outcomes, such as productivity growth and resource misallocation, were also examined (Weinberger et al., 2021; Zhang, 2019).

Our work is closely related to that of Eisenbarth (2017), who investigates the impact of environmental concerns on China's export VAT rebates and export taxes. Nonetheless, our work departs from Eisenbarth (2017) in several ways. First, Eisenbarth (2017) studies whether environmental performance is a driving force for export VAT rebates and export taxes, while our work explores the micro-environmental consequences and mechanisms of the export rebate policy. Furthermore, Eisenbarth (2017) shows that export tax discourages solid waste exports using a two-way fixed-effect econometric model. In this study, we causally identify firms' responses to export VAT rebate reductions in a DiD setting. Third, we employ a battery of firm-level datasets covering firms' information on trade, pollution emissions, production, and financial performance. This allows us to closely examine micro responses to the policy and the underlying mechanisms.

More broadly, this study relates to literature on the determinants of firm-level green performance. In addition to environmental regulations and economic policies, other micro- and macro-level factors can influence pollutant emissions. Brunnermeier and Cohen (2003) show that environmental innovations are affected by pollution-abatement expenditures and are more prevalent in internationally competitive industries. Horbach (2008) further finds that improvements in technological capabilities through R&D can trigger environmental innovation. In

[2] Environmental policies usually take the form of subsidizing renewable energies or environment-friendly technologies adoption, or directly impose quotas for pollutant emission of a firm/region/industry. See Kalkuhl et al. (2013), Abrell et al. (2019), and Fan et al. (2019).

addition to supply side factors, customer requirements for corporate social responsibilities also drive firms' investment in eco-innovations (Kesidou and Demirel, 2012). There are also studies on the macro-level determinants of pollutant emissions, including urbanization, trade openness, FDI, and institutional quality (Sun et al., 2019; Hu and Fan, 2020; Rafiq et al., 2016). Examining the environmental outcomes of the VAT rebate policy would help us better understand how changes in the export structure caused by an economic policy would reshape firms' financial, production, and environmental performance.

The rest of this paper is organized as follows. Section 2 presents the background of the export VAT rebate policy and hypothesis development. Section 3 introduces the measurement construction for the key variables and empirical strategies. Section 4 describes the datasets used for the empirical analysis. Section 5 presents the main results, robustness checks, and a heterogeneity analysis. Section 6 further tests the potential channels reshaping a firm's pollution activities following the reduction of export tax rebates. Section 7 concludes the paper and discusses policy implications and future research.

2. Policy background and hypothesis development

2.1. Export VAT rebates in China

Export tax rebate is a vital trade policy instrument for China's policymakers. It was first implemented in 1985, and the tax was fully refunded in 1988 (Weinberger et al., 2021). The rebate rate was relatively low in the pre-VAT period at approximately 11.2%. Since 1994, VAT has gradually become the central tax system in the country, and the export tax rebate rate has increased to 17%, which is the VAT rate in China. The increased rebate rates spurred exports in the following years and brought financial burden to the government. In 1996, the rebate rates were adjusted to 3%, 6%, and 9% for different exports. There were also subsequent adjustments in the rebate rates. Before 2004, the trade-off between increasing exports and decreasing fiscal burdens was a major concern for rebate rate adjustments. Since then, the government has intended to use export tax rebate as a policy tool to influence the industrial structure and avoid trade friction.

In June 2007, the Ministry of Finance in China announced a large-scale export VAT rebate adjustment policy that aimed to reduce or cancel tax rebates for high energy consumption, high pollution, and resource-intensive exports and exports that had caused trade friction. In particular, VAT rebates were canceled for highly energy-consuming and polluting exports (e.g., steel products, pesticides, chlorine, and other chemical products) and resource-based exports (e.g., rare earth metals, silicon, and wooden products).[3] Export VAT rebates were reduced for exporting products that caused trade frictions (e.g., textiles, clothing, and toys).

The policy became effective on July 1, 2007, and it covered over 2500 HS 8-digit products, which comprised approximately 37% of the total exporting products. On average, rebate rates decreased by 11.06% for polluted exports, while rebate rates decreased by 5.1% for products causing trade frictions (Bai et al., 2011). Fig. 1 shows the proportion of exports in 2006 affected by the policy for each CIC-2d industry, which displays significant cross-industry variations in the affected shares.

In 2008, the financial crisis in the US led to a drop in China's exports. To stabilize exports, the Chinese government raised export tax rebate rates seven times in 2008 and 2009 for some products. However, the goal of reducing exports of pollution-intensive and energy-intensive products remained unchanged, and the export tax rebate rates for these products have not increased since 2007. This provides us with a quasi-natural experimental setting to examine the environmental outcomes of export tax rebate adjustments in 2007.

[3] In short, these industries are called "three high" industries.

2.2. Hypothesis development

2.2.1. Financial consequences of the export VAT rebate reduction policy

The export VAT rebate policy is an effective export-promoting trade policy. In what follows, we use a simple monopolistic competition trade model to illustrate how changes in export VAT rebates can influence firms' financial performances, which would have further implications for firms' environmental outcomes.

Suppose there is a continuum Ω of possible varieties and each firm produces a distinct $\omega \in \Omega$. Following Bernard et al. (2011), we assume that firms engage in monopolistic competition and that consumers in each country have constant elasticity of substitution preferences. In this framework, the demand for firm i's product is given by

$$q_{ic} = p_{ic}{}^{-\sigma} Y_c P_c^{\sigma-1}$$

where c denotes the destination country and σ is the elasticity of demand for firm i's output. Y_c represents country c's income level and P_c is the Dixit-Stiglitz price index.

A representative firm requires labor and intermediates for production. For simplicity, we assume that the cost of producing one unit of output is w_i/φ, where φ represents firm i's productivity. w_i includes the VAT that the firm pays for its intermediates. Assuming that the government implemented an export VAT rebate rate of t, we can express firms' profit level as

$$\pi_{ic} = \left(p_{ic} - \frac{w_i}{\varphi}\tau_{ic}\right) q_{ic} + t p_{ic} q_{ic}$$

where $\tau_{ic} > 1$ denotes the iceberg costs between exporting and importing countries. $tp_{ic}q_{ic}$ represents the total amount of exported VAT rebates a firm receives from the government.

Substituting the demand expression into the profit function, we can calculate the optimal price the firm sets for its exporting products:

$$p_{ic} = \frac{\sigma \tau_{ic}}{(\sigma-1)(1+t)} \frac{w_i}{\varphi}$$

This expression suggests that a higher export VAT rebate rate leads to lower prices. Given the expression for firms' optimal pricing and demand, we can write firms' total revenue and total profit in terms of exogenous variables:

$$r_{ic} = \left(\frac{\sigma \tau_{ic}}{(\sigma-1)(1+t)} \frac{w_i}{\varphi}\right)^{1-\sigma} Y_c P_c^{\sigma-1}$$

$$\pi_{ic} = \left(\frac{1+t}{\sigma}\right) r_{ic}$$

To analyze the effect of export VAT rebate changes, we take the first-order derivative of r_{ic} and π_{ic} with respect to t, which leads to the following expression:

$$\frac{\partial r_{ic}}{\partial t} = (\sigma-1)\left(\frac{\sigma \tau_{ic}}{(\sigma-1)} \frac{w_i}{\varphi}\right)^{1-\sigma} Y_c P_c^{\sigma-1} (1+t)^{\sigma-2} \quad (1)$$

$$\frac{\partial \pi_{ic}}{\partial t} = \left(\frac{\sigma \tau_{ic}}{(\sigma-1)} \frac{w_i}{\varphi}\right)^{1-\sigma} Y_c P_c^{\sigma-1} (1+t)^{\sigma-1} \quad (2)$$

Since $\sigma > 1$, we have $\partial r_{ic}/\partial t > 0$ and $\partial \pi_{ic}/\partial t > 0$. A reduction in the export VAT rebate is equivalent to a decrease in t, which would subsequently lead to a decline in firms' total revenue and total profits.

These theoretical predictions have been confirmed in previous empirical studies. Feldstein and Krugman (1990) suggest that the partial refund of VAT is equivalent to an export tax that raises exporters' costs. Using China's firm- and product-level export data, previous studies have identified the positive and significant effect of export VAT rebates on firms' export volumes at both intensive and extensive margins (Braakmann et al., 2020; Chandra and Long, 2013).

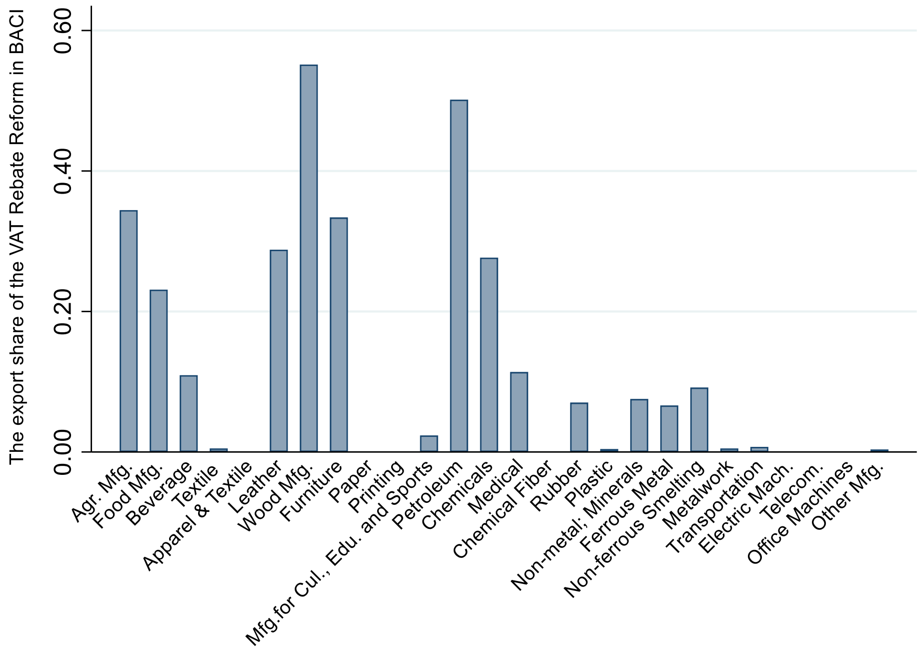

Fig. 1. Export shares of HS-6d products experiencing export VAT rebate reduction over total export value within CIC-2d industries.
Notes: This figure plots the distribution of export shares of HS-6d products experiencing export VAT rebate cut over total export value across China's CIC-2d industries. Product-level export flows are obtained from the 2006 CEPII-BACI dataset.

2.2.2. Pollution decomposition and the role of financial constraints

How can the above-mentioned effects of export tax rebate reduction be related to firms' environmental performance? To obtain a better understanding of the underlying forces driving firms' total pollutant emissions, we follow Martin (2011) and Fan et al. (2019) and perform the following decomposition:

$$Emission_{it} = \underbrace{\frac{Emission_{it}}{Output_{it}}}_{technique\ effect} \times \underbrace{Output_{it}}_{scale\ effect} \tag{3}$$

This formula suggests that firm-level total pollutant emissions are determined by firms' output level, the "scale effect," and firms' emission intensity, the "technique effect." A reduction in the export VAT rebate can potentially influence affected firms' total pollutant emissions through these two effects. First, as Eq. (1) suggests, a reduction in the export VAT rebate would lead to decreases in firms' export revenues. If increases in domestic market sales cannot compensate for the loss in the export market, we would see a decrease in firms' overall output level, leading to a negative scale effect.

Second, firms' pollutant emission intensities are closely related to their capacity to use energy efficiently and clean up pollutants. Firms' investment in environment-protection and productivity-enhancing technologies can reduce pollutant emission intensities. According to Eq. (2), affected firms would experience decreases in profits as a result of export VAT rebate reduction. With limited financial resources, firm managers may prioritize investments that improve firms' market outcomes, which would crowd out environment-protection-related investments. Additionally, internal financial constraints may reduce firms' engagement in productivity-enhancing activities, such as R&D (Chen and Guariglia, 2013). This, in turn, leads to increased pollution emission intensities.

Previous studies have confirmed the negative effect of poor financial performance on firms' environmental performance. Using an unbalanced panel of Czech firms in the 1990s, Earnhart and Lizal (2006) show that higher profitability leads to lower total emissions and emission intensities. Using a general equilibrium model and establishment-level data from the US, Andersen (2020) finds that increases in firms' default risks would raise borrowing costs, and thus, lower technology investment, which leads to increases in emission intensities. Aigbedo (2021) uses firm-level data from 32 countries and finds a positive influence of revenue growth on environmental performance.

Based on the analysis above, we propose the following hypothesis:

H1. A reduction in export VAT rebate would lead to increases in affected firms' pollutant emission intensities, and decreases in firms' total outputs. The effect on total emissions depends on the relative magnitude of the scale effect and technique effect.

When faced with worsened internal financial conditions, firms can turn to external financial institutions to relax their financial constraints. Previous studies have documented the importance of external finance to different aspects of firm performance, including firms' size of employment, investment, trade activities, and innovative behaviors (Giebel and Kraft, 2020; Amiti and Weinstein, 2018; Chodorow-Reich, 2014; Giebel and Kraft, 2019; Manova, 2013). As documented in recent literature, easy access to external finance can improve firms' environmental performance. For instance, Chen et al. (2021b) show that the expansion of city commercial banks in China reduces regional pollution levels by improving innovation capacity, attracting FDI, and upgrading the industrial structure. At the firm level, Chen et al. (2023) find that banking deregulation in China improved firms' production efficiency, leading to decreased COD emission intensity. Using World Bank Survey data from 2011 to 2013, Tian and Lin (2019) show that obstacles to financing activities would undermine a firm's environmental performance.

In China, debt financing from commercial banks is the primary source of external finance (Chen et al., 2020). Additionally, there are vast cross-regional differences in accessing external finance in China, which influence local firms' access to external finance. Even though firms affected by the Export VAT rebate reduction policy would experience worsened financial performance, we expect firms located in regions with easier credit access to be less financially constrained and thereby, have relatively better environmental performance. We formulate the above analysis using the following hypothesis:

H2. Firms located in financially developed regions with easier access to loans would experience a smaller increase in pollutant emission intensities following the export VAT rebate reduction policy.

2.2.3. Distorted investment and decreases in environment-technology upgrade

H1 and H2 emphasize the crucial role played by credit constraints in determining firms' pollution emissions following the export VAT rebate reduction policy. We argue that the distortion in investment decisions is the primary channel for policy-induced credit constraints to negatively influence firms' environmental performance. Technological progress has been one of the most important driving forces for decreased pollution intensity over the years (Zeng et al., 2022; Ma and Stern, 2008). Similar to technology upgrade in production activities, firms can realize environment-technology upgrade through either technology adoption or in-house innovation (Verhoogen, 2021). However, the purchase of environment-protection equipment may crowd out production-related investments, which can directly improve the outputs and profits of financially stressed firms. Therefore, firms affected by the export rebate reduction policy are likely to reduce their purchases of environment-protection equipment.

Additionally, financially constrained firms have more incentives to seek external financing such as bank credit. The in-house development of green technologies involves intangible, firm-specific, and human-capital-intensive assets that are difficult to use as collateral. Therefore, financially constrained firms over-invest in tangible assets and under-invest in intangible assets such as green innovations (Andersen, 2017). Thus, we propose the following hypothesis:

H3. Firms affected by the export VAT rebate reduction policy would reduce the purchase of environment-protection equipment and facilitate green innovation. However, this effect can be mediated by the local financial development level.

2.2.4. TFP and energy efficiency

Environment-protection investment could promote energy-saving technologies that increase energy and resource use efficiency in the production process and end-of-pipe technologies that eliminate generated pollutants before discharging them into the environment (Yizhong et al., 2021). In addition to reducing environment-protection investment, financial constraints induced by export VAT rebate reduction policy can also negatively influence firms' overall productivity owing to reduced financial resources for productivity-enhancing activities such as R&D (Chen and Guariglia, 2013; Grifell-Tati and Lovell, 1999). Meanwhile, firms' productivity level embodied in the technological process is a critical determinant of energy efficiency (Chen et al., 2021a, 2021b; Li and Lin, 2018; Qi et al., 2020). Qi et al. (2020) study 14 coal-intensive industries in China and find that technological progress has been the main driver for increasing energy efficiency over the years. Therefore, we argue that energy efficiency decrease owing to productivity slowdown is an additional channel for policy-induced credit constraints that negatively influence firms' environmental performance.

This study focused on two types of pollutant emissions: SO_2 and COD. SO_2 is a by-product of the burning of sulfur-bearing fossil fuels, especially coal (Greenstone et al., 2019). In China, coal accounts for 85% of energy consumption in the industrial sector, indicating that burning coal is the major contributor to manufacturing firms' SO_2 emissions (Chen et al., 2021a). COD measures the degree of organic pollution in water bodies and is a critical parameter in water quality assessment (Li et al., 2018). Suppose that firms' internal credit constraints cause reduced investment in environment-protection upgradation and lower productivity. In this case, we expect firms to increase their use of coal and water for each output unit, leading to increased pollutant emissions per output. Based on the above analysis, we propose the following hypothesis:

H4. Export VAT rebate reduction policy leads to decreases in TFP, which in turn increases energy and resource use intensities.

3. Variable construction and regression specification

In this section, we introduce an empirical design to examine how exporters would respond to export VAT rebate reduction. Before introducing the identification strategy, we first describe the construction of firm-level exposure to export VAT rebate reduction.

3.1. Construction of firm exposure to the export VAT rebate reduction policy

The exposure to export VAT rebate reduction is heterogeneous across firms. Firms exporting larger shares of the VAT-reform-targeted products before 2008 are likely to experience a more severe reduction in export VAT tax rebate following policy implementation. These firms are referred to as the "treatment" group in the analysis. Firms exporting smaller shares of VAT-policy-targeted products before 2008 are less likely to be affected by the policy, and they can be considered as the "control" group in the DiD framework. The non-exporters are also in the "control" group since they are not affected by the rebate adjustment.

Guided by this idea, we construct a measure for firms' exposure to export tax rebate adjustments using firms' pre-policy exporting structure with information from Customs Data. Especially, we focus on whether the policy affects firms' core export products. We first rank exporters' products according to their export values in 2006, and define the top three products in export value as firms' core export products. We construct a dummy variable $RebateCore_i$ that equals 1 if one of firm i's core product is on the adjustment list, and 0 otherwise. We further construct alternative exposure measures for robustness checks. For instance, we construct another treatment variable $RebateFull_i$ that equals 1 if any of the firms' exporting products are on the adjustment list, and otherwise 0. We also construct a continuous treatment variable $RebateShr_i$ that equals to the share of exporting products that are on the adjustment list.[4]

3.2. Regression specification

Based on the pre-policy rebate measures constructed above, we employ a DiD strategy to examine the policy effect on firms' environmental performance. Specifically, we compare the pollution emission responses of firms that are exposed to the policy to that of firms that are not exposed to the rebate adjustment policy. The regression specification is as follows:

$$y_{it} = \beta_0 + \beta_1 RebateCore_i \times Post07_t + \mathbf{\Gamma}' \boldsymbol{X_{it}} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{4}$$

The dependent variable y_{it} represents firm-level economic and environmental outcomes for firm i in year t, including the log of exporting value, pollution emission, and emission intensity. $RebateCore_i$ indicates firms' treatment status as introduced in Section 3.1. $Post07_t$ is a dummy variable that equals to one in years after 2007 (2007 not included), and zero otherwise. The key variable of interest is the interaction term $RebateCore_i \times Post07_t$, whose coefficient β_1 captures the different responses of the treated and non-treated firms before and after the policy implementation.

To further alleviate the omitted bias and simultaneity issue, we incorporate a battery of control variables and fixed effects. $\boldsymbol{X_{it}}$ contains a series of firm-level characteristics, including sales, employment,

[4] The construction is as follows

$$RebateShr_i = \sum_{p \in \omega_i} \left(\frac{Exp_{ip}^{2006} \times VAT_p}{Exp_i^{2006}} \right)$$

where VAT_p is a dummy indicating whether a product p is one of the export-rebate-treated goods. Exp_i^{2006} is firm i's total exports of all products across all destinations in 2006.

leverage, liquidity, and TFP, which could potentially affect a firm's exports portfolio and pollution outcomes. We then include the firm fixed effect λ_i to account for other unobserved time-invariant confounders across firms. The year fixed effect γ_t captures time-varying factors, such as other policies or economic shocks for all firms and cities. ε_{it} is the error term. Standard errors are clustered at the city level to deal with heteroskedasticity across firms within the same city.

To capture the sources driving pollution emission changes, we further decompose total pollution emissions into the scale effect and the technique effect as in Eq. (3) . In Eq. (3), $Emission_{it}$ represents the total pollution emissions of SO_2 and COD from firm i in year t. The first term on the right-hand side is the emission intensity, which is equal to the total emissions divided by total output, indicating the technique effect of a firm. The second term on the right-hand side is the firm's output level in a given year, which captures the firm's scale effect.

3.3. Endogeneity issues

Although we use a DiD specification by exploiting the exogenous change in export VAT rebate reduction, our identification still faces several endogeneity concerns that could lead to biased estimates. The first concern is the anticipation effect. Despite the rapid implementation of the export VAT rebate reduction, firms may have already anticipated the policy given the deteriorating environmental conditions. Therefore, firms may adjust their exports and pollution behaviors in advance, which could contaminate the exogeneity of treatment $RebateCore_i$ and thus bias our estimates.

The second concern is the simultaneity issue, which arises if omitted variables correlate with both the explanatory and dependent variables and could confound the policy effect. The products targeted by rebate reduction may differ systematically from non-targeted products, leading to unobserved differences between treated and non-treated firms. In this case, the estimated β_1 could reflect a differential time trend rather than the causal impact of the export VAT rebate cut.

Controlling for firm fixed effects could partly relieve the above concerns. To further test whether these factors confound our baseline findings, we conduct an event-study analysis of firms' polluting and production outcomes to check whether any pre-trends exist before policy implementation. Specifically, we run the following specification:

$$y_{it} = \beta_0 + \sum_{\substack{\tau=2000 \\ \tau\neq 2007}}^{\tau=2013} (\beta_t D\{t=\tau\} \times RebateCore_i) + \Gamma' X_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{5}$$

Eq. (5) includes the same battery of controls and fixed effects as in Eq. (4). We drop the dummy variable for 2007, one year before the export VAT rebate policy took effect, to circumvent the multicollinearity issue. In addition to testing the existence of pre-trends, the event-study design can capture the dynamic impacts of the policy.

4. Data and summary statistics

4.1. Data

To investigate the environmental consequences of export VAT rebate reduction, we need to acquire information on firms' export structure, pollution, and other production and financial performance information. We employ several micro datasets: (1) the Chinese Customs Dataset (CCD) maintained by China's General Administration of Customs, (2) the ASIF maintained by the National Bureau of Statistics of China (NBSC), and (3) the AESPF of China maintained by the Ministry of Ecology and Environment (formerly known as the Ministry of Environmental Protection).

Chinese Customs Dataset. This dataset covers the universe of import and export transactions since 2000. The dataset includes detailed information for each transaction, such as the name and firm identifier of the exporter/importer, the 8-digit HS product code, trade regimes (ordinary or processing trade), trade value and quantities, and sourcing or destination countries. By taking advantage of such highly disaggregated trade records, we can construct firm-level exposure to the VAT rebate rate adjustment in the pre-policy period, following the method introduced in Section 3.1.

Annual Environmental Survey of Polluting Firms (AESPF). The AESPF dataset is an above-scale dataset that covers firms with one of the reported pollutants ranking in the top 85% of the total emission volume at the county level. It contains rich information on firms' environmental outcomes, including emissions of pollutants such as effluents, waste air, COD, NH_3, NOx, SO_2, smoke, and dust. The AESPF dataset also provides additional information on abatement facilities and energy consumption for coal, fuel, clean gas, and so on.

Annual Survey of Industrial Firms (ASIF). The ASIF provides comprehensive balance-sheet information on China's manufacturing firms, including their names, industry, location, production, and financial information such as employment, wages, output, use of intermediate inputs, and net fixed assets. It covers all state-owned manufacturing enterprises (SOEs) and non-SOEs with annual sales of over 5 million yuan before 2011 and those with annual sales of over 11 million yuan after 2011. We clean the data following Cai and Liu (2009) and the general accounting procedure, and construct a panel dataset following Brandt et al. (2012). As industry classification differs before and after 2002, we convert industry codes before 2002, namely GB/T 4754–1994, into GB/T 4754–2002. Inconsistencies also exist in administrative area codes, which we convert to 2003 administrative area codes. As the AESPF and ASIF datasets both report firms' names, institutional numbers, and addresses, we can match AESPF with ASIF using this information.

Firm-level patent and green patent datasets. The Chinese Patent dataset is maintained by the China National Intellectual Property Administration. It provides detailed information on each patent application, including the application year, name of applicants, and patent description. Patents are classified into three categories: invention patents, utility models, and design patents. By matching the Chinese Patent dataset with the ASIF dataset using firm names, we can obtain the firm-patent-level dataset. The Green Patent dataset is a subset of the Chinese Patent dataset. We employed the IPC "green inventory" classification from the World Intellectual Property Organization to identify green patents. We construct firm-level patent and green patent datasets by aggregating the number of patents for each category for further mechanism tests.

Other datasets. City-level controls are obtained from China's city statistical yearbooks. From the National Bureau of Statistics, we also obtain the classification list for green technology and environment-protection equipment.

4.2. Sample construction and summary statistics

To examine the direct impact of export VAT rebate reduction on dirty exports using Eq. (4), we first match firms in the ASIF and Customs datasets to construct the sample for regression analysis. Although these two datasets have different firm identifiers, detailed contact information, such as the firm's name, zip code, and contact person, allows us to match firms in the two datasets. This restricts our sample to manufacturing firms engaging in trade activities and enables us to investigate the policy's impact on dirty product exports.

To further examine how export VAT rebate reduction alters firms' polluting activities using Eq. (4), we construct a sample by matching firms in the ASIF and AESPF datasets using firms' registration numbers, firm names, zip codes, and legal person information. The resulting matched sample contains both production and pollution information before and after the reform implementation, which allows us to evaluate the environmental consequences of the rebate policy.

For the ASIF-Customs matched dataset, there are 75,465 firms in total over the sample period 2000–2013, which covers 219 CSIC-3d manufacturing industries and 296 prefectures. For the ASIF-AESPF matched dataset, there are 111,474 firms over the sample period 2000–2013, covering 212 CSIC-3d industries and 285 prefectures.

As we exploit within-firm variations before and after the policy, we need firm-level observations both before and after policy implementation. Thus, our regression sample is restricted to 34,126 firms over the entire sample period. For the ASIF-AESPF matched sample, 32,401 firms (whose core products were not on the export rebate list) were regarded as the control group and 1725 firms the treatment group. The number of firms in the treatment and control groups also varies across industries. For instance, there are 4063 firms in the control group and 557 firms in the treatment group in chemical raw materials and chemical products manufacturing. However, in high-technology industries, for example, special equipment manufacturing, there are 1401 firms in the control group and 5 firms in the treatment group.

Table 1 presents the means, standard deviations, and different percentiles for the outcome variables, explanatory variables, and control variables. Fig. 2 plots the mean export values, output values, employment size, and sales for firms in different industries, which also display large cross-industry variations in these firm characteristics. Fig. 3 plots the changes in the output share of the affected firms from 2000 to 2013. It is clear from the figure that output share has dropped significantly since the implementation of the rebate reduction policy. In what follows, a more rigorous empirical analysis is conducted to examine the economic and environmental outcomes of the export VAT rebate reduction policy.

5. Empirical results

Here we present the baseline results examining the firm-level outcomes of the export VAT rebate reduction policy. We first show the direct impact of export VAT rebate reduction on firms' exports of dirty goods. Next, we unpack the policy impact on firms' environmental outcomes, including their pollution emissions and emission intensity. We also conduct a battery of robustness checks on the baseline findings considering other contemporaneous policies and adopting alternative specifications.

5.1. *The impact of export VAT rebate reduction on exports of dirty goods*

We present the direct impact of export VAT rebate cuts on firms' dirty exports in Table 2. Columns (1) and (2) of Table 2 use firms' gross exports as the outcome variable. The results show that the reduction in export tax rebate indeed exerts a significant negative impact on firms' total export value. Specifically, firms experiencing policy shock would suffer a 33.4% decrease in their export value compared with unaffected firms. This is consistent with previous studies that also found a negative effect of export VAT rebate reduction on export performance (Braakmann et al., 2020; Chandra and Long, 2013). Furthermore, as the decrease in export VAT rebate rates would directly increase firms' export prices, the reduction in exports suggests that export demand to price is rather elastic.

To further investigate the impact of export VAT rebate cuts on exports of dirty goods, we run additional regressions by replacing outcome variables with the export values of dirty goods, and export share of dirty goods, as shown in columns (3)–(6) of Table 2. We find that the implementation of the export rebate reduction policy reduces firms' the value of dirty exports by 87.4%, and the share of dirty exports by 6.1%, indicating that the policy significantly reduced exports of dirty products and made the exports cleaner. We further examine the effect on the domestic sales share of a firm, which captures the relative importance of domestic sales and market for a firm, as shown in columns (7)–(8) of Table 2. The positive and significant estimates of the interaction term suggest that firms experiencing export rebate reduction would increase their relative sales in the domestic market. Finally, in columns (9) and (10) of Table 2, we present firms' probability of exiting the export market if affected by the export rebate reduction policy. We construct a dummy that takes a value of 1 if a firm exports in period t-1 but stops exporting in period t. Regression results suggest that a firm's probability of exiting the export market increases if its core export product receives less export VAT rebate following the policy.

Table 1
Summary statistics.

	Mean	Std. Dev.	Min	25%	50%	75%	90%	Max	Obs.
Panel A. Environmental performance									
SO_2 emission	11.758	1.449	5.784	10.751	11.657	12.639	14.286	19.240	183,208
SO_2 intensity	0.468	0.678	0	0.022	0.180	0.635	1.916	12.717	183,208
COD emission	11.567	1.520	0	10.483	11.472	12.508	14.249	19.093	183,208
COD intensity	0.277	0.591	0	0.005	0.043	0.238	1.458	12.294	183,208
Effluent emission	12.094	1.581	0	10.977	12.027	13.123	14.787	20.581	180,679
Effluent intensity	0.811	0.973	0	0.089	0.421	1.207	2.915	14.827	180,679
NH_3-N emission	11.337	1.538	0	10.221	11.217	12.293	14.050	19.080	149,022
NH_3-N intensity	0.036	0.170	0	0	0	0.009	0.140	5.338	149,022
Dust & Smoke emission	11.394	1.639	5.106	10.176	11.222	12.417	14.351	18.708	108,192
Dust & Smoke intensity	0.351	1.002	0	0	0	0	3.019	13.333	108,192
Panel B. Production performance									
Output	11.289	1.525	0	10.181	11.169	12.235	13.976	19.077	183,208
Patent	0.277	0.768	0	0	0	0	2.079	8.720	183,208
Green paten	0.022	0.188	0	0	0	0	0	5.425	183,208
Employment	5.663	1.157	2.079	4.860	5.617	6.378	7.672	11.993	183,208
TFP	5.272	1.449	−6.882	4.254	5.149	6.255	7.751	15.499	183,208
Liquidity	−0.036	0.377	−9.152	−0.163	0.026	0.179	0.398	1.749	183,208
Leverage	0.593	0.294	−0.581	0.406	0.596	0.771	0.987	19.296	183,208
Fixed assets	−1.131	0.703	−11.622	−1.467	−1.002	−0.640	−0.275	2.172	183,208
Panel C. Export performance									
Export value	16.095	2.201	5.728	14.944	16.342	17.506	19.219	26.421	431,031
No. dirty goods	0.306	0.951	0	0	0	0	2	95	431,031
Dirty export value	2.421	5.419	0	0	0	0	15.893	22.035	431,031
Dirty export share	0.076	0.242	0	0	0	0	0.902	1	431,031
Domestic sales share	0.472	0.407	0	0.016	0.435	0.928	1	1	354,796

Notes: This table provides the summary statistics for sample in the empirical analysis. All variables are in logarithm.

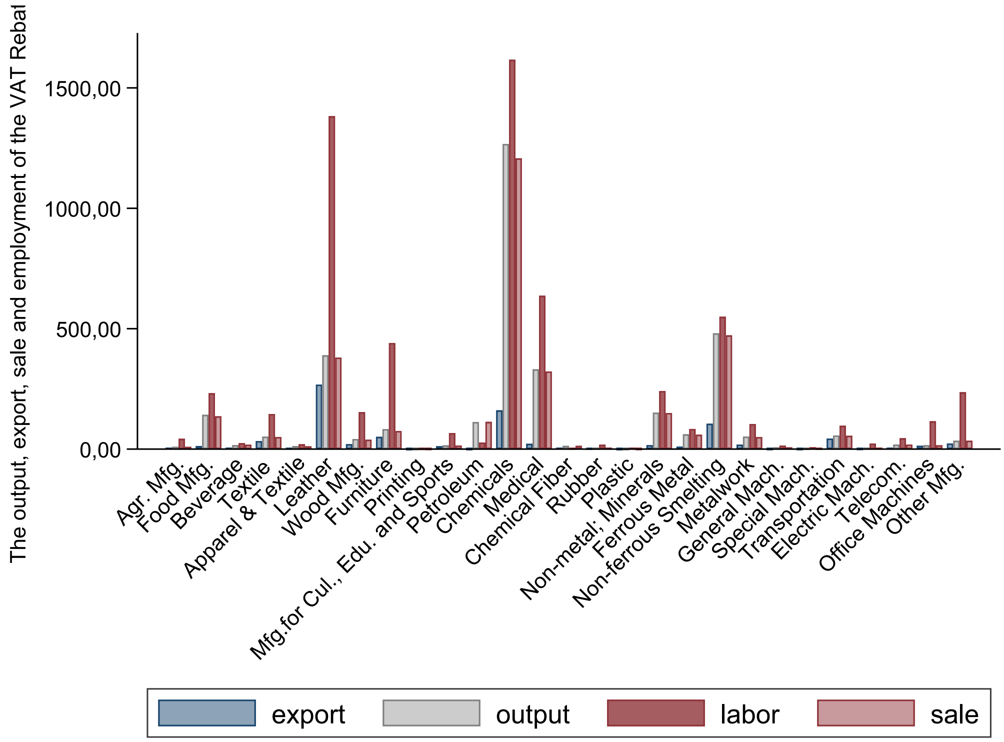

Fig. 2. Production performance of treated firms.
Notes: This figure plots the distribution of the average exports, output, employment, and sales of 2006 for firms experiencing export VAT rebate cuts across CIC-2d industries. The statistics are calculated from the matched dataset of the ASIF and custom databases.

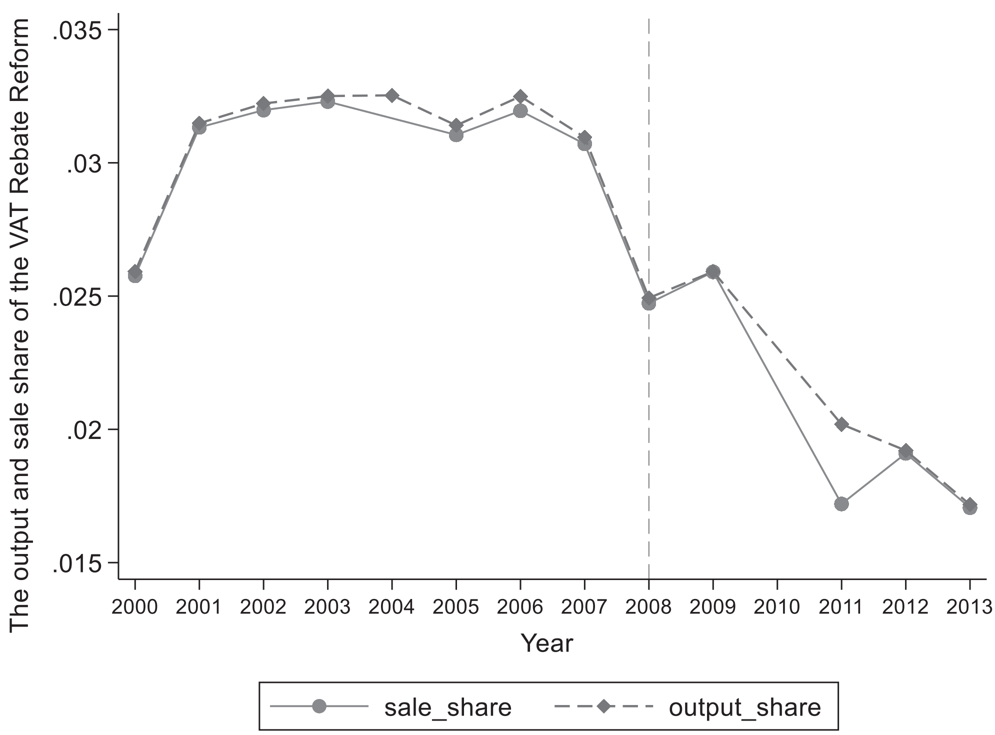

Fig. 3. Output and sales shares of firms experiencing export VAT rebate cuts during 2000–2013.
Notes: This figure plots the output and sales shares of firms experiencing export VAT rebate cuts from 2000 to 2013. Statistics were calculated from the matched dataset of the ASIF and custom databases.

Table 2
Impact of export VAT rebate cut on firms' exports of dirty goods.

	Export value		Dirty export value		Dirty export share		Domestic sales share		Exit from export	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RebateCore×Post07	−0.315***	−0.334***	−0.924***	−0.874***	−0.058***	−0.061***	0.030***	0.030***	0.023***	0.015***
	(0.030)	(0.032)	(0.115)	(0.115)	(0.009)	(0.009)	(0.006)	(0.006)	(0.004)	(0.004)
Employment		0.496***		0.208***		−0.0002		−0.023***		−0.047***
		(0.017)		(0.018)		(0.001)		(0.002)		(0.002)
TFP		0.294***		0.154***		0.001***		0.004		−0.013***
		(0.014)		(0.013)		(0.0004)		(0.003)		(0.001)
Liquidity		0.122***		0.106***		0.001		−0.007		−0.019***
		(0.019)		(0.038)		(0.002)		(0.005)		(0.004)
Leverage		0.240***		0.114**		−0.0002		−0.0173**		−0.001
		(0.037)		(0.058)		(0.002)		(0.008)		(0.005)
Fixed assets		0.050***		0.042***		0.001*		0.0001		−0.003**
		(0.010)		(0.014)		(0.0005)		(0.002)		(0.001)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Obs.	420,199	359,183	420,199	359,183	420,199	359,183	344,348	319,828	420,199	359,183
R^2	0.776	0.796	0.819	0.825	0.906	0.910	0.768	0.780	0.290	0.197

Notes: This table shows the direct impact of export VAT rebate cut on firms' exports of dirty goods. The dependent variables are firms' log of total export value (columns 1–2), log of exports of dirty goods (columns 3–4), share of dirty goods exports over total exports (columns 5–6), share of firms' domestic sales over total sales (columns 7–8), and exit from the exporting market dummy (columns 9–10). All regressions control for firm-level, city-level and year fixed effects. The sample period is 2000–2013. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5.2. *The impact of export VAT rebate reduction on firms' pollution outcomes*

Table 3 shows firm-level environmental outcomes for the adjustment of the export tax rebate rates. We focus on two major pollutants, SO_2 and COD, that are responsible for air pollution and water pollution respectively. Column (1) uses total emissions of SO_2 as the outcome variable, while column (3) uses total emissions of COD as the outcome variable. In both columns, the estimates on the $RebateCore_i \times Post07_t$ are negative, suggesting that firms that are affected by the export VAT rebate cuts would reduce their total pollutant emissions. The effect is more significant for COD emissions than for SO_2 emissions.

The pollution-reduction effect of the policy could be a result of either the scale effect (reduced total output) or technique effect (improved pollution emission technology), which have different economic implications. If the pollution-reduction effect of the policy is because of the scale effect, the output reduction would imply higher unemployment and negative shocks to the local economy. On the contrary, if the technique effect dominates, the affected firms could achieve pollution-reduction goals without reducing employment and output levels, which would be a more desirable outcome.

To test which of the two channels drives the patterns in columns (1) and (3) of Table 3, we use firms' SO_2 emission per output, COD emission per output, and total output as outcome variables in columns (2), (4), and (5), respectively. The estimates in columns (2) and (4) are positive and significant at the 1% and 5% levels, respectively, indicating that reduced export rebates lead to a relative increase in emission intensities for SO_2 and COD. Column (5) shows that the total output of the treated firms dropped in comparison to that of the control firms. Since the policy effect on output is larger than that on SO_2 and COD emission intensities (−0.077 vs. 0.060 and − 0.077 vs. 0.030), the negative scale effect dominates and leads to the overall negative effect of export rebate reduction effect on total pollution emissions. Although relative decreases in total output may help reduce total pollutant emissions, the

Table 3
Export VAT rebate cut and pollution emission and intensity.

	SO_2		COD		Output
	Emission	Intensity	Emission	Intensity	
	(1)	(2)	(3)	(4)	(5)
RebateCore×Post07	−0.016	0.060***	−0.047**	0.030**	−0.077***
	(0.018)	(0.013)	(0.019)	(0.012)	(0.016)
Employment	0.447***	−0.060***	0.455***	−0.052***	0.507***
	(0.007)	(0.005)	(0.007)	(0.005)	(0.005)
TFP	0.512***	−0.159***	0.569***	−0.103***	0.671***
	(0.009)	(0.008)	(0.011)	(0.006)	(0.013)
Liquidity	0.036***	0.007	0.019**	−0.009	0.028***
	(0.009)	(0.007)	(0.008)	(0.007)	(0.007)
Leverage	−0.035**	0.018*	−0.065***	−0.012	−0.053***
	(0.014)	(0.010)	(0.014)	(0.009)	(0.014)
Fixed assets	0.073***	−0.032***	0.082***	−0.024***	0.105***
	(0.005)	(0.004)	(0.005)	(0.003)	(0.005)
Firm FE	**Y**	**Y**	**Y**	**Y**	**Y**
City FE	**Y**	**Y**	**Y**	**Y**	**Y**
Year FE	**Y**	**Y**	**Y**	**Y**	**Y**
Obs.	180,481	180,481	180,481	180,481	180,481
R^2	0.926	0.766	0.933	0.739	0.963

Notes: This table shows the impact of export VAT rebate cut on firms' SO_2 and COD emissions, and intensity. The dependent variables in columns (1) and (2) are firms' total emissions and emission intensity of SO_2, respectively. The dependent variables in columns (3) and (4) are firms' total emissions and emission intensity of COD, respectively. Emission intensity is defined as the pollution emission per unit output. The dependent variable in column (5) is firms' total output value. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

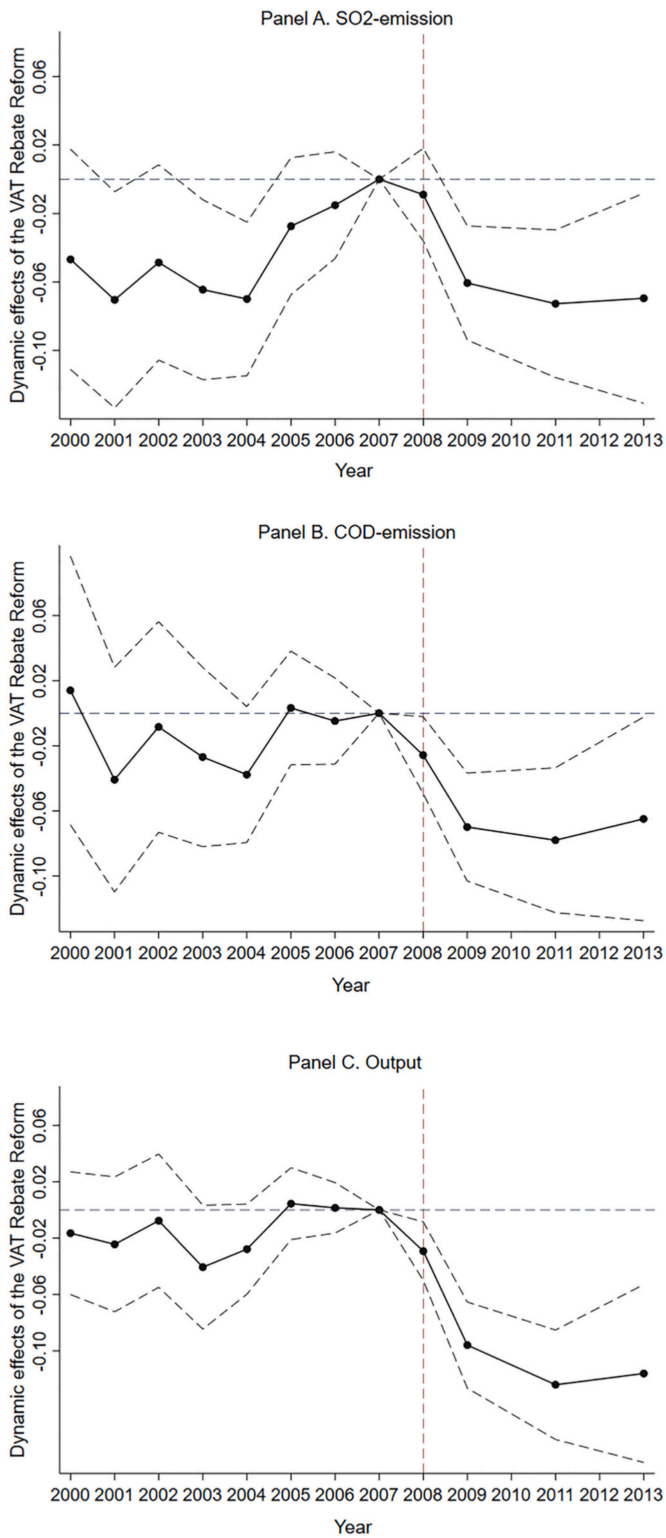

Fig. 4. Dynamic impact of export VAT rebate cut on output and emission.
Notes: This figure shows the dynamic impact of export VAT rebate cut on firms' total outputs and total emissions of SO_2 and COD. The year prior to the policy is 2007, and it is set as the reference year. The 95% confidence intervals are presented.

positive technique effect suggests that affected firms become less capable of clean production than their non-affected peers. From the interaction estimate in column (2), we can observe that firms affected by the policy would experience a 6% larger increase (or 6% smaller decrease) in SO_2 emission intensity compared with that of unaffected firms. The interaction estimate in column (4) suggest that firms affected by the policy would experience a 3% larger increase (or 3% smaller decrease) in COD emission intensity compared with that of unaffected firms.

5.3. Checks on the identifying assumptions

An important assumption of our DiD identification strategy is that the different overtime changes in pollution activities across firms are solely caused by the implementation of the export VAT rebate reduction, rather than by any pre-existing differential time trends across firms. To check the validity of the identifying assumptions, we estimate an event-study specification, as shown in Eq. (5).

Fig. 4 plots the estimates on the $RebateCore_i$ and year dummies' interactions for firms' total outputs and emissions of COD and SO_2. For all three outcome variables, we observe no significant pre-trends before 2008, suggesting that firms targeted by the policy and not targeted show little differential trends in total pollutant emissions and total output movements. After the policy is implemented, we observe a drop in the interaction estimates for firms' total outputs and total emissions of COD and SO_2, with the drop more significant for COD emissions and total outputs.

Fig. 5 further displays the dynamic impact of the policy in terms of pollutant emission intensities. Before the export VAT rebate reform in 2007, all firms had similar trends. In 2008 and after, the emission intensities of firms exposed to the export VAT rebate reduction increased

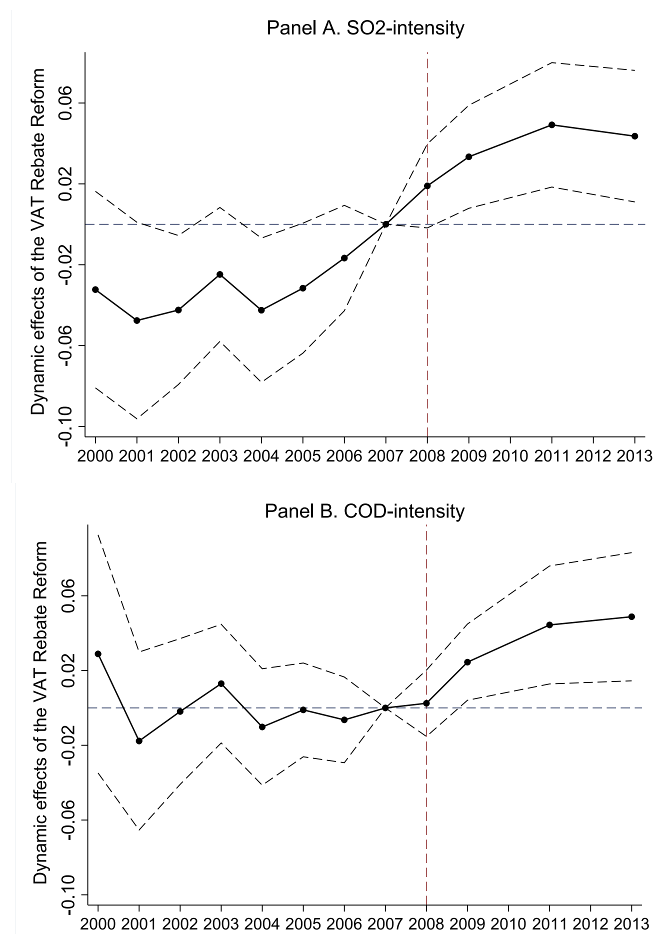

Fig. 5. Dynamic impact of export VAT rebate cut on pollution intensity.
Notes: This figure plots the dynamic impact of export VAT rebate cut on firms' SO_2 and COD emission intensity. One year prior to the policy is 2007, and it is set as the reference year. The 95% confidence intervals are presented.

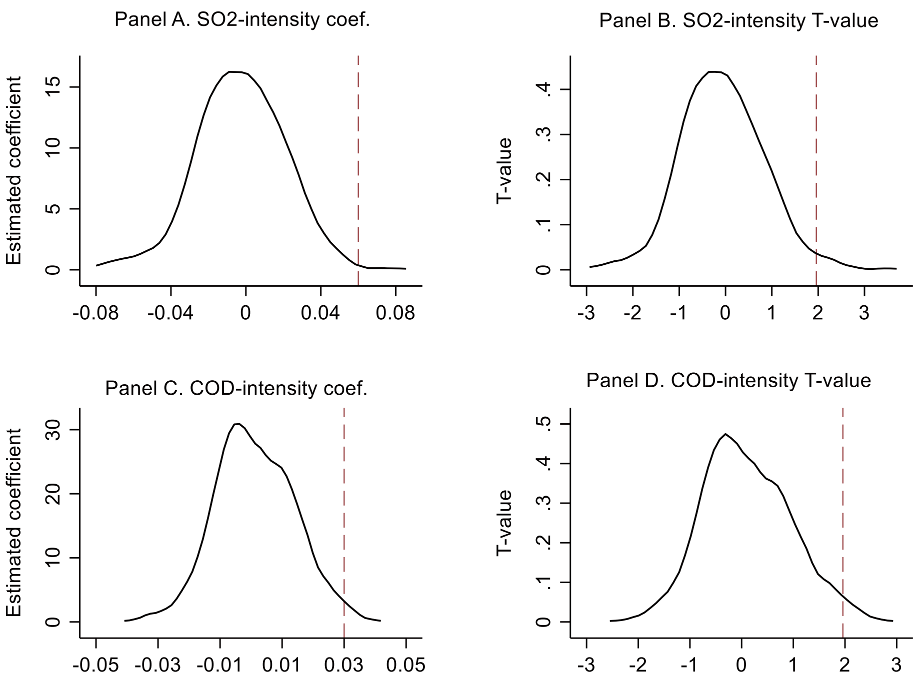

Fig. 6. Placebo test of export VAT rebate cut on pollutant intensities.
Notes: This figure plots the placebo test for the impact of the export VAT rebate reduction on firms' SO_2 and COD emission intensity. We randomly assign the treatment variable *RebateCore* and rerun the model to estimate the coefficient 500 times. The distributions of the estimated coefficients and the corresponding t-values are reported. Red lines are actual estimates.

significantly compared to those of non-treated firms. Overall, the event-study analysis in Figs. 4 and 5 further validates the causal impact of the export VAT rebate cut on firms' total pollutant emissions and emission intensities.

Although we control for a comprehensive set of firm characteristics, some unobserved factors may drive the baseline patterns. To further verify the robustness of our baseline findings, we conduct placebo tests by randomly assigning the treatment variable $RebateCore_i$ to the sample firms and rerunning the baseline regressions to obtain the pseudo-estimates. We repeat the above process 500 times, and the results are shown in Fig. 6. It shows the estimated coefficients and corresponding t-values for the placebo tests for the pollution intensity of COD and SO_2. The pseudo-estimates for both pollutants have close-to-zero mean values, and most of the t-values are smaller than 1.64 and insignificant. These placebo tests further substantiate our empirical design and estimate the policy effect.

5.4. Robustness checks

In addition to pre-trends, another major concern for endogeneity is the contemporaneous economic and policy shocks that may correlate with the export VAT reduction policy and firms' environmental outcomes. In this section, we perform a battery of robustness checks accounting for these confounding factors. Moreover, we check the robustness of the baseline results using alternative treatment measures and specifications.

5.4.1. Contemporaneous domestic policy shocks

The export VAT rebate reduction policy signals the effort made by the Chinese government to reduce pollution emissions using trade policy tools. There exist other contemporaneous environmental policies aiming to reduce pollutant emissions. For instance, in the 11th Five-Year Plan from 2006 to 2010, emission reduction targets were pursued more seriously compared to in the 9th and 10th Five-Year Plan periods. Specifically, national emission targets were subdivided among all levels of government, and local environmental performance was closely linked to government officials' achievement evaluations and promotion prospects. Polluters also faced more stringent administrative penalties. Fan et al. (2019) evaluate the effectiveness of the 11th Five-Year Plan in reducing pollutant emissions and find that more stringent environmental regulations led to fewer pollutant emissions.

To disentangle the influence of the 11th Five-Year Plan, we exploit cross-province differences in emission targets set by the central government, which can proxy for stringency in the enforcement of environmental regulations. We obtain information on provincial levels' emission reduction targets for SO_2 and COD from the official website of the State Council and then interact it with the $Post06_t$ dummy. The interaction term is included as a control in columns (1) and (2) of Table 4 to account for regional variations in the enforcement of the 11th Five-Year Plan. The interaction term has little impact on the baseline results, suggesting that regional differences in environmental regulation enforcement play little role in confounding our baseline results.

In addition to regional variations, different industries face varying levels of environmental regulation. Industries with high pollutant emissions are exposed to more regulatory supervision. We classify industries into dirty and non-dirty based on their pollutant emission levels and interact the dirty dummy with the $Post06_t$ dummy. The inclusion of the interaction term in columns (3) and (4) of Table 4 does not change the baseline findings. Overall, the results in columns (1)–(4) of Table 4 suggest that the enforcement of environmental regulations in the 11th Five-Year Plan period does not confound our baseline results.

Another contemporaneous environmental regulation we consider is the increase in SO_2 emission fees starting in 2007. Firms that emit pollutants have been required to pay pollutant discharge fees since 1979. However, vast cross-regional differences exist in regulation enforcement. To improve air quality, a regulation regarding pollutant emission fees was announced in 2005, which stipulated that each kilogram of SO_2 emissions be subject to 0.63 RMB discharge fees. In 2007, the State Council raised a discharge fee for SO_2 emissions to 1.26 RMB per kilogram. The timing of SO_2 discharge fee adjustments varied across provinces. For instance, Jiangsu Province raised the discharge fee in 2007, while Zhejiang Province raised it in 2014.

We account for cross-regional differences in SO_2 emission fee adjustments in columns (5) and (6) of Table 4. We construct a dummy $SO_2Disfee_p$ that takes a value of 1 if province p has adjusted SO_2 emission fees in the sample period. $ReformYr_t$ indicates the year of policy adjustment in different provinces. Controlling for provincial-level treatment of SO_2 emission fee adjustment has little impact on the estimates of the $RebateCore_i \times Post07_t$ interaction term. Firms also differ in their exposure to SO_2 emission fee adjustment policy. Firms with higher

Table 4
Robustness check: Considering contemporaneous environmental policies.

Dep.var.: intensity	11th Five-Year Plan				Increase of SO_2 emission fees			
	Provincial treatment		Dirty-industry treatment		Provincial treatment		Firm-level treatment	
	SO_2	COD	SO_2	COD	SO_2	COD	SO_2	COD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RebateCore×Post07	0.059***	0.030**	0.063***	0.032***	0.055***	0.024**	0.055***	0.024**
	(0.013)	(0.012)	(0.013)	(0.012)	(0.013)	(0.012)	(0.013)	(0.012)
11thFiveYr × Post06	0.005	−0.006						
	(0.011)	(0.010)						
Dirty×Post07			−0.113***	−0.106***				
			(0.010)	(0.009)				
SO_2Disfee × ReformYr					0.018**	0.018**		
					(0.007)	(0.007)		
SO_2Ems. × Post07							0.001**	0.001**
							(0.001)	(0.001)
Firm controls	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Obs.	180,481	180,481	180,481	180,481	180,481	180,481	180,481	180,481
R^2	0.766	0.739	0.767	0.740	0.767	0.739	0.766	0.739

Notes: This table provides a robustness check considering other contemporaneous environmental policies. The dependent variables are firms' emission intensities of SO_2 and COD. Columns (1)–(4) consider the impact of the 11th Five-Year Plan. Specifically, columns (1)–(2) use provincial-level policy targets as treatment, while columns (3)–(4) use the dirty industry dummy as treatment. Columns (5)–(8) consider the reform of disposable fees for SO_2 since 2008. Specifically, columns (5)–(6) use provincial-level treatment and columns (7)–(8) use firm-level pre-period SO_2 as treatment. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

SO_2 emissions would face an increase in their pollutant discharge fees. To check whether this confounds our baseline findings, we include the interaction term between firms' initial SO_2 emission intensity and the $Post07_t$ dummy as a control, which does not change the baseline results either.

5.4.2. Contemporaneous global economic shocks

In addition to domestic economic policy shocks, global economic changes can influence firms' financial outcomes, and consequently, their environmental performance. One of the most significant global economic shocks that occurred at the time of the export VAT rebate cut was the Global Financial Crisis (GFC), which originated in the United States in late 2007. It led to economic downturns in the affected countries and negatively affected global trade. The baseline estimates on the $RebateCore_i \times Post07_t$ interaction term could be biased if firms affected by the export tax rebate reduction policy are also severely influenced by the GFC. Since the US is the country of origin and the country most affected by the GFC, firms exporting a large share of their products to the US may suffer from a high level of export slowdown. Thus, we control for the interaction between firms' pre-policy export share to the US and the $Post07_t$ dummy to consider firms' exposure to the GFC. The inclusion of the interaction term does not change the baseline results, suggesting that the GFC does not confound the effect of the export VAT reduction policy.

Firms' exports could also be affected by the tariff imposed by the destination country and international fluctuations in exchange rates. We obtain each destination country's tariffs imposed on China's exports at the ISIC-Rev3 level from the TRAINS database. Using firms' pre-policy export information from the Customs database, we can construct firm's time-varying export tariff barriers.[5] We obtain exchange rate fluctuations of different currencies against the Chinese yuan from the Penn World Tables and use firms' pre-policy export structure to construct time-varying exchange rates faced by firms.[6] We control for time-varying firm-specific export tariff shocks and exchange rate shocks in columns (3) and (4) of Table 5; the estimates on the interaction term remain positive and significant.

5.4.3. Alternative measurements of the treatment

The baseline results use firms' core export products to measure whether the firm is being treated by the policy. In this section, we use two alternative firm-level exposure measures to consider the firms' treatment status, as discussed in Section 3.1. Specifically, we consider the full export structure of a firm when constructing the dummy $RebateFull_i$ which takes the value of 1 if at least one of the exported products is on the rebate reduction list. We then construct a continuous treatment $RebateShr_i$ to better capture the share of pre-policy exports that are exposed to rebate reduction. These two measures are then interacted with the *post07* dummy and included as controls. We present the results in columns (1) and (2) of Table 6, which show that using alternative treatment measures yields results consistent with the baseline findings. This suggests that our baseline findings are not sensitive to different treatment variables.

5.4.4. Alternative econometric specifications

Firms may also display heterogeneity across different industries and regions, which may confound the baseline results. Unobserved time-varying industry- and region-specific factors could simultaneously influence firms' treatment status from the rebate reduction policy and firms' environmental performance. As the variable of interest varies at the firm-year level, we can control for industry- and prefecture-year fixed effects to absorb these macro-level confounders. We present the

[5] The time-varying export tariff barriers are constructed as

$$Tariff\_exp_{ft} = \sum_{c=1}^{C} \sum_{k=1}^{K} \frac{Exp_{fkc}^{2006}}{\sum_{c=1}^{C} \sum_{k=1}^{K} Exp_{fkc}^{2006}} \times Tariff\_exp_{kct}$$

where k indicates industry and c, country. $Tariff\_exp_{kct}$ is country c's import tariff on China's exports in industry k year t.

[6] The time-varying firm-specific exchange rates are constructed as

$$Exrate\_exp_{ft} = \sum_{c=1}^{C} \frac{Exp_{fc}^{2006}}{\sum_{c=1}^{C} Exp_{fc}^{2006}} \times Exrate_{ct}$$

with $Exrate_{ct}$ indicating country c's exchange rate against the Chinese yuan in year t.

Table 5
Robustness check: International economic shocks.

Dep. var.: intensity	2008 financial crisis		Trade and exg. Rate shocks	
	SO_2	COD	SO_2	COD
	(1)	(2)	(3)	(4)
RebateCore×Post07	0.061***	0.027**	0.060***	0.030**
	(0.014)	(0.012)	(0.013)	(0.012)
USExpShr×Post07	−0.007	0.024		
	(0.031)	(0.025)		
Export tariff shock			0.001	0.002
			(0.002)	(0.002)
Exchange rate shock			−0.001	0.000
			(0.001)	(0.002)
Firm controls	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs.	180,481	180,481	180,481	180,481
R^2	0.766	0.739	0.766	0.739

Notes: This table provides a robustness check for international economic shocks. The dependent variables are firms' emission intensities of SO_2 and COD. Columns (1)–(2) consider the 2008 financial crisis by including the interactive term of firms' pre-08 export shares to the US with Post07. Columns (3)–(4) consider both export shocks and exchange rate shocks by including firm-level export tariff shocks and exchange rate shocks. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

results with these additional fixed effects in columns (5)–(8) of Table 6. As evident from the table, the baseline findings still hold after controlling for city- or industry-year fixed effect.

5.4.5. Selection bias and propensity score matching

The control group in the baseline analysis consists of non-exporting firms that are not affected by the rebate adjustment policy. However, firms may self-select into exporting, leading to large differences between exporting and non-exporting firms. The differences between exporters and non-exporters may confound the baseline findings. To further cope with the selection bias, we use the propensity score matching (PSM) method to find a subsample of control firms with more similar characteristics to firms in the treatment group. We use 1:10 nearest-neighbor matching with the matching variables being firm size, labor force, TFP, and asset structure. After obtaining the matched control group, we perform the baseline regressions again, and the results are shown in columns (9) and (10) of Table 6. Our regressor of interest, $RebateCore_i \times Post07_t$ remains positive and significant, consistent with the baseline results.

5.5. Heterogeneous analysis

Having established the causal relationship between export VAT rebate cuts and pollutant emissions, we test whether firm responses differ according to firm characteristics. We explore heterogeneous responses from two perspectives: firm ownership and industry characteristics. Heterogeneity analysis can help us gain a deeper understanding of the determinants of the effectiveness of export VAT rebate cuts on firms' polluting behavior, thus offering useful policy implications.

First, the discrepancy between the production process and environmental performance of different industries can be large in some cases. As we have a large number of firms in our sample, we can examine whether the effect of export VAT rebate adjustment on emissions varies across firms in various industries. More importantly, as mentioned in Section 2.1, the export VAT rebate reduction aimed at reducing highly polluting, energy-consuming, and pollution-intensive products' export VAT rebate in 2007. These products are mainly concentrated in industries with severe pollution. We are interested in examining the effect of export VAT rebate reduction on a firm's environmental performance across industries with different polluting intensities. To this end, we divide the firms into two groups. We generate a new variable, dirty (i.e., dirty industry), a dummy variable that measures industrial pollution intensity. This variable equals 1 for heavily polluting industries and 0 for lightly polluting ones.[7]

Columns (1) and (2) of Table A3 show that the changes in the dirty and non-dirty industries for total emissions and total output are not significantly different. However, the relative increase in emission intensities is smaller for firms in dirty industries, as evidenced by the negative and significant coefficients of RebateCore×Post07 × dirty in columns (1) and (2). One possible explanation is that polluting industries are regulated in the concurrent 11th Five-Year Plan, which limits their polluting activities (Fan et al., 2019).

In addition, Chen et al. (2022) argue that SOEs are created for strategic purposes and are more responsible for social welfare improvements. Therefore, it is possible that SOEs' increase in pollutant emission intensities may be smaller in comparison to when export tax rebates are reduced. To test this hypothesis, we interact the SOE dummy with RebateCore × Post07. Columns (3) and (4) of Table A3 suggest that the relative increase in SO_2 emission intensity is smaller for SOE, which partly supports the SOE corporate social responsibility hypothesis.

6. Mechanism testing

So far, we have causally identified the impact of the export VAT rebate reduction policy on firms' pollutant emission intensities. In Section 2.2, we propose a monopolistic competition model with export tax rebate and derive several hypotheses to explain the underlying mechanism. Specifically, the model shows that a reduction in export VAT rebate shrinks firms' output size and subsequently dampens firms' investment in environment-protection equipment and green innovation.

In this section, we empirically test the hypotheses outlined in Section 2.2. We first examine how export VAT rebate cuts affect firms' production and financial performance and then examine the role of external credit access. By documenting the substantial role of external credit access, we further study its mitigating impact on the policy effect on a firm's environment-friendly equipment purchase, green innovation, and resource recycling activities.

6.1. Export VAT rebate reduction and firms' financial performance

The reduction in the export VAT rebate rate directly increases firms' export cost; if the elasticity of export quantity to price is rather large, such an increase in export price would result in sales revenue in the international market. As shown in Table 2, the treated firms' export values and shares decreased significantly compared to non-treated firms. Owing to decreases in output following the rebate reduction policy, firms' financial performance may worsen, thus increasing financial constraints for affected firms. This, in turn, affects the environmental performance of firms. In this subsection, we examine the role of a firm's production performance on the impact of export VAT rebate cuts on its pollution emission intensity.

Table 7 tests how firms' production performance, such as sales, profitability, and TFP, would alter the impact of rebate reduction on the pollution intensity of the two pollutants, SO_2 and COD, in two separate panels. Column (1) of Table 7 replicates the baseline regression results on the impact of export VAT rebate reduction on pollution intensity. When we further include firm sales in the baseline specification and rerun the model, the estimated coefficient is still positive and

[7] Following Fan et al. (2019), we calculate the COD emission intensity at the industry level, indicated by each industry's proportion of total COD emissions in all industries in 2006. Then we classify the industries with pollution emission intensity greater than the median as dirty industries.

Table 6
Robustness check: Alternative treatments and specifications.

	Full product list		Continuous measure		City-yr FE		Industry-yr FE		PSM	
	SO_2	COD	SO_2	COD	SO_2	COD	SO_2	COD	SO_2	COD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RebateFull ×Post07	0.068***	0.034***								
	(0.011)	(0.011)								
RebateShr ×Post07			0.046***	0.026*						
			(0.017)	(0.015)						
RebateCore×Post07					0.042***	0.026**	0.056***	0.034***	0.036***	0.021*
					(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.012)
Firm controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	N	N	N	N	Y	Y
Year FE	Y	Y	Y	Y	N	N	N	N	Y	Y
City-Year FE	N	N	N	N	Y	Y	Y	Y	N	N
Industry-Year FE	N	N	N	N	N	N	Y	Y	N	N
Obs.	180,481	180,481	180,481	180,481	180,363	180,363	180,363	180,363	86,223	86,223
R^2	0.766	0.739	0.766	0.739	0.787	0.762	0.790	0.768	0.771	0.745

Notes: This table shows the robustness checks. The dependent variables are firms' emission intensities of SO_2 and COD. Columns (1)–(4) use alternative treatments, among which columns (1)–(2) let the treatment be 1 if one of the products of a firm experienced a rebate cut, and columns (3)–(4) consider a continuous treatment measure. Columns (5)–(8) use alternative specifications. Columns (9) to (10) show the PSM estimates. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

economically significant at the 1% level, but its absolute magnitude drops 50% (0.035/0.070) as shown in column (3) in Panel A in Table 7. We further provide the direct impact of export VAT rebate reduction on firm sales in column (2) Panel A Table 7, and the estimated coefficient of $RebateCore_i \times Post07$ is negative and significant at the 1% level. Columns (1), (2), and (3) unveil the intermediating effect of firm sales; in other words, the reduction in export rebate rate would shrink firms' sales revenue; poorer production performance subsequently hurts firms' investments in SO_2 emission and results in higher SO_2 emission intensity. We further replace firms' sales revenue with firms' profitability and rerun the regressions in columns (4) and (5) in Panel A Table 7 to examine the role of firms' financial performance. The estimated coefficient of RebateCore × Post07 in columns (5) still stays significant at the 1% level but drops from 0.07 to 0.06, indicating that profitability also exerts an intermediating effect. The above findings on sales revenue and profitability also echo the theoretical predictions in Section 2.2.1, which shows that a decrease in export rebate rate would subsequently lead to a decrease in firms' total revenue and total profit.

Finally, guided by H4, we investigate the productivity effect in columns (6)–(7) of Panel A of Table 7. The estimates show that the export VAT rebate reduction leads to a decrease in TFP and subsequently increases its SO_2 emission intensity. We also replace SO_2 emission intensity with that of COD and replicate the regressions in Panel B of Table 7; the results are still robust.

Table 7 shows that both firms' production and financial performance are key channels at work in shaping the effect of export VAT rebate cut on firms' environmental performance, that is, pollution intensity. Our findings provide not only empirical evidence for the theoretical predictions in Section 2.2, but are also consistent with those of Zhang (2019) and Xu and Kim (2022), who identify TFP and financial constraints as important channels affecting firms' environmental outcomes.

6.2. The role of local credit supply

In Section 6.1, we empirically examine the intermediating impact of a firm's internal production and financial conditions in shaping the technique effect of the export VAT rebate reduction. We are also interested in how a firm's external financial conditions such as access to credit alter the policy effect. In Section 2.2.2, we propose the hypothesis that a firm located in a financially developed region with easier access to loans would experience a smaller increase in pollutant emission intensities following the export VAT rebate reduction. In this section, we conduct a series of triple DiD regressions to empirically test this hypothesis.

We use a city's loan-to-GDP ratio in the initial period $Loan_c$ to proxy for its financial development, as well as firms' differentiated access to credit across space. Our variable of interest in the triple DiD regression is the interaction term $RebateCore_i \times Post07_t \times Loan_c$, whose coefficient captures the heterogeneous impact of the export VAT rebate reduction on firms' pollutant emission intensity across cities with differentiated credit access. The triple DiD estimation results using SO_2 and COD emission intensities as outcome variables are presented in Table 8. Columns (1) and (3) of Table 8 present the triple DiD estimation for SO_2 and COD, and the coefficients of the interaction term $RebateCore_i \times Post07_t \times Loan_c$ are both negative and significant at the 1% level, showing that firms located in a financially developed region with easier access to loans would experience a smaller increase in pollutant emission intensities following the export VAT rebate reduction. We further consider alternative rigorous specifications by controlling for city- and industry-year FE in columns (2) and (4), and the results remain robust.

6.3. Export VAT rebate reduction, local credit supply, and firms' other environmental performance

How does the local credit supply further mitigate the impact of export VAT rebate cuts on firms' other environmental outcomes? H3 predicts that firms affected by the export VAT rebate reduction policy would reduce the purchase of environment-protection equipment and reduce green innovation, and such an impact can be alleviated by local credit supply. H4 predicts that an export VAT rebate reduction would decrease TFP, which in turn increases energy and resource use intensities. However, local financial development can also mediate this effect. In this section, we empirically test the hypotheses.

Imports of environment-protection equipment. As detailed information on firms' investment and usage of environment-protection technology is unavailable in the AESPF dataset, we collect firms' imports of environment-protection equipment from the China Customs database to proxy for firms' adoption of environment protection technology. We further group environment-protection equipment into two types: energy-saving equipment and pollution-abatement equipment. Energy-saving equipment mainly aims to improve energy efficiency, and pollution-abatement equipment aims to reduce pollution emissions in the production process. Columns (1)–(2), (3)–(4), and (5)–(6) of Table 9 present the policy impacts on the imports of environment-protection, energy-saving, and emission-abatement equipment, respectively. The regressions in all odd-number columns of Table 9 are DiD estimations,

Table 7
Export VAT rebate cut and pollution intensity: Firm performance.

	Pollutant intensity	Revenue		Profitability		TFP	
		Revenue	Pollutant intensity	Profitability	Pollutant intensity	TFP	Pollutant intensity
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A SO_2							
RebateCore×Post07	0.070***	−0.184***	0.035***	−0.282***	0.060***	−0.116***	0.054***
	(0.013)	(0.030)	(0.012)	(0.061)	(0.012)	(0.027)	(0.012)
Revenue			−0.188***				
			(0.007)				
Profitability					−0.034***		
					(0.002)		
TFP							−0.139***
							(0.007)
Firm Controls	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
Obs.	143,575	143,575	143,575	143,575	143,575	143,575	143,575
R^2	0.763	0.930	0.778	0.783	0.766	0.899	0.773
Panel B COD							
RebateCore×Post07	0.041***	−0.184***	0.018	−0.282***	0.034***	−0.116***	0.030**
	(0.013)	(0.030)	(0.013)	(0.061)	(0.013)	(0.027)	(0.013)
Revenue			−0.121***				
			(0.007)				
Profitability					−0.022***		
					(0.002)		
TFP							−0.090***
							(0.006)
Firm Controls	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
Obs.	143,575	143,575	143,575	143,575	143,575	143,575	143,575
R^2	0.743	0.930	0.751	0.783	0.745	0.899	0.748

Notes: This table presents a mechanism test for firms' financial and production performance in terms of the impact of export VAT rebate on pollution intensity. *Profitability* is a firm's profit divided by its sales revenue. TFP is estimated following Olley and Pakes (1996): Firm-level controls include the log of firms' employment, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8
Export VAT rebate cut and pollution intensity: City's credit access.

	SO_2 intensity		COD intensity	
	(1)	(2)	(3)	(4)
RebateCore×Post07	0.084***	0.072***	0.071***	0.059***
	(0.022)	(0.021)	(0.019)	(0.019)
RebateCore×Post07 × Loan	−0.325***	−0.288***	−0.307***	−0.267***
	(0.122)	(0.106)	(0.118)	(0.097)
Loan×Post07	0.216***		−0.117	
	(0.077)		(0.139)	
RebateCore×Loan	−0.070	−0.118*	0.063	−0.019
	(0.057)	(0.071)	(0.063)	(0.072)
Firm controls	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
City FE	Y	N	Y	N
Year FE	Y	N	Y	N
City-Year FE	N	Y	N	Y
Industry-Year FE	N	Y	N	Y
Obs.	179,865	179,749	179,865	179,749
R^2	0.767	0.790	0.739	0.768

Notes: This table conducts a mechanism test for a city's credit access on the impact of export VAT rebate reduction on pollution intensity. Credit access loans are a city's total industrial loans divided by its GDP. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

and we find that the estimated coefficients of the interactive term $\text{RebateCore}_i \times \text{Post07}$ in columns (1), (3), and (5) are all negative and significant, indicating that the export VAT rebate cuts restrain firms' imports of environment-friendly equipment. The regressions in all even-numbered columns of Table 9 are triple DiD estimations. The coefficient of the triple interactive terms in column (2) and (6) are positive and significant at 1% level, suggesting that although export VAT rebate cuts hurt firms' imports of environment-friendly equipment, such an impact is mitigated by the city's credit access for the purchase of pollution reduction equipment.

Green innovation. In addition to external access to green technology, we are interested in the policy effect on firms' internal green technology innovation activities. We further examine the effect of the export rebate cut on firms' green innovation activities, and report the estimation results in Table 10. Column (1) of Table 10 shows that the export rebate reduction policy has little impact on firms' green patent number, and columns (3) and (5) of Table 10 show that the policy has a negative and significant impact on the firms' total patent number and green patent share. There are two potential channels at play in explaining the decrease in innovation activities owing to the export rebate reduction. One is firms' poorer internal financial condition, which results in less investment in innovation. The other is that firms are less incentivized to innovate as the global market share shrinks.

We further investigate how innovative activities in response to rebate reduction policy differ in terms of access to external credit access in columns (2), (4), and (6) of Table 10, where our variable of interest is the triple interaction of $RebateCore_i \times Post07_t \times Loan_c$. We do not find any significant effect of the triple interactive term in any regression, suggesting that locating in financially developed regions does not relax firms' financial stress and encourages innovative activities.

Energy use efficiency. We examined the mechanism of the impact of export tax rebate cuts on pollution emissions by reducing economic

Table 9
Export VAT rebate cut, credit access and firms' imports of environment-friendly equipment.

	Environment-protection		Energy-saving		Pollution-reduction	
	(1)	(2)	(3)	(4)	(5)	(6)
RebateCore×Post07	−0.437***	−0.650***	−0.015*	−0.017	−0.173***	−0.302***
	(0.064)	(0.084)	(0.008)	(0.013)	(0.052)	(0.087)
RebateCore×Post07 × Loan		0.171***		−0.005		0.101***
		(0.035)		(0.008)		(0.036)
Loan×Post07		−0.267***		−0.016***		−0.181***
		(0.054)		(0.005)		(0.053)
RebateCore×Loan		0.002		−0.005**		−0.000
		(0.005)		(0.003)		(0.004)
Firm controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Obs.	359,183	358,795	359,183	358,795	359,183	358,795
R^2	0.524	0.530	0.161	0.161	0.479	0.485

Notes: This table shows the impact of export VAT rebate cut on firms' imports of environment-friendly facilities. Environment-friendly equipment is classified into three types: environmental protection, energy-saving, and pollution-emission-reduction equipment. Credit access loans are a city's total industrial loans divided by its GDP. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 10
Export VAT rebate cut, credit access and firms' green innovation.

	Log(1+ green patents)		Log(1+ patents)		Green patent share	
	(1)	(2)	(3)	(4)	(5)	(6)
RebateCore×Post07	−0.008	−0.009	−0.054*	−0.058	−0.005***	−0.004
	(0.005)	(0.009)	(0.028)	(0.051)	(0.002)	(0.003)
RebateCore×Post07 × Loan		0.023		0.178		−0.001
		(0.074)		(0.418)		(0.020)
Loan×Post07		0.008		−0.020		0.000
		(0.012)		(0.056)		(0.004)
RebateCore×Loan		0.014		0.106		0.002
		(0.021)		(0.096)		(0.006)
Firm controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Obs.	180,481	179,865	180,481	179,865	180,481	179,865
R^2	0.489	0.491	0.520	0.520	0.302	0.302

Notes: This table provides the impact of the export VAT rebate cut on firms' green innovation. The dependent variables in columns (1) and (2) are the log of 1 plus the number of green patents of a firm. The dependent variables in columns (3)–(4) are the log of 1 plus the total number of patents of a firm. The dependent variables in columns (5)–(6) are the shares of green patents over the total patents. Credit access loans are a city's total industrial loans divided by its GDP. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

performance and abatement expenditure, reducing the import of green equipment, and restraining innovation. These channels belong to the end treatment of pollution emissions and green technology reduction, respectively (Fan et al., 2019). For manufacturing firms, factor input and energy efficiency affect pollution from the input side. For example, Gutiérrez and Teshima (2018) find that import competition improves energy efficiency and promotes emission reduction by Mexican manufacturing firms. More importantly, in Section 6.3, we find that the export tax rebate adjustment reduces the import value of energy-saving equipment. Does this imply that firms will also change their energy efficiency?

We unpack the impact of export tax rebate cut on firms' energy use efficiency with regard to coal and water in Table 11. Estimates on the interaction term in columns (1) and (2) of Table 11 for total coal use are insignificant. Nevertheless, columns (1) and (2) of Table 11 show a significant and positive impact of rebate reduction on firms' raw coal usage intensity, which indicates that firms exposed to the policy are less efficient in terms of raw coal usage. Higher raw coal usage intensity would directly result in higher SO_2 emission intensities, conditional on unchanged abatement equipment and investment. This finding is consistent with the results of the baseline analysis. In addition to coal use, the use of industrial water also affects pollution emissions, particularly COD. Columns (3)–(4) of Table 11 repeat the results for fresh water use intensity. Firms can reuse industrial water by improving sewage treatment and recycling technologies. Recycling industrial water can simultaneously achieve water conservation and reduce pollution. Since recycling industrial water requires extra investment, a reduction in the export tax rebate may also change firms' water consumption patterns. Column (3) of Table 11 shows that the export VAT rebate adjustment has insignificant impact on the fresh water consumption intensity.

When we include triple interaction terms with the prefecture loan-to-GDP ratio, we find that the estimates on the triple interaction terms are all significantly negative for all specifications in Table 11. These results suggest that locating in financially developed regions can partly alleviate the negative impact of export tax rebate on energy use efficiency. Our findings differ from those of Fan et al. (2019), who find that stricter environmental regulations spur firms' water recycling. This may be because the environmental regulations studied by Fan et al. (2019) set pollution targets directly (the 11th Five-Year Plan), while export VAT rebate reduction affects firms' environmental performance indirectly through firms' financial conditions. At this point, we find that export

Table 11
Export VAT rebate cut, credit access and energy use efficiency.

	Raw coal		Fresh water	
	(1)	(2)	(3)	(4)
RebateCore×Post07	0.018**	0.028**	0.023	0.096***
	(0.009)	(0.014)	(0.017)	(0.030)
RebateCore×Post07 × Loan		−0.163**		−0.587***
		(0.074)		(0.225)
Loan×Post07		0.079		0.103
		(0.052)		(0.157)
RebateCore×Loan		−0.060***		0.087
		(0.019)		(0.093)
Firm controls	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs.	100,178	99,833	179,164	178,556
R^2	0.796	0.796	0.816	0.816

Notes: This table shows the impact of export VAT rebate cut on firms' production energy efficiency. The dependent variable in columns (1)–(2) is the usage of raw coal per unit of output. The dependent variable in columns (3)–(4) is the usage of freshwater per unit output. Credit access loans are a city's total industrial loans divided by its GDP. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

VAT rebate cuts reduce the import of environmental protection equipment, squeeze green innovation, and discourage energy use efficiency. Next, we investigate the effect on pollution-abatement competence. Table A2 shows the impact of export tax rebate reduction on firms' abatement capacity and equipment for sewage and exhaust gases.

We find that the negative and statistically significant result in column (1) and the result in column (3) is not significant. We include triple interactions with the local credit supply in columns (2) and (4) to check whether the financing constraint affects the pollution treatment capacity. We find that local credit capacity can effectively alleviate this negative effect on firms' pollution control ability, which is consistent with the findings of (Wang et al., 2018).

7. Conclusion and policy implications

China has achieved unprecedented economic success, but at the expense of the environment. In June 2007, the Ministry of Finance in China announced a large-scale reduction in export tax rebates for exports of highly polluting, energy-consuming, and resource-based products. To what extent does China's rebate reduction refine its export structure and alleviate its environmental issues? How do exporting and non-exporting firms respond differently to the policy? In this study, we use a quasi-natural experiment to examine the impact of China's 2007 export VAT rebate reduction on firms' environmental performance in a DiD framework. Our empirical analysis shows that the export VAT rebate reform exerts a negative and significant impact on firms' exports of dirty goods in terms of export value, dirty product variety, and dirty export share. We further decompose firms' total emissions into emission intensity and overall output size (Martin, 2011) to examine the within-firm technique effect and scale effect of export VAT rebate cuts. We find that the reduction in export VAT rebate rates reduces firms' output size, while it increases their pollution intensity in terms of SO_2 and COD, suggesting that export VAT rebate cuts shrink firm size and worsen environmental performance. We develop a theoretical model with a firm's product heterogeneity and monopolistic competition to demonstrate the effect of export VAT rebate cuts on firms' production and financial performance. Based on a battery of empirically testable hypothesis predictions, our mechanism test shows that a firm's external credit access plays a key role in mitigating the positive effect of the export VAT rebate reduction on a firm's emission intensity. Moreover, we find that firms located in more financially developed regions with richer access to external loans would experience a smaller increase in pollutant emission intensity following the export VAT rebate reduction. In addition, the export VAT rebate reduction worsens a firm's pollution intensity by restraining the purchase of environment-protection equipment and green innovation activities, while such an effect is alleviated by firms' external credit access. Finally, the policy has a negative effect on the firm's TFP and thus increases its energy and resource use intensities.

This study concludes by delivering novel policy implications from the perspective of economic growth and environmental protection for the government in designing economic policies. First, by documenting the unintended environmental consequences of a trade policy, the export VAT rebate reduction, our study shows that a trade policy instrument could exert a broader and more profound effect on a firm's production and financial and environmental performance through the firm's internal adjustment. Faced with revenue uncertainty, tighter financial constraints, and poorer external credit access, firms are more likely to prioritize restraining environment-related investments such as the purchase of clean equipment or green innovation investment in production investment. When governments try to employ trade policy instruments for export promotion, indirect firm-level responses and overall environmental performance should also be considered. Moreover, governments should account for the joint environmental effect of economic policies and adopt policies such as subsidizing the purchase of green equipment, cutting tax for green enterprises, and promoting green R&D activities.

Second, by demonstrating the unexpected negative technique effect of export VAT rebate cuts, this study offers new implications on the balance between economic growth and the quality of the environment for other emerging economies that are possibly encountering the same pollution haven effect issue and seeking solutions. Previous studies on the determinants of firms' environmental performance mostly focus on environmental regulations, such as pollutant emission stringency, and seldom investigate the indirect environmental impact of other economic policies, such as trade or industrial policies. To achieve sustainable development and improve firms' green performance, it is imperative to consider other fundamental economic policies, such as tax incentives or industrial subsidies, which could be substantial determinants of firms' environmental performance.

Finally, our mechanism test emphasizes the significance of firms' external credit access on environmental performance. Previous studies have mainly examined the impact of credit access on firms' economic performance, such as output size or profitability, while our work shows that providing more liquidity to enterprises, especially median and small firms, could work as a catalyst for the implementation of many economy-promoting policies. Hence, green financial support from commercial banks and governments such as green finance services, preferential loans, and green loans should be further enhanced.

This study also suffers from several limitations. Owing to data limitations on firms' pollution activities, such as green investment, abatement investment, and other energy usage, additional environmental outcomes of export VAT rebate reduction could not be unpacked. Furthermore, because of data limitations on firms' detailed financial performance, which is available for publicly listed firms, we could not completely disentangle the credit access mechanism. Nevertheless, our study suggests topics for future research. The first potential research topic is to conduct other trade policy evaluations of firms' environmental consequences using publicly listed firms' data. Although it may shrink the sample size, the rich financial and environmental information would enable researchers to examine the underlying mechanisms. The second topic is to match the bank loan data with firm-level data and evaluate the impact of the green finance policy on firms' production and financial and environmental performance, which indicates the significance of credit access for green development.

CRediT authorship contribution statement

Angdi Lu: Supervision, Resources, Writing – review & editing, Project administration. **Jiang Zhang:** Investigation, Data curation, Formal analysis, Writing – original draft. **Jie Li:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Acknowledgement

Jie Li acknowledges funding support from National Science Foundation of China (Grant No. 72203150). Angdi Lu acknowledges funding support from National Science Foundation of China (Grant No. 72273149).

Appendix A. Appendix

Table A1
Export VAT rebate cut and pollution intensity: Entry and exit.

	Full sample		Balance panel: 05–11	
	SO_2	COD-	SO_2	COD
	(1)	(2)	(3)	(4)
RebateCore×Post07	0.059***	0.026**	0.049*	0.022
	(0.017)	(0.012)	(0.026)	0.019
Firm Control	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs.	317,409	306,282	35,752	38,889
R^2	0.791	0.784	0.776	0.771

Notes: This table shows the impact of the export VAT rebate cut on a balanced panel sample. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A2
Export VAT rebate cut, credit access, abatement capacity, and equipment.

	Abatement capacity				Number of abatement equipment			
	Sewage		Exhaust gases		Sewage		Exhaust gases	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RebateCore×Post07	−0.181***	−0.341***	0.136	0.338	−0.033***	−0.035**	0.007	0.015
	(0.057)	(0.089)	(0.142)	(0.227)	(0.011)	(0.017)	(0.025)	(0.039)
RebateCore×Post07 × Loan		1.120		−0.303		0.258***		0.214
		(0.688)		(1.369)		(0.095)		(0.216)
Loan×Post07		−0.152		−0.318		0.040		0.099
		(0.255)		(0.702)		(0.038)		(0.089)
RebateCore×Loan		−0.322		1.214*		0.163***		0.210**
		(0.269)		(0.733)		(0.049)		(0.101)
Firm controls	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y	Y	Y
Obs.	174,310	173,713	165,342	164,796	174,184	173,587	173,612	173,030
R^2	0.826	0.826	0.740	0.740	0.773	0.773	0.759	0.759

Notes: This table shows the impact of export VAT rebate cut on firms' abatement capacity and equipment. The dependent variables in columns (1)–(4) are firms' abatement capacity for sewage and exhaust gas, respectively. The dependent variables in columns (5)–(8) are firms' numbers of abatement equipment for sewage and exhaust gases, respectively. Credit access loans are a city's total industrial loans divided by its GDP. Firm-level controls include the log of firms' employment, TFP, fixed assets, liquidity, and leverage. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A3
Export VAT rebate cut and pollution intensity: Heterogeneity analysis.

	Dirty industry		SOE	
	SO_2	COD	SO_2	COD
	(1)	(2)	(3)	(4)
RebateCore×Post07	0.080***	−0.026	0.076***	0.035***
	(0.015)	(0.016)	(0.015)	(0.013)
RebateCore×Post07 × Dirty	−0.359	0.711***		
	(0.233)	(0.196)		
Dirty×Post07	−0.264***	−1.039***		
	(0.045)	(0.089)		
RebateCore×Dirty	0.937*	0.574*		
	(0.501)	(0.299)		
RebateCore×Post07 × SOE			−0.104**	−0.031

(*continued on next page*)

Table A3 (*continued*)

	Dirty industry		SOE	
	SO_2	COD	SO_2	COD
	(1)	(2)	(3)	(4)
			(0.041)	(0.028)
SOE × Post07			0.011	0.013
			(0.010)	(0.010)
RebateCore×SOE			0.042	0.020
			(0.031)	(0.024)
Firm Control	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs.	180,481	180,481	180,481	180,481
R^2	0.767	0.744	0.766	0.739

Notes: This table shows the impact of export VAT rebate cut on firms' SO_2 and COD intensities. The dependent variables in columns (1) and (3) are firms' emission intensity of SO_2. The dependent variables in columns (2) and (4) are firms' COD emission intensity. Emission intensity is defined as the pollution emission per unit output. Standard errors are clustered at the city level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106630.

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