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Is Chinese trade policy motivated by environmental concerns?

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ABSTRACT

This paper analyses whether China's export VAT rebates and export taxes are driven by environmental concerns. Since China struggles to enforce environmental regulation, trade policy can be used as a second-best environmental policy. In a general equilibrium model it is possible to show that the second-best export tax increases in a product's pollution intensity. The empirical analysis investigates whether the export tax equivalent of partial VAT rebates and export taxes are higher for products which are more pollution intensive along several dimensions. The results indicate that the VAT rebate rates are set in a way that discourages exports of water pollution intensive, SO_2 intensive and energy intensive products from 2007 on. Moreover, the conservation of natural resources such as minerals, metals, wood products and precious stones seems to be a key determinant of China's export VAT rebate rates. There is little evidence that export taxes are motivated by environmental concerns.

Introduction

Since 2007, China has introduced export taxes and reduced export value-added tax (VAT) rebates for a range of products. According to China's National Development and Reform Commission, the VAT rebate adjustments aim at controlling "exports of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favorable to promote a cleaner and optimal energy mix" (NDRC, 2007, p. 31). Statements which link VAT rebates and export taxes to environmental concerns appeared repeatedly in consecutive years (Wang et al., 2010; WTO, 2008).

This paper investigates whether, in practice, Chinese trade policy reflects environmental motives. It is not obvious that the VAT rebate and export tax adjustments are driven by environmental concerns. Other potential motives include an attempt to manipulate the terms of trade in China's favour, a desire to attract downstream producers to China or lobbying pressure by different industries.

The policy relevance of the motivation behind Chinese export restrictions manifests itself in the WTO dispute settlement cases on Chinese export restrictions for raw materials (WTO, 2013a) and rare earths (WTO, 2014). In both cases, China is a leading producer of the goods in question which are used as intermediate inputs into high-tech products. The complainants

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hold that China uses export restrictions to manipulate the world market price and to force intermediate producers to move to China where supply of these crucial inputs is stable. China, however, argues that the export restrictions are necessary to protect China's natural resources and the health of its citizens since the production is highly polluting. Even though China committed to cancelling its export taxes on most products in its Accession Protocol to the WTO, it argues that the export restrictions are justified under Article XX of the GATT. Article XX of the GATT allows an exemption from GATT rules for environmental objectives such as the protection of exhaustible natural resources and health considerations (WTO, 2013b).

The export VAT rebate and export tax reforms have to be assessed against the background of China's environmental agenda. In the last decade, the Chinese government has launched an ambitious attempt to tackle the country's environmental problems. There are several reasons for this increasing focus on environmental policy. Firstly, the Chinese leadership realized that environmental problems might hamper China's growth in the long run. Secondly, public discontent concerning pollution has been growing (Gang, 2009, p. 119). This has become obvious in mass protests in response to environmental degradation and in increasing participation in environmental NGOs. Gang (2009) argues that addressing environmental issues might be crucial for the government to consolidate its rule. Finally, international pressure on China to adopt stricter environmental policies is increasing.

It is well-known that local environmental distortions are best internalized through the use of domestic policy instruments such as pollution taxes (see e.g. Copeland, 2011). Copeland (1994), however, shows that a country which fails to implement optimal pollution regulation can use trade policy as a second-best instrument to reduce pollution. Arguably, the second-best scenario applies to China. The Chinese government's attempts to reduce pollution are reflected in ambitious targets for environmental protection in recent Chinese Five Year Plans. However, corruption and difficulties with the enforcement of environmental regulation limit the Chinese government's ability to use pollution levies in order to reduce domestic pollution. Trade policy instruments like export taxes and partial export VAT rebates can, thus, be used as second-best environmental policy instruments.

The theoretical foundation for our analysis is an extension of Copeland's (1994) model to a large country which sets trade and environmental policy unilaterally. We solve the model for the second-best export tax and find that the second-best export tax increases in a product's pollution intensity. The intuition behind this result is simple: The export tax reduces production and exports of a particular good. As a result, resources are reallocated to sectors which are subject to a lower export tax. If the export tax is largest for the most pollution intensive goods, more resources are allocated to the production of relatively clean goods and the pollution intensity of production declines.

The prediction that the second-best export tax is positively correlated with a product's pollution intensity guides our empirical analysis. We investigate whether the export tax equivalent of partial export VAT rebates, henceforth called VAT tax, or the export tax are higher for products which are more pollution intensive along several dimensions. The analysis considers pollutants for which the Chinese government has specified emission reduction targets in its Five Year Plans. These include waste water, chemical oxygen demand (COD), ammonium nitrogen, soot, SO_2, solid waste and energy use.

The dataset used for this analysis covers the years 2005–2009. Since Chinese officials repeatedly linked trade policy to environmental concerns from 2007 on, we are particularly interested in the relationship between trade policy variables and pollution intensities for the years 2007–2009. The data for the years 2005 and 2006 allow us to test whether there is a stronger link between trade policy variables and pollution intensities as a consequence of the VAT rebate and export tax reforms from 2007 on compared to the situation prior to 2007.

Our empirical results suggest that the VAT tax is larger for industries with a higher water pollution intensity, SO_2 intensity and energy intensity from 2007 on. This pattern is in line with the actions of a regulator who uses partial VAT rebates to reduce exports of water-pollution, SO_2 and energy intensive products. Our analysis also reveals that the VAT tax is significantly higher for resource products, indicating that the VAT tax is used to curb exports of natural resources like wood, mineral and metal products as well as precious stones.

There is little evidence for an environmental motive behind China's export taxes. However, the export tax is significantly higher for primary products. This could create an incentive for downstream producers to relocate to China in order to get access to raw materials at a lower price.

The paper is structured as follows. A review of the related literature is followed by information on the policy background for our study. In the Environmental policy in China section, we argue that environmental problems play a prominent role on the Chinese policy agenda, but that the government struggles to implement and enforce effective domestic pollution taxes. The policy background section on export value-added tax rebates explains why partial export VAT rebates are similar to export taxes, followed by a section which provides background information on Chinese export taxes.

In the Second-best export taxes as environmental policy section we derive a formula for a second-best export tax and show that it increases in a product's pollution intensity. This prediction is the foundation for our empirical analysis. We investigate whether the export tax and the VAT tax are higher for more polluting products. The precise empirical strategy is explained in the Empirical strategy section. The paper focuses on the determinants of the VAT tax (defined as VAT–export VAT rebate) but it also investigates whether there is an environmental motive behind China's export tax. Both the VAT tax and the export tax are analysed as a function of the pollution intensities and a set of control variables.

The dataset section describes the dataset followed by a Summary statistics in Summary statistics section. The regression results with the VAT tax as dependent variable are presented in the Determinants of VAT taxes section. The subsequent Export tax as dependent variable section-briefly discussed of the determinants of the export tax However, the robustness checks in the Sensitivity analysis section focus on the determinants of the VAT tax. The last section of this paper concludes.

Related literature

Wang et al. (2010) provide an analysis of the environmental aspects behind China's trade policy. Wang et al. (2010) calculate the implicit export carbon tax behind China's export taxes and export VAT rebates for 8 energy-intensive sectors and find that it differs considerably across sectors. The implicit export carbon tax ranges from 18 US$ per ton of CO_2 emissions for basic chemicals to 764 US$ for chemical fibre.

Yet, this finding does not imply that the VAT rebate and the export tax reforms are not based on environmental concerns. CO_2 emissions may not have been the Chinese government's only concern when it designed the policy. We study the relationship between trade policy instruments and a range of pollutants. This reveals whether Chinese trade policy reflects concerns about air, water or solid waste pollution as well as energy use and indicates which pollutant has the largest impact on the respective trade policy instruments. As opposed to Wang et al. (2010) we consider the overall pollution generated in all stages of the production process and not only a sector's direct pollution emissions.

A description of the rational behind China's export restrictions can also be found in Karapinar (2011), who highlights that Chinese export restrictions could be motivated by an attempt to protect downstream producers in China as well as environmental motives. This is confirmed in Korinek and Kim's (2011) description of Chinese export restrictions for Molybdenum. Both Korinek and Kim (2011) and Pothen and Fink (2015) analyse export restrictions for Chinese rare earths. The potential objectives behind those export restrictions include the protection of downstream producers in China, the conservation of natural resources and environmental protection.

OECD (2002, 2003), Kim (2010) and Piermartini (2004) discuss objectives to introduce export taxes for a wide range of countries. OECD (2002, 2003) and Kim (2010) collect information on export restrictions and export duties from WTO Trade Policy reports and find that export duties and export restrictions are mostly applied to renewable resources such as forestry and fishery products, agricultural products as well as leather and hides and mineral and metal products. Fiscal revenues, the promotion of downstream producers as well as attempts to protect the environment and conserve resources are identified as the main drivers for the implementation of export restrictions and export duties in these sectors.

The above-mentioned papers highlight important motives for the introduction of export taxes and restrictions. However, they are of purely descriptive nature and do not employ an empirical analysis which would allow them to capture the importance of different motives. Our analysis investigates whether the VAT taxes and export taxes are higher for polluting products and resources, controlling for a range of non-environmental motives such as export taxes for raw materials in order to protect downstream producers and a terms of trade motive. This approach allows us to single out the importance of environmental motives.

Empirical work which explicitly takes the relationship between tariffs and pollution regulation or pollution intensity into consideration is very sparse. One exception is the paper by Ederington and Minier (2003), which looks at pollution policy as a second-best trade barrier. If the regulator is constrained in setting import tariffs due to WTO membership, lenient environmental policy reduces production costs and can, thus, be used as a secondary means to protect the domestic industry. However, the empirical results show that tariffs are negatively correlated with environmental regulation.

Our paper analyses the determinants of trade policy instruments. Just like Ederington and Minier (2003), we refer to the literature on the political economy of protection for the choice of our control variables. Baldwin (1989), Gawande and Krishna (2003) and Ethier (2011) provide excellent surveys of that literature. We refer to the relevant papers for our work in the section that explains the control variables. Three papers, which analyse Chinese trade policy, however, are worth describing in detail.

Wang and Xie (2010) study the industry characteristics which determine the structure of Chinese VAT rebates in 2008. Wang and Xie (2010) find that industries with a higher export share have a higher rebate rate, since China supports an export-oriented strategy. The VAT rebate rate is also positively related to the share of national capital. This is interpreted as a sign that state-owned enterprises (SOEs) receive a favourable treatment. Moreover, Wang and Xie (2010) argue that the VAT rebate rates reflect an attempt to reduce adjustment cost and achieve social stability, as reflected by the fact that the rebate rate is higher for less profitable industries, industries with a lower labour productivity and industries with a lower ratio of value added. The results also show that industries with more assets, a large number of firms and a large presence of foreign capital receive higher VAT rebates. Chen and Feng (2000) analyse the determinants of Chinese tariffs and find that most of the variation in tariffs can be explained by information on industry size.

The complainants in the WTO dispute settlement cases against China hold that China introduced export taxes on primary products in order to induce downstream producers to relocate to China. Garred's (2014) findings support this hypothesis in showing that the joint export tax equivalent of Chinese export taxes and VAT rebates increased faster for raw materials than for other products over a sample period from 2002 to 2012. Even though we focus on cross-sectional variation rather than variation over time, we also come to the conclusion that the export tax discourages exports of primary products.[1]

The papers by Wang and Xie (2010), Garred (2014) and Chen and Feng (2000) highlight important determinants of Chinese trade policy. Their findings guide the choice of our control variables. However, our study differs considerably from Wang and Xie (2010), Garred (2014) and Chen and Feng (2000). While we are mostly interested in the relationship between

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[1] Evenett et al. (2012) also describe Chinese VAT rebate reforms and highlight that there is significant variation in VAT rebate rates across time and products. However, they do not analyse the motives behind these adjustment in detail.

VAT rebates or export taxes and pollution intensities as well as resource intensities, this aspect is completely neglected in Wang and Xie (2010), Garred (2014) and Chen and Feng (2000).

Policy background

Environmental policy in China

In recent years, the Chinese government has launched an ambitious agenda to tackle the country's environmental problems. Firstly, it adopted ambitious targets to reduce pollution and energy consumption in recent Five Year Plans (FYPs). During the sample period of our study, the Chinese government aimed at reducing water pollution (waste water, chemical oxygen demand and ammonium nitrogen emissions), air pollution (soot, SO_2 and dust emissions) as well as the generation of solid waste. Moreover, China planned to considerably reduce energy consumption per unit of GDP.[2]

In addition to ambitious environmental targets, the Chinese government undertook substantial reforms of its administrative structure to give environmental protection a more prominent role in its political hierarchy (Gang, 2009, Ren and Shou, 2013). The State Environmental Protection Agency was elevated to the rank of a Ministry in 2008 and received a larger budget and more staff. Moreover, China set up a National Leading Group to Address Energy Saving, Emission Cutting and Climate Change. It is headed by the Premier and has thus got a high rank in the political hierarchy. I addition to that, the government started to incentivize local leaders to protect the environment by linking the measure for local officials' performance not only to economic growth but also to environmental achievements.

Even though China embraced ambitious attempts to protect the environment, the lack of enforcement is “the single biggest weakness in China[']s environmental law” (Stalley, 2010, p. 33). The implementation of environmental regulation and the collection of levies is in the hands of provincial and municipal local environmental protection bureaus (EPBs).[3] Local EPBs often lack the power to implement the regulations for several reasons. Firstly, even though their personnel has grown, EPBs are still short of staff to guarantee satisfactory implementation (Ren and Shou, 2013; Stalley, 2010; Brettell, 2013). Secondly, local environmental agencies lack the skills and the technology to detect infringements of pollution standards (Ren and Shou, 2013). Thirdly, local firms are an important source of government revenue and are thus promoted by local authorities. Pollution emissions from these firms are often ignored or permitted. If local leaders consider a certain company important for the local economy, Environmental Protection Bureaus are often impeded from collecting levies (Dean et al., 2009; OECD, 2005).

Endemic corruption exacerbates the weak enforcement power of local environmental agencies (Stalley, 2010). There is ample anecdotal evidence that local authorities negotiate levy payments with firms (Dean et al., 2009; OECD, 2005; Wang et al., 2003). The precise environmental cost of corruption is difficult to estimate, but it is likely to be significant. According to a statement by Zhou Shengxian, the director of the State Environmental Protection Agency, in 2006, the government investigated pollution control approvals for construction projects and discovered violations in about 40% of the cases (Stalley, 2010, p. 35).

Even if environmental regulation is enforced and levies are collected, environmental policy can only be effective if it induces producers to reduce pollution. The Chinese government has taken several steps to improve compliance with environmental regulations and standards such as increased criminal liability, higher fines for non-compliance in some cases and attempts to improve enforcement. However, the deterrent effect of those measures is limited. There is evidence that violating pollution standards and paying the levies is still cheaper than compliance (Brettell, 2013, p. 49). This is consistent with recent empirical evidence by Cole et al. (2008), who find that neither formal nor informal regulation have a deterrent effect on industry level emissions.

Weak enforcement power by local environmental protection bureaus, corruption as well as a questionable deterrent effect of pollution levies make it difficult for the central government to tighten environmental policy in China. Hence, trade policy might be a second-best option to reduce domestic pollution.

Policy background: export value-added tax rebates

Since the mid 2000s, the Chinese government has adjusted VAT rebate rates on a frequent basis. The Chinese government quotes environmental protection as a main motivation for these adjustments. According to the Communication on China's Policies and Action for Addressing Climate Change[4] these VAT rebate adjustments are geared towards reducing energy-intensive and polluting exports and can be considered part of China's climate policy. However, environmental concerns were not the only motive for the VAT rebate rate adjustments. The reforms were also meant to serve China's development strategy and foster the production of high-tech and high-value added exports (Wang et al., 2010).

Most countries levy value added taxes. It is common practice to exempt exporters from VAT payments or refund the VAT

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[2] Table 10 lists the relevant emission reduction targets for the years 2001–2010.

[3] According to Article 16 of China's National Environmental Protection Law “the local people's governments at various levels shall be responsible for the environment quality of areas under their jurisdiction and take measures to improve the environment quality” (NPC, 1989).

[4] Information Office of the State Council of the People's Republic of China (2008).

that exporters paid for their intermediate inputs. In China, exporters only get partial VAT rebates. Partial export VAT rebates have similar effects as export taxes if the export destination levies VATs on its imports (Feldstein and Krugman, 1990). In the absence of (full) VAT rebates, producers face double taxation since they are taxed both in the country of origin and in the export destination. The partial refund is a comparative disadvantage for Chinese producers compared to producers from countries with full export VAT rebates. The lower the rebate rate, the higher the double taxation of exporters. Hence, a reduction in the VAT rebate rate has a similar effect as an increase in the export tax.

This theoretical prediction is supported by empirical evidence, which shows that partial export VAT rebates curb Chinese exports considerably (Chao et al., 2001, 2006; Chen et al., 2006; Chandra and Long, 2013; Gourdon et al., 2014). According to Chandra and Long (2013), an increase in the actual VAT rebate rate by one percentage point is estimated to raise exports by 13%. Gourdon et al. (2014) find that an increase in the VAT rebate rate by one percentage point leads to an increase in exports quantities by 6.5% for products which are eligible to VAT rebates.

Since there is ample theoretical and empirical evidence that partial VAT rebates have similar effects as export taxes, this paper treats the difference between the VAT and the VAT rebate rate as an export tax. We define the variable VAT tax

$$VAT\ tax_i = VAT\ rate_i - export\ VAT\ rebate\ rate_i. \tag{1}$$

An analysis of the VAT rebate rate itself is not informative due to differences in the value-added tax across products. The VAT amounts to 17% for most goods and 13% for some agricultural products. A small range of products is not subject to a VAT. A VAT rebate of 5% generates a lower burden for an exporter whose final product is subject to a VAT of 13% rather than 17%. In order to asses the export tax equivalent of the partial VAT rebate policy on producers, it is necessary to use information on VATs.[5]

Policy background: export taxes

In its Accession Protocol to the WTO, China agreed to levy export taxes on no more than 84 product lines and the export taxes were not allowed to exceed a certain threshold. This threshold ranges between 20% and 40%, depending on the product.

In practice, China introduced export taxes on far more products since 2007. The first row in Table 1 shows that only 29 products at the HS8 digit level in our sample were subject to an export tax in 2006. In 2009, the government levied export taxes on 231 products in our sample. Since the export taxes only affect a small fraction of a total of about 5700 HS8 digit product lines in our sample, the empirical analysis in the paper and the discussion of the results focus on the determinants of the VAT tax.

Second-best export taxes as environmental policy

China seems determined to reduce its emissions but struggles to enforce pollution regulation to internalise the environmental distortion. Under these circumstances, an export tax can be used as a second-best environmental policy instrument.

This section derives a formula for the second-best export tax based on an extension of Copeland's (1994) model to the large country case. In the model, a perfectly competitive large open economy produces or consumes $N_g + 1$ goods. Good 0 is the numeraire. Production and consumption of good 0 are denoted by y_0 and c_0. The vectors y and c represent production and consumption of all other N_g goods.

Production of all non-numeraire goods causes domestic pollution z. Pollution reduces the consumer's utility but does not affect the productivity in other sectors. The model considers N_p different pollutants. Firms face pollution taxes s per unit of pollution.

The government levies export taxes for all non-numeraire goods. These export taxes are represented by the vector t. The world market and domestic price vectors for the non-numeraire goods are denoted by p and $q = p - t$, respectively. There is no export tax for the numeraire. Hence, both the domestic and the world market price for the numeraire equal 1.

The representative consumer's utility is a function of consumption and of the public bad pollution $u(c_0, c, z)$. We assume that the utility function is continuous, locally unsatiated and strictly convex. Utility can be represented by the expenditure function $E(1, q, z, u)$. The expenditure function is concave and non-decreasing in q and increasing in z and u. By Shephard's lemma, $E_q = \partial E/\partial q'$ is the compensated demand vector. Throughout this section, subscripts denote partial derivatives and the prime ($'$) denotes a transpose. E_z represents the marginal willingness to pay for a one unit reduction in pollution. In other words, E_z is the marginal damage caused by pollution.

Following Copeland (1994), the production side of the economy is represented by the aggregate revenue or GNP function. Firms maximize their profits, taking the pollution tax s and the prices q as given. The profit maximizing behaviour of the

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[5] The VAT rebate rule the applies to most products can be summarized by the following formula (Chan, 2008):*VAT rebate = input VAT − (value of export sale − value of bonded materials)*(VAT rate − rebate rate)*. This implies that it is appropriate to analyse the rebate rate for the export product itself and not the VAT rebate rate that applies to intermediate inputs.

Table 1
Number of HS 8 digit products with export taxes.

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
Number of products with export tax > 0	29	39	128	252	231
Average export tax for all products	0.093	0.128	0.294	0.629	0.651
Average export tax, given export tax > 0	18.517	18.929	13.252	14.370	16.034

This table refers to export taxes and not to VAT taxes.

individual firms also maximizes GNP less the pollution tax. Hence, the private sector implicitly solves the problem

$$G(1, q, s, v) = \max_{y,z}\{y_0 + q'y - s'z \qquad s.\,t.\;\; (y_0, y, z) \in T(v)\} \tag{2}$$

where v is the endowment of the economy and $T(v)$ is the technology set. Based on the envelope theorem, $y = G_q = \partial G/\partial q$ and $z = -\,G_s = -\,\partial G/\partial s$.

The world in this model consists of China and the rest of the world. China is modelled as a large country. The Chinese regulator unilaterally chooses the optimal export tax in response to local pollution and in order to manipulate the terms of trade. We assume that the rest of the world does not adjust its trade and environmental policy in reaction to changes in Chinese trade policy. This assumption is not unusual in papers which analyse optimal policy (see e.g. Markusen, 1975; Turunen-Red and Woodland, 2002 for related papers) and it is justified since the rest of the world consists of many countries which do not coordinate their trade and environmental policy to an extent that would warrant a model in which the rest of the world responds to changes in Chinese policy.[6]

The goods market equilibrium is characterized by the following equation

$$-E_q(1, q, z, u) + G_q(1, q, s, v) - E_p^*(1, p) + G_p^*(1, p) = 0_N \tag{3}$$

where E^* and G^* denote foreign compensated demand and foreign production, respectively. Since we abstract from the foreign policy process, foreign production and consumption are functions of the world market price, but not of Chinese policy variables. This goods market equilibrium equation states that global supply equals global demand at the equilibrium world market price p.

Assuming that pollution taxes are rebated to the consumer, the equilibrium in the economy is characterized by the following equations and Eq. (3):

$$X = G_q(1, q, s, v) - E_q(1, q, z, u) \tag{4}$$
$$E(1, q, z, u) = G(1, q, s, v) + s'z + t'X \tag{5}$$
$$z = -\,G_s \tag{6}$$

The variable X in Eqs. (4) and (5) represents the net export vector which equals output (G_q) minus compensated demand (E_q). Eq. (5) is like a budget constraint for the economy. It states that consumer expenditure equals GNP plus the rebated pollution tax and export tax income. If the economy-wide budget constraint is satisfied, trade is balanced. Eq. (5) does not allow for a trade deficit or surplus. Eq. (6) pins down the equilibrium pollution level in the economy.

The total differentials of equilibrium conditions (3)–(6) allow us to solve for the second-best export tax. The second-best export tax is the export tax that yields the highest level of utility u in a situation in which environmental policy cannot be altered.

A step-wise solution for the second-best export tax can be found in Appendix A. A few assumption are necessary to come to the solution presented below and it is worth mentioning them in the main text. In order to make the solution tractable, we assume that income effects attach to the numeraire, i.e. that $E_{qu} = 0$.[7] Moreover, we assume that compensated demand for good i, E_{q_i}, is independent of pollution, i.e. $\frac{\partial E_{q_i}}{\partial z_k} = 0$.[8] Finally, we assume that the matrix $X_q = G_{qq} - E_{qq}$ is invertible. The matrix X_q captures the change in the domestic export supply of good i in response to changes in the domestic price of good j, q_j. Note that invertibility implies that the matrix X_q is positive definite.

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[6] Moreover, there is no evidence to suggest that China's large trading partners use trade policy for environmental reasons. Most of China's large export destinations are developed economies. The usual concern is that those countries use lenient environmental regulation to improve the competitiveness of domestic industries (see e.g. Ederington and Minier, 2003). According to OECD (2002, 2003) and Kim (2010), export restrictions and export taxes which may reflect environmental concerns are mostly used by developing and least developed countries.

[7] $E_{qu} = 0$ implies that an increase in utility is associated with an increase in the consumption of the numeraire as long as prices stay constant. See Vlassis (2013) for a recent paper which makes the same assumption. The assumption ensures tractability in the large country case, but it could be relaxed.

[8] If pollution has a negative effect on utility, this assumption implies that the consumer has to be compensated for higher pollution through additional consumption of the numeraire. This assumption is used to ensure that the determinant of the matrix $H_{qq} + E_{qz}G_{sq}$ is positive.

With these assumptions, the second-best export tax can be written as follows:

$$t^{*'} = -\underbrace{M^{*'}(M_p^*)^{-1}}_{\text{Terms of trade motive}} + \underbrace{(E_z^{'} - s')\frac{\partial z}{\partial q}(X_q)^{-1}}_{\text{Environmental motive}} \tag{7}$$

where t^* is the vector of second-best export taxes, $M^* = E_p^*(1, p) - G_p^*(1, p)$ is the vector of foreign imports and M_p^* is the matrix of derivatives of foreign import demand with respect to the world market price p. The matrix $\frac{\partial z}{\partial q}$ contains the pollution intensities.

The second-best export tax features a terms of trade motive and an environmental motive. The terms of trade motive captures the incentive to introduce an export tax in order to reduce the supply of the good on the world market. As long as the country is a large supplier on the world market, this drives up the world market price and allows the country to get a higher price for its exports. The terms of trade motive equals the inverse of the foreign elasticity of import demand.

The environmental motive reflects the attempt to reduce pollution through the use of export taxes. An export tax reduces production and hence reduces emissions which are generated during the production process. If the government increases the export tax for the most polluting product, the production of this pollution intensive product declines. The resources which are set free in the polluting sector are allocated to the production of cleaner goods. This way, the pollution intensity of production in the economy declines.

To be more precise about this concept, we follow Copeland (1994) and define good i as *pollution intensive in pollutant* k if an increase in the price of good i raises emissions of pollutant k, i.e. if $\partial z_k/\partial q_i > 0$. An increase in the price of good i leads to an expansion of industry i, drawing resources from other industries. If the expanding industry emits more of pollutant k at the margin than the contracting part of the economy, industry i is pollution intensive with respect to pollutant k.

In order to show that the second-best export tax increases in a product's pollution intensity, we consider a world in which the cross-price elasticities of export supply are negligible. In other words, we look at a case in which all the off-diagonal elements of X_q are zero or considerably smaller than the own-price elasticities in absolute terms. In that case it is easy to see that, holding everything else constant, the second-best export tax in Eq. (7) increases in a product's pollution intensity as long as the domestic pollution tax does not internalise the environmental distortion ($E_z > s$). This yields the testable hypothesis for this paper.

Testable hypothesis: *The second-best export tax increases in a product's pollution intensity if the pollution tax is lower than marginal damage.*

The relationship between the second-best export tax and the pollution intensity should be stronger, the larger the gap between marginal damage and the pollution tax.

This result from the theoretical model can be tested using Chinese data on VAT taxes, export taxes and pollution intensities.

Empirical strategy

Estimating equation

The Chinese government claims to use VAT rebates and export taxes to reduce "exports of energy-intensive, pollution-intensive and resource-intensive products" (NDRC, 2007, p. 31). Our empirical analysis tries to reveal whether, in practice, the VAT taxes and the export taxes reflect an attempt to protect the environment. If the VAT taxes or the export taxes are used as a secondary pollution policy, they should be higher for more polluting products as long as environmental policy is too lenient.

Our estimating equation is motivated by Eq. (7):

$$\text{VAT tax}_{it} = \alpha_0 + \sum_{k} \beta_k \,\text{Reg\_ gap}_{itk} {*} \text{pol\_int}_{itk} + \text{Controls}_{it} + \delta_t + \varepsilon_{it} \tag{8}$$

where the dependent variable is the VAT tax for product i at time t. In the Export tax as independent variable section, we also use the export tax as dependent variable. Due to the small number of products which are subject to an export tax, the analysis focuses on the determinants of the VAT tax.

The variable Reg_gap_{itk} is a proxy for the difference between marginal damage and the pollution tax for pollutant k at time t and pol_int_{itk} represents the overall pollution intensity of exports with respect to pollutant k. The interaction term $Reg\_gap_{itk}{*}pol\_int_{itk}$ follows Eq. (7) and reflects the fact that the relationship between the pollution intensity and the VAT tax should be stronger, the larger the gap between marginal damage and the pollution tax. Time fixed effects are represented by δ_t and ε_{it} is the idiosyncratic error term. The control variables include a measure for the terms of trade motive.

Which pollutants should be considered in the analysis? The NDRC's announcement does not tell us which pollutants the Chinese government targets with its policy. In order to gauge which pollutants play a prominent role in China's environmental agenda, we refer to the environmental section of the Chinese Five Year Plan (FYP), which sets out specific pollution reduction targets for major pollutants. We expect that the set of pollutants K which determine trade policy is similar to the set of pollutants for which the government specifies emission reduction targets in the FYP.

The relevant FYPs for our sample period specify emission reduction targets for water pollution (waste water, COD, ammonium nitrogen emissions), air pollution (soot, SO_2 and dust emissions) as well as energy use per unit of GDP. Moreover, China aims at reducing the amount of solid waste generated and at increasing the ratio of solid waste that is recycled. This indicates that the Chinese regulator's objective function puts weight on the above-mentioned pollutants and suggests that our analysis focuses on precisely those pollution indicators.[9]

When we analyse the relationship between trade policy and the pollution intensity of exports, we are interested in the overall pollution generated during all stages of the production process taking place within China. In order to obtain the overall pollution content of exports, it is necessary to use input-output analysis. The precise construction of the overall pollution intensities is described in The dataset section.

The theoretical model predicts that a higher pollution intensity has a stronger effect on the export tax if the gap between marginal damage and the pollution tax is larger. Hence, it is necessary to interact the pollution intensities with a measure for the gap between marginal damage and the pollution tax. This regulatory gap, or *Reg_gap*, is proxied by the share of emissions not meeting discharge standards. This measure varies at the industry level and over time. The share of emissions not meeting discharge standards is a useful measure of the regulatory gap since the national authority can set discharge standards such that they internalize marginal damage. The enforcement is left to local authorities. If local enforcement is lax, firms have few incentives to satisfy discharge standards. Hence, a low ratio of emissions meeting discharge standards means that regulation is ineffective since it does not have a strong deterrent effect on emissions.

Data on the ratio of a pollutant meeting discharge standards is only available for waste water, soot and SO_2 emissions. However, the Five Year Plans for the years 2000–2010 foresee reductions in the emissions of all pollutants in our analysis. The fact that the government intends to reduce emissions and sets targets for emission reductions indicates that the emissions are above the social optimum, which is equivalent to a situation in which the pollution tax is too lax.

With the pollution tax not internalizing the distortion to the desired extent, we would expect to see a positive relationship between the VAT tax and the pollution intensity if the VAT tax is used as a second-best environmental policy. In other words, we expect the coefficients β_k in Eq. (8) to be positive.

According to the NDRC, the VAT rebate adjustments are also geared towards reducing exports of resource-intensive products. In order to control for this aspect of policy setting, we introduce dummy variables which take the value of 1 if a product is resource intensive. We distinguish between four categories of resources: mineral products, wood products, precious stones and metal products. The resource dummy variables are constructed based on the HS classification. The dummy variable *Mineral* takes the value of 1 for all products in the HS2 digit categories 25–28. The range of products in these categories includes ores, mineral fuels and oil as well as rare earths. The dummy variable *Wood* takes the value of 1 for all wood products, articles of wood and wood charcoal (HS2 digit code 44). *Stones* is a dummy variable for all products in the HS2 digit category 71. This includes precious metals, precious stones, pearls and jewellery. The dummy variable *Metal* takes a value of 1 for all metal products in the HS2 digit categories 72–81, including iron and steel, copper, aluminium, lead, zinc, tin and articles thereof. We expect a positive relationship between the VAT tax and the resource dummy variables if the trade policy reforms are a substitute for resource conservation.[10]

The equation for the second-best export tax applies to the cross-section and therefore our identification comes from cross-sectional variation. Eq. (7) demonstrates that the second-best export tax is higher for goods which are more pollution intensive at a particular point in time. A comparison of export taxes and pollution intensities between goods at one particular moment in time requires a cross-sectional analysis. Even though we have a panel dataset, we will not use product fixed effects, since the latter eliminate cross-sectional variation.

The time-series dimension of the dataset is used to allow the coefficient estimates to vary across time. The Chinese government repeatedly linked VAT rebate adjustments to environmental concerns from 2007 onwards (see e.g. Wang et al., 2010). Since the dataset spans the years 2005–2009, we have information on trade policy and pollution intensities both before and after the policy announcement. Hence, the panel dimension of the dataset allows us to test whether there was a policy change in the years 2007–2009 compared to the years 2005–2006.

If the VAT rebate rate and export tax adjustments from 2007 onwards were motivated by an attempt to reduce emissions of a particular pollutant k, we would expect the magnitude of the coefficient estimate $\hat{\beta}_k$ to increase in the 2007–2009 sample compared to the 2005–2006 sample. We will, thus, run two pooled cross-sectional regressions of Eq. (8), one for the sample spanning the years 2005–2006 and one for the sample spanning the years 2007–2009. Moreover, we will test for a statistically significant difference in the coefficient estimates between the two sample periods. Towards that end, we interact all of the independent variables in our model with a dummy variable that takes the value of 1 for the years 2007–2009, denoted by D_{2007}. An increase in the pollution intensity of a particular pollutant k is associated with a larger increase in the VAT tax after 2007, if the coefficient estimate for the interaction term between D_{2007} and the pollution intensity with

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[9] Dust emissions will not be considered in the analysis. Due to a large number of missing observations it is not possible to generate the overall dust emission intensities.

[10] Note that the resource dummy variables include both primary products and processed products. The dummy variable *Wood* for example, takes a value of 1 for raw logs as well as wooden furniture. Hence, the resource dummy variables do not measure whether the government protects primary products more than raw materials.

respect to pollutant k is statistically significant and positive. This would suggest that the VAT tax was adjusted to discourage pollution intensive production.

The dependent variable in our model varies at the HS8 digit level. However, data on pollution intensities are only observed at the industry level. In order to take account of the fact that our main explanatory variable varies at a higher level of aggregation, we cluster the standard errors at the industry level.[11]

Control variables

The second-best export tax in Eq. (8) features an environmental component as well as the terms of trade motive. This terms of trade motive depends on the foreign elasticity of import demand and is difficult to measure. However, the terms of trade motive reflects China's market size on the world market and is thus reflected in China's share in global exports. In order to control for the terms of trade motive, we use two dummy variables. The first dummy variable *Exp share* [5–15) takes the value of one if China exports at least 5% and less than 15% of global exports. About 28% of the observations in our sample fall into this category. The second dummy variable *Exp share* 15+ takes the value of one if China exports more than 15% of global exports. Another 32% of the observations in our sample fall into the latter category. Since the second-best export tax is larger for products for which China has market power, we expect the coefficient estimates for those dummy variables to be positive.

The complainants in the WTO dispute settlement case on rare earths argue that China introduced export restrictions on raw materials in order to grant downstream producers in China protected access to those raw materials (WTO, 2014). In order to test for this hypothesis, we add a dummy variable to the regression which takes the value of one if a product is classified as a primary product according to the United Nation's Classification of Broad Economic Categories.[12] A positive coefficient estimate for this variable would suggest that the export restrictions target primary products. This could provide an incentive for downstream producers to relocate to China where the primary products are available at a lower price.

The literature on the political economy of protection highlights alternative motives that can drive the government's choice of trade policy. Corden (1974), e.g., links trade policy to social concerns. Social considerations might be particularly important in China, since the Chinese government under president Hu Jintao emphasised the goal to build a “harmonious society” and reduce inequality within the country.[13] In Corden (1974), the regulator grants protection to industries which suffer from adverse economic shocks.[14] This would suggest that the VAT tax or the export tax is lower in industries in which output growth is lower. Therefore, we control for output growth compared to the previous year.

Even though the Chinese government does not face any elections, we can still assume that it tries to gain popular support for its policies in order to consolidate its power.[15] Therefore, it may protect industries with a larger number of employees[16] and firms and we control for both variables.

Moreover, the government might grant more protection to industries with a larger share of state-owned enterprises (SOEs). SOEs are likely to have links to the government which allow them to lobby for protection. Branstetter and Feenstra (2002) show that the Chinese government gave between four and seven times more weight to SOEs than to consumer welfare in the context of policies that facilitate foreign direct investment. This suggests that SOEs have a significant influence on government decisions which might also be reflected in China's trade policy. We, thus, control for the output share of state owned enterprises in an industry, measured as the output value of SOEs relative to the output value in the industry.

In a similar vein, the Chinese government might try to grant foreign firms better treatment in order to enhance the investment climate in China. This would imply that industries with a higher share of foreign output get higher protection. Since foreign firms might use less polluting production technologies, it is necessary to control for the output share of foreign firms. The output share of foreign firms is measured as the output value of foreign firms relative to the overall output value in an industry.

Several authors argue that protection should be higher in industries for which the country does not have a comparative advantage (e.g. Ray, 1981a, 1981b; Trefler, 1993). As a country with an abundant labour supply, China is traditionally associated with a comparative advantage in labour-intensive industries (Yue and Hua, 2002). Hence, the VAT tax or export tax might be higher in labour-intensive industries. We, thus, control for labour intensity which is constructed as the number of employees over fixed assets in an industry. If the government protects industries in which it does not have a comparative advantage, the protection could also be expected to be higher in export-intensive industries. The export intensity is measured as the value of exports relative to the output value.

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[11] Alternatively, one could aggregate the trade policy data to the industry level and conduct the analysis at the industry level. We find similar relationships between the trade policy variables and the pollution intensities in the industry level data.

[12] Details on the Broad Economic Categories are available on http://unstats.un.org/UNSD/cr/registry/regcst.asp?Cl=10&Lg=1.

[13] The concept of the harmonious society was incorporated in China's 11th FYP (Ma, 2006).

[14] See Freund and Özden (2008) for a recent and micro-founded theoretical model on loss aversion in trade policy.

[15] A large literature argues that protection is granted in exchange for political support (e.g. Caves, 1976; Grossman and Helpman, 1994). However, it is not obvious that Grossman and Helpman's (1994) model can be applied to China. China does not have democratic elections and lobbying is not officially allowed. Moreover, none of the measures for lobbying power which are typically used in the literature is available for China.

[16] See e.g. Caves (1976).

The choice of the VAT rebate rate could also be driven by concerns about government revenue. Evenett et al. (2012) show that the expenses for VAT rebates constitute 8–10% of final government spending between 2007 and 2010. The theoretical model presented in the Second-best export taxes as environmental policy section incorporates the revenue generated by export taxes in the regulator's welfare maximization problem. Hence, there is no need to control for government revenue if we implement Eq. (8). If the government is concerned about the effect of the policy on its budget, it might, however, take income taxes from firms into consideration. A higher VAT tax or export tax can be expected to lead to a contraction of the industry and reduce taxes that firms have to pay on their business. Hence, the government might set a lower VAT tax or export tax for industries which pay a higher tax on their principal business. We control for this motive using data on the firms' income tax.

Some of the above-mentioned control variables may be endogenous if we use the contemporaneous value. It is possible that an increase in the export tax or a reduction in the VAT rebate rate reduce China's export share on the world market or the number of firms and employees in an industry. Moreover, trade policy may affect output growth in an industry or the industry's profitability. In order to avoid reverse causality, we use the lagged value of the control variables.[17]

We also control for the export tax in order to avoid an omitted variable bias. The export tax is correlated with the VAT tax and it may also be correlated with the regressors in our model.

The data reveal that the Chinese authorities set the maximum VAT tax before they introduce export taxes which violate China's obligations under the WTO Accession Protocol. The average rebate rate is zero for all but 15 products for which the export tax is positive and equal to or higher than the export tax allowed under the WTO Accession Protocol. Generally, the VAT rebates are zero for 92% of the products on which the Chinese government levies an export tax. The fact that an export tax goes along with the highest possible VAT tax in most cases suggest that the Chinese government exploits export VAT rebates as an instrument before it resorts to export taxes. Due to potential reverse causality between the export tax and the VAT tax, we use the maximum export tax allowed under China's WTO Accession Protocol as an instrument for the export tax and estimate Eq. (8) using a 2SLS estimator. The maximum export tax which is allowed under the WTO Accession Protocol is arguably exogenous to the export tax in the mid 2000s, since the Accession Protocol was negotiated at the end of the 1990s and became effective in 2001.

China's export taxes differ from the export taxes negotiated under the WTO Accession Protocol. In a few instances, the Chinese government reduced export taxes below those allowed under the Accession Protocol or introduced additional temporary export taxes. The correlation coefficient between the actual export tax and the export tax allowed under the WTO Accession Protocol is 0.47.

We also control for the ad valorem tariff. Even though the government does not link the import tariff to environmental concerns, the tariff might be determined by similar political economy motives as the VAT tax. If protection on the import side is a substitute for the VAT tax, the tariff would be negatively correlated with the VAT tax.

A complete list of variables used in the analysis as well as the variable definition and the expected sign of the coefficient estimates is available in Table 2.

The dataset

Trade policy data

For the construction of the dependent variable VAT tax, we gather data on VAT and VAT rebate rates at the product level (HS10 digit). The VAT data are from the China Customs homepage[18] and from the Customs Import and Export Tariff of the People's Republic of China.[19]

Data on VAT rebate rates for the years 2005–2006 are from the China Customs homepage. From 2006 onwards, we only have information on changes in export VAT rebate rates. This information is used to update the VAT rebate rate schedule. A list of VAT rebate rate reforms and the data source can be found in Table 13 in Appendix A.

In 2007 there was an international reclassification of HS tariff lines which also affects the Chinese tariff lines. To the best of our knowledge, there is no concordance table at the HS8 or HS10 digit level that relates Chinese tariff lines prior to 2007 to tariff lines from 2007 on. Concordance tables only exist at the HS6 digit level. Since we cannot link the tariff lines before and after the reclassification, we only use the VAT rebate rates for tariff lines which were not affected by the reclassification. This should not bias our results, since the HS reclassification at the HS6 digit level is undertaken by the World Customs Organization and not by the Chinese government itself.

Information on export taxes at the product level (HS10 or HS11) for the years 2005–2007 is available on the China Customs homepage. The homepage of the Ministry of Finance provides export tax data at the HS8 digit level for the years 2008–2009.

Data on applied most favoured nation (MFN) import tariffs at the HS8 digit level are from the WITS TRAINS database.

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[17] This does not affect the coefficient estimates for the pollution intensities. We get very similar results if we use the contemporaneous value of the control variables.

[18] http://china-customs.com/.

[19] The Editorial Depatment of the Customs Import and Export Tariff of the People's Republic of China, 2006, 2007, 2009.

Table 2
Variable definition.

Variables	Description	Expected sign
Dependant variables		
VAT tax	VAT minus export VAT rebate	
Export tax	Defined as ordinary export tax or temporary export tax	
Environmental variables		
Water Reg_gap*Int	Interaction term of waste water emissions not meeting discharge standards with the overall waste water intensity (in tons/million yuan output. The output value is deflated using the manufacturing producer price index.)	+
COD Int	Overall COD intensity (tons/million yuan output)	+
Ammonium N. Int	Overall ammonium nitrogen intensity (tons/million yuan output)	+
Soot Reg_gap*Int	Interaction term of the ratio of soot emissions not meeting discharge standard with the overall soot intensity (in tons/million yuan output)	+
SO2 Reg_gap*Int	Interaction term of the ratio of SO_2 emissions not meeting discharge standards with the overall SO_2 intensity (in tons/million yuan output)	+
Waste Int	Overall waste intensity (tons/million yuan output)	+
Recycling Ratio	Overall solid waste utilized/overall solid waste generated	–
Energy Int	Overall energy intensity (tons of SCE/million yuan output)	+
Mineral	Dummy variable for mineral products in the HS2 categories 25–27.	+
Metal	Dummy variable for metal products in the HS2 categories 72–81.	+
Wood	Dummy for wood products in HS2 category 44.	+
Stones	Dummy for precious stones in HS2 category 71.	+
Control variables		
Primary	Dummy variable for primary products	+
Exp share [5–15)	Dummy variable, 1 if China's export relative to global exports are between 5 and 15%.	+
Exp share 15+	Dummy variable, 1 if China exports are at least 15% of global exports.	+
Employees	Employees (in millions)	–
Firm No	Number of firms in the industry (in thousands)	−
Profits	Industry profits (in billion yuan)	−
ΔOutput	Output growth compared to the previous year	+
Labour Intensity	Employees/million fixed assets in the industry	+
Export Intensity	Exports in an industry/industry output	+
SOE share	Output share of state-owned enterprises	−
Foreign share	Output share of foreign enterprises	−
Income tax	Taxes and other charges on firms' principal business (billion yuan)	−
Tariff	Applied MFN Tariff	?

Environmental data

The China Statistical Yearbook on Environment provides information on water pollution, air pollution and solid waste at the industry level. Data on energy consumption at the industry level are from the China Statistical Yearbook. The Chinese industry level data distinguish between 40 industry sectors. These sectors include mining, manufacturing as well as production and supply of electricity, gas and water. However, there is no trade in the sectors *Production and Supply of Gas* and *Production and Supply of Water*. Hence, these sectors do not appear in our analysis. A list of industries in our dataset is available in Appendix A in Table 11.

Emissions are scaled by an industry's output level in order to obtain the pollution intensities. Output data are from the Industry Chapter of the China Statistical Yearbook and we deflate the output value using the manufacturing producer price index from the China Statistical Yearbook.

As suggested in the Empirical strategy section, it is necessary to work with the pollution embodied in China's exports rather than the pollution generated by each industry sector. The pollution intensity of China's exports can be obtained using input-output analysis.

Input-output analysis makes use of the condition that the supply of N goods, $S_{[Nx1]}$, equals the demand for those N goods.[20] The demand can be expressed as $A_{[NxN]}S_{[Nx1]} + Y_{[Nx1]}$ where A is the matrix of input coefficients a_{ij}. The input coefficients a_{ij} represent the inputs of commodity i needed to produce commodity j. AS is the amount of goods which are used as intermediate inputs for production and Y is final demand. Final demand Y consists of domestic consumption Y^D, imports Y^M and exports Y^X, i.e. $Y = Y^D + Y^M + Y^X$. Supply equals demand if $S = AS + Y$. Solving for S yields

$$S = (I - A)^{-1}Y \tag{9}$$

where $(I - A)^{-1}$ is the Leontief inverse. The element c_{ij} of the Leontief inverse represents the amount of units of input i which is needed for the production of output good j. An increase in exports of good j by one unit thus requires c_{ij} additional units of

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[20] See e.g. Miller and Blair (1985). Milner and Xu (2009) use input-output analysis to study the pollution content of China's trade.

good i as intermediate input.

To obtain the overall pollution intensities, we use the matrix of emission intensities $E_{[MxN]}$ whose elements e_{ki} denote emissions of pollutant k caused during the production of one unit value of good i. Multiplying Eq. (9) with the matrix of emission intensities, the emissions generated during production are related to the emissions embodied in exports through the following relationship:

$$ES = E(I - A)^{-1}Y \tag{10}$$

The matrix $E(I - A)^{-1}$ represents the overall pollution intensity. Its elements tell us how much additional pollution is generated for an additional unit of final demand (which includes exports).

In order to obtain the overall pollution intensity, we need the direct pollution intensity E and the Leontief inverse $(I - A)^{-1}$. The direct pollution intensities in matrix E are obtained by dividing the pollution emissions of a sector by the value of output. The Leontief inverse can be derived using the Chinese input-output (IO) table. We use the most disaggregate Chinese input-output table which contains 135 sectors ranging from agriculture and manufacturing to services. The disaggregate input-output tables are only produced every 5 years. We use the table for 2007.

Chinese IO tables treat all imports as final deliveries. Since this is not in line with the real world experience, we follow Milner and Xu (2009), Hummels et al. (2001) and Feenstra and Hanson (1999) and use the import proportionality assumption. We assume that imports and domestically produced goods within a sector are perfect substitutes and that the same proportion of the sector's output is used as intermediate input irrespective of whether the output is produced domestically or imported. In order to implement the import proportionality assumption we have to use an adjustment matrix. Let q_i be defined as $q_i = \frac{Gross\ Output_i}{Gross\ Output_i + Imports_i}$ where $Gross\ Output_i$ is the gross output of industry i and $Imports_i$ are the imports of industry i. The adjustment matrix D is a diagonal matrix with the values q_i on its diagonal. Using the adjustment matrix, the Leontief inverse is given by $(I - DA)^{-1}$.

The input-output table is slightly more disaggregated than the industry classification in the environmental data. Hence, it is necessary to aggregate the IO table to the industry level for which we have environmental data. We then calculate the input-output coefficients and the adjusted Leontief inverse for the aggregate table.

Note that the input-output table includes information on agricultural and service sectors. However, there are no corresponding emission data for these sectors. Hence, we aggregate all of these sectors into one sector and delete the respective row and column from the IO table. Therefore, the overall pollution intensity represents the total pollution generated by a final product and all its manufacturing inputs. It does not include the pollution generated by intermediate outputs from agricultural and service sectors.

Control variables

The information on the number of employees, the number of firms in an industry, output growth compared to the previous year, the output share of SOEs and foreign firms, profits, the capital intensity and the income tax is from the industry chapter of the China Statistical Yearbook. The export intensity variable is constructed using data on the trade volume from the BACI trade database. Since the BACI trade data are denoted in US$, we use the average annual exchange rate from the China Statistical Yearbook to obtain the volume of exports in RMB. The export volume is divided by the output value to obtain the export intensity. Table 12 in Appendix A summarizes the data source for all variables which are used in the analysis.

The trade policy data at the HS8 digit level are merged to the industry-level data using two concordance tables. The first table, which is available in the appendix of the 2007 Chinese input output table, links the HS8 digit tariff lines to the sectors in the Chinese input-output table for 2007. The second concordance table links the relevant sectors from the input-output table to the 40 industry sectors in our dataset. This table is constructed manually based on the subcategories of the Chinese industry classification system GB/T4754-2002.

Summary statistics

This section provides summary statistics for all trade policy variables, pollution intensities and the control variables. Table 3 provides means and standard deviations. Table 4 allows us to track the changes in the means of all variables over time.

The summary statistics in Table 3 show that the average difference between the VAT and the export VAT rebate (variable *VAT tax*) is 5.7%. The average VAT tax increases from 4.4% in 2005 to 7.9% in 2008 and falls to 6% in the aftermath of the economic and financial crisis (see Table 4).

The average export tax increases from 0.09 in 2005 to 0.65 in 2009 due to an increase in the scope of the export tax. The last row of Table 1 shows that the average export tax for products which are subject to a positive export tax falls from 18.5% in 2005 to 16% in 2009.

The pollution intensity for all pollutants declines over the sample period. In levels, waste water, solid waste and energy use increase in the course of the sample period. However, output grows faster than emissions.

Table 3
Summary statistics.

	(1) mean	sd	min	max
VAT tax	5.717	4.393	0.00	17.00
Export tax	0.313	2.573	0.00	40.00
Tariff	9.856	7.220	0.00	68.00
Water Int	2004.624	1616.863	138.96	15793.41
Water Stand_Rat	0.938	0.039	0.77	0.99
COD Int	0.426	0.626	0.02	7.02
Ammonium N. Int	0.032	0.035	0.00	0.21
Soot Int	0.604	0.413	0.03	4.40
Soot Stand_Rat	0.876	0.085	0.50	1.03
SO2 Int	1.503	0.796	0.10	12.28
SO2 Stand_Rat	0.855	0.079	0.12	1.00
Waste Int	142.383	137.265	15.46	2830.84
Recycling Ratio	0.605	0.096	0.17	0.79
Energy Int	157.208	73.275	14.07	443.68
Mineral	0.063	0.243	0.00	1.00
Metal	0.084	0.278	0.00	1.00
Wood	0.011	0.105	0.00	1.00
Stones	0.011	0.102	0.00	1.00
Primary	0.054	0.226	0.00	1.00
Exp share [5–15)	0.281	0.449	0.00	1.00
Exp share 15+	0.324	0.468	0.00	1.00
Employees	2.940	1.787	0.02	6.77
Firm No	14.144	9.658	0.12	37.37
Profits	69.330	62.573	−100.31	460.12
ΔOutput	1.261	0.158	0.71	3.68
Labour Intensity	12.010	8.454	0.65	46.46
Export Intensity	0.000	0.003	0.00	0.37
SOE share	0.217	0.211	0.00	0.99
Foreign share	0.298	0.147	0.00	0.84
Income tax	13.834	29.381	0.02	241.76
Output Value	14163.413	10016.649	79.50	44727.96
Observations	34494			

Table 4
Summary statistics by year.

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
VAT tax	4.407	4.871	6.755	7.899	5.997
Export tax	0.093	0.128	0.294	0.629	0.651
Tariff	9.938	9.758	9.876	9.551	9.492
Water Int	2425.646	2023.989	1760.782	1522.497	1301.721
Water Stand_Rat	0.939	0.938	0.931	0.932	0.955
COD Int	0.561	0.441	0.354	0.274	0.227
Ammonium N. Int	0.052	0.032	0.022	0.016	0.013
Soot Int	0.853	0.636	0.475	0.358	0.286
Soot Stand_Rat	0.843	0.860	0.885	0.872	0.919
SO2 Int	1.910	1.622	1.317	1.087	0.903
SO2 Stand_Rat	0.798	0.835	0.853	0.887	0.901
Waste Int	157.862	142.115	134.757	124.984	115.189
Recycling Ratio	0.572	0.588	0.609	0.637	0.676
Energy Int	176.180	160.187	141.520	134.938	124.507
Exp share [5–15)	0.262	0.286	0.292	0.300	0.294
Exp share 15+	0.290	0.318	0.343	0.359	0.375
Employees	2.666	2.831	3.026	3.387	3.372
Firm No	11.538	12.882	14.425	18.271	18.609
Profits	39.745	51.583	82.295	88.195	120.604
ΔOutput	1.384	1.266	1.291	1.262	1.095
Labour Intensity	13.788	12.625	11.593	10.359	8.974
Export Intensity	0.000	0.000	0.000	0.000	0.000
SOE share	0.234	0.215	0.203	0.189	0.179
Foreign share	0.308	0.309	0.309	0.295	0.272
Income tax	7.294	8.912	11.959	15.455	33.857
Output Value	9604.670	12076.022	15534.552	19540.003	21171.487
Observations	5758	5769	5771	5759	5685

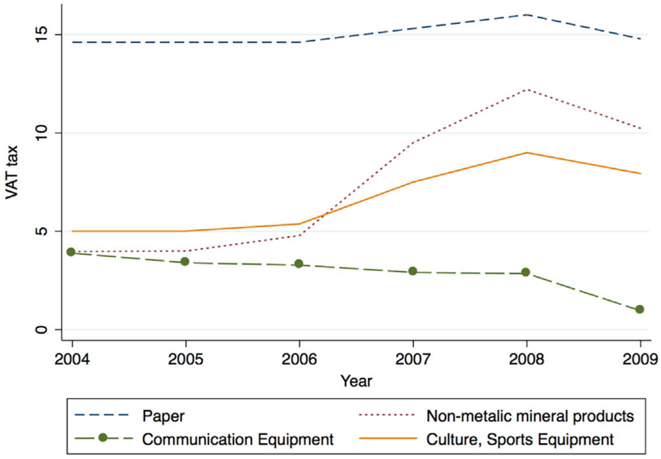

Fig. 1. Development of the average VAT tax for several industries.

Relationship between the VAT tax and the pollution intensities

Prior to the analysis of our results, we look at the relationship between the VAT tax and the pollution intensities in the raw data. Fig. 1 plots the development of the average VAT tax from 2004 to 2009 for the two pollution-intensive industries *Paper* and *Non-metallic Mineral Products* against the VAT tax of the relatively clean industries *Articles for Culture/Education* and *Manufacture of Communication Equipment*.

Paper Production is the most water, COD and ammonium nitrogen intensive industry in 2007.[21] The average VAT tax for *Paper Production* is close to 15% points throughout the sample period. It is raised to about 16% points in 2008.

The graph also shows the average VAT tax for *Non-metallic Mineral Products*. The latter is the second most soot, SO_2 and energy intensive industry. The average VAT tax for *Non-Metallic Mineral Products* is 4% in 2004. From 2006 on it increases gradually and reaches 12% points in 2008. A surge in the VAT tax for a pollution intensive industry from a very low level could represent an adjustment towards an environmentally motivated VAT tax.

The industries *Articles for Culture/Education* and *Communication Equipment* have low pollution intensities across almost all of the pollutants. From 2007 on, the average VAT tax for the two clean industries is lower than the VAT tax for the polluting industries. We would expect this pattern if the VAT tax was motivated by environmental concerns.[22]

As a consequence of the adjustments in the VAT tax, the incentive to produce relatively clean goods increases whereas the incentive to produce polluting goods declines. The VAT rebate adjustments could thus lead to a reallocation of resources from pollution intensive industries to clean industries. As a result, the overall pollution intensity of production could decline.

Ex ante, there is little evidence that the Chinese government uses export taxes to reduce pollution along any other dimension than solid waste. The correlation coefficient between the export tax and most of the pollution intensities is negative (see Table 14 in Appendix A). Only the solid waste intensity and the energy intensity are positively correlated with the export tax. However, the correlation between the export tax and the energy intensity is close to zero.

Results

This section presents our empirical results. The Determinants of VAT taxes section explains our findings for the determinants of the VAT tax. The results for regressions using the export tax as dependent variable are explained in the Export tax as dependent variable section.

Determinants of VAT taxes

When we estimate the determinants of the VAT tax, we use the export tax allowed under China's WTO Accession Protocol as an instrument for the export tax. Prior to the discussion of the results, we assess the quality of our instrument and the necessity of an instrumental variable procedure. The F-statistic for the first-stage regression shows that the instruments are jointly highly significant and that the 2SLS results do not suffer from problems related to weak instruments.

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[21] See Table 16 in Appendix A. The table ranks industries according to their pollution intensities. A higher rank indicates that the product is more polluting.

[22] The correlation Table 14 in Appendix A shows that the VAT tax is significantly positively correlated with the waste water, COD, SO_2, solid waste and energy intensity. This is in line with the VAT tax being used as a second-best pollution policy.

Table 5
Dependent variable: VAT tax.

	(1) 2005–2006	(2) 2007–2009	(3) Difference
Water Reg_gap*Int	0.003**	0.012*	
	(0.002)	(0.004)	
COD Int	1.525***	−1.418	**
	(0.353)	(1.093)	
Ammonium N. Int	−7.090*	42.871*	**
	(3.859)	(25.302)	
Soot Reg_gap*Int	−3.005**	−4.591	
	(1.412)	(6.338)	
SO2 Reg_gap*Int	0.563	4.209*	
	(0.697)	(2.313)	
Waste Int	0.001	−0.006**	***
	(0.001)	(0.003)	
Recycling Ratio	1.190	6.471	
	(1.847)	(5.358)	
Energy Int	0.008***	0.036***	***
	(0.003)	(0.008)	
Mineral	2.511***	5.735***	***
	(0.457)	(0.830)	
Metal	0.657	4.481***	***
	(0.451)	(1.450)	
Wood	6.634***	6.560***	
	(0.734)	(0.778)	
Stones	2.712*	4.073***	
	(1.550)	(0.820)	
Primary	1.131*	0.617	
	(0.651)	(0.898)	
L.Exp share [5–15)	0.094	−0.197	*
	(0.187)	(0.183)	
L.Exp share 15+	0.204	−0.143	
	(0.342)	(0.371)	
L.Employees	0.015	−0.808***	***
	(0.196)	(0.282)	
L.Firm No	−0.126**	−0.047	
	(0.053)	(0.055)	
L.Profits	0.006	0.002	
	(0.004)	(0.005)	
L.ΔOutput	0.811	3.487	
	(0.497)	(3.261)	
L.Labour Intensity	0.003	0.048	
	(0.019)	(0.060)	
L.Export Intensity	19.721	43.181	
	(20.779)	(44.559)	
L.SOE share	−5.455***	−9.189***	
	(1.407)	(3.402)	
L.Foreign share	−1.990*	−0.519	
	(1.103)	(2.606)	
L.Income tax	0.057**	0.092**	
	(0.024)	(0.039)	
Tariff	−0.023**	−0.031	
	(0.009)	(0.022)	
Export tax	0.489***	0.328***	
	(0.187)	(0.102)	
Observations	11373	16954	
r2	0.451	0.614	
F	1292.568	273.398	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007–2009 sample compared to the 2005–2006 sample. No entry means that there is no statistically significant difference.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

We also test for the exogeneity of the export tax using a test that allows for clustered standard errors and reject the null-hypothesis that the export tax is exogenous.[23]

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[23] We use the user-written ivreg2 command (Baum et al., 2002).

Table 6
Predicted change in the VAT tax.

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	0.572	0.928
COD Int	0.580	−0.353
Ammonium N. Int	−0.213	0.590
Soot Reg_gap*Int	−0.299	−0.151
SO2 Reg_gap*Int	0.106	0.496
Waste Int	0.063	−0.545
Recycling Ratio	0.168	0.839
Energy Int	0.749	2.816
Observations	11373	16954

Change from the 25th percentile to the 75th percentile.

Column 1 of Table 5 shows the relationship between the VAT tax and the pollution intensities as well as the control variables for the years 2005–2006. The result in Column 1 are used as a benchmark against which we assess the VAT rebate adjustments. The relationship between the pollution intensities and the VAT tax for the years 2007–2009 is displayed in Column 2 of Table 5. Since the Chinese government linked VAT rebates to environmental motives from 2007 on, we expect to see positive coefficient estimates for the pollution intensities in Column 2 of Table 5 and the discussion therefore focuses on the results in Column 2.

The third column of the table indicates whether there is a statistically significant difference between the coefficient estimates for the 2005–2006 sample and the coefficient estimates for the 2007–2009 sample. In other words, Column 3 shows whether the interaction term between the respective regressor and the dummy variable D_{2007} is statistically significant.

The results support the Chinese government's claim that VAT rebate rates are used for environmental motives. An F-test demonstrates that the coefficient estimates for the pollution intensities as well as the energy intensity are jointly significant in both sample periods. Hence, the pollution intensities are a significant determinant of the VAT tax even when we control for other motives to manipulate trade policy.

Concerns about water pollution seem to be one reason for China's VAT rebate adjustments. The statistically significant positive coefficient estimate for Water Reg_gap*Int in Column 2 of Table 5 demonstrates that there is a positive relationship between the VAT tax and the overall waste water intensity (interacted with the share of waste water emissions not meeting discharge standards) from 2007 onwards. This is in line with our expectations if the VAT tax is motivated by concerns about waste water discharge from 2007 on.

The coefficient estimate for the waste water intensity indicates that the VAT tax increases by 0.012% points as the waste water intensity increases by 1 ton per million yuan output. In order to asses whether the magnitude of the coefficient estimate is economically meaningful, we calculate the predicted change in the VAT tax that results from an increase in a product's pollution intensity with respect to pollutant k from the 25th percentile to the 75th percentile. The predicted change in the VAT tax is displayed in Table 6. Table 6 shows that a jump in the waste water intensity from the 25th to the 75th percentile would lead to an increase in the VAT tax of 0.92% points in the 2007–2009 sample.

Moreover, the VAT tax is significantly higher for ammonium nitrogen intensive products in the 2007–2009 sample, hence discouraging exports of those products. The VAT tax is predicted to increase by 0.59% points as the ammonium nitrogen intensity increases from the 25th to the 75th percentile (see Table 6). Since ammonium nitrogen is a water pollutant, this gives further support to the notion that the VAT rebates are a second-best instrument to reduce water pollution.

Despite the evidence that the VAT taxes discourage water pollution intensive exports, the COD intensity does not seem to be a significant determinant of the VAT tax in the 2007–2009 sample. This result could be due to the high correlation between the waste water intensity and the COD intensity. Table 14 in Appendix A shows a correlation coefficient of 0.92 between the two variables. It is, thus, possible that the COD intensity does not affect the VAT tax once we control for the waste water intensity.

Considering the water scarcity and the severity of water pollution, it is not surprising that China uses trade policy to discourage waste water intensive exports. Per capita availability of water in China is only a quarter of the world average and the availability of water is unevenly distributed with the North being particularly water-scarce (Xie et al., 2009). Water scarcity is exacerbated by pollution. In 2004, only 40% of the monitored river sections and 29 of the monitored lakes and reservoirs were safe for human consumption after treatment and the situation has not improved since then.[24] More than 300 million people in rural China lacked access to safe drinking water in the mid 2000s (Xie et al., 2009).

The economic costs of water pollution in China are considerable. World Bank (2007) estimates that water-pollution related water scarcity imposes a cost of 147 billion RMB or about 1% of GDP. The cost of ground water depletion amounts

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[24] According to a report cited by The Economist (2014), 85% of China's biggest rivers are polluted to the extent that the water is undrinkable even after treatment. Moreover, the proportion of polluted ground water increased from 37% in 2000 to 60% in 2013.

92 billion RMB. Moreover, water pollution affects the health of more than 300 million people who do not have access to safe drinking water in China. The cost of the resulting health damages is estimated to be between 0.3 and 1.9% of rural GDP.

There is also some evidence to suggest that the VAT tax discourages exports of air pollution intensive products. The VAT tax is significantly higher for SO_2 intensive products. An increase in the SO_2 intensity, interacted with the share of emissions not meeting discharge standards, from the 25th to the 75th percentile is associated with an increase in the VAT tax by 0.49 percentage points (see Table 6). According to Xie et al. (2009), China is the country with the highest SO_2 emissions globally. It did not meet its goal to reduce SO_2 emissions during the 11th FYP (2001–2005) with emissions being 42% higher than the target. Therefore, the use of VAT rebate rates as a second-best way of reducing SO_2 emissions would not be surprising.

The VAT tax is not significantly correlated with the soot intensity. This may be due to the high correlation of 0.94 between the soot and SO_2 intensity. Moreover, the Five Year Plan for the years 2005–2010 does not include a target to reduce soot emissions (see Table 10 in Appendix A). If the government does not plan do reduce soot emission, it is unlikely to use trade policy as a second-best instrument towards that end.

Furthermore, the data support the Chinese authorities' claim that the VAT rebate adjustments aim at reducing energy consumption. Based on our coefficient estimates for the 2007–2009 sample, the VAT tax is 2.81percentage points higher for a product with an energy intensity at the 75th percentile than for a product with an energy intensity at the 25th percentile, ceteris paribus (see Table 6).[25] This difference is economically meaningful. Table 6 also shows that differences in the energy intensity can explain more of the difference in the VAT tax than differences in the pollution intensity with respect to any other pollutant *k*. The Chinese government seems to be most concerned about China's energy consumption when it chooses the VAT tax.

This finding could be explained by two factors. Firstly, China is the world's second largest energy consumer in the mid 2000s (Rosen and Houser, 2007). However, domestic oil, gas and coal can no longer satisfy the energy appetite of China's growing economy. In the early and mid-2000s China was struggling with energy shortages, increasing import dependence and price volatility. Secondly, 70% of China's energy supply results from the combustion of coal, which is a major source of air pollution (Chan and Yao, 2008). Xie et al. (2009) attributes rising SO_2 emissions to higher energy consumption and in particular to the high use of coal. An attempt to clean up the air should thus be accompanied by a reduced reliance on energy from pollution intensive coal-fired power plants.

The results do not suggest that the VAT tax is used as a second-best policy instrument to address the generation of solid waste or increase recycling. The recycling ratio is not significantly correlated with the VAT tax. Moreover, the VAT tax is adjusted such that it declines in the solid waste intensity in the 2007–2009 sample, thus, encouraging exports of solid waste intensive products.

The fact that the coefficient estimates do not reflect an attempt to encourage recycling or reduce the generation of solid waste is not startling if we look at China's environmental achievements in the 10th FYP. China planned to recycle 50% of its solid waste in the 10th FYP period. This target was overachieved with a recycling ratio of 56% (State Council of People's Republic of China, 2006). Moreover, the generation of industrial solid waste was meant to decline by 10%. In fact, China achieved a reduction in industrial solid waste of 48%. This indicates that domestic instruments might suffice to increase recycling and reduce the generation of solid waste. The use of trade policy as a second-best policy instrument does not seem to be necessary.

Moreover, the results support the claim that the VAT rebate adjustments are meant to contribute to the conservation of China's natural resources. In the period from 2007 on, the VAT tax for mineral and metal products is estimated to be 5.7 and 4.5 percentage points higher than the VAT tax for other products, respectively.[26] The VAT tax for wood and precious stones exceeds the VAT tax for other products by 6.6 and 4.1 percentage points respectively. The conservation of resources seems to be the most important motive behind China's VAT rebate rate adjustments especially when we compare the magnitude of the coefficient estimates for the resource dummy variables to the predicted changes in the VAT tax as a consequence of changes in the pollution intensities.

As a large producer on the world market, China could introduce export taxes in order to manipulate the terms of trade in its favour. This would be reflected in positive coefficient estimates for the dummy variables *L.Exp share* [5–15) and *L.Exp share* 15+, which capture the share of Chinese exports in global exports in the previous period. The findings in Table 5, however, show that the export tax is not significantly related to China's share in global exports. Hence, there is no evidence that the VAT tax reflects an attempt to raise the world market price for Chinese exports. Moreover, there is no evidence that the VAT tax is set in a way that discourages exports of primary products.

The sign of the coefficient estimates for the control variables is largely in line with our expectations. Industries with a larger output share of state-owned enterprises face a significantly lower VAT tax. The finding indicates that links between the government and SOEs lead to a preferential treatment of industries in which SOEs produce a large proportion of the

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[25] Column 3 of Table 5 shows that the coefficient estimate for the energy intensity is significantly larger in the 2007–2009 sample than in the 2005–2006 sample. This implies that an increase in the energy intensity is associated with a larger increase in the VAT tax from 2007 on and supports the idea that the VAT rebate rate adjustments intend to reduce the energy intensity of exports.

[26] The coefficient estimates for the Mineral and Metal dummy variables are significantly higher in the 2007–2009 sample than prior to 2007, suggesting that the VAT tax adjustments attempt to discourage exports for mineral and metal products.

Table 7
Dependent variable: export tax.

	(1) 2005–2006	(2) 2007–2009	(3) Difference
Water Reg_gap*Int	−0.003**	−0.001	
	(0.001)	(0.001)	
COD Int	0.027	−0.208	
	(0.130)	(0.241)	
Ammonium N. Int	5.292	1.462	
	(4.035)	(11.479)	
Soot Reg_gap*Int	0.773	1.592	
	(0.872)	(3.056)	
SO2 Reg_gap*Int	0.157	−2.875***	***
	(0.288)	(0.809)	
Waste Int	0.002**	0.008***	***
	(0.001)	(0.001)	
Recycling Ratio	1.706*	4.108**	
	(0.873)	(1.692)	
Energy Int	−0.006*	−0.008*	
	(0.003)	(0.004)	
Mineral	−0.450	0.782*	***
	(0.282)	(0.418)	
Metal	1.030	1.125	
	(1.004)	(1.011)	
Wood	−1.415*	−1.413**	
	(0.708)	(0.664)	
Stones	−0.442	−1.164**	**
	(0.328)	(0.458)	
Primary	0.555*	1.135**	*
	(0.274)	(0.447)	
L.Exp share [5–15)	−0.150	−0.117	
	(0.115)	(0.121)	
L.Exp share 15+	−0.112	0.314	*
	(0.110)	(0.260)	
L.Employees	−0.009	0.186	*
	(0.073)	(0.120)	
L.Firm No	0.027	−0.034	
	(0.031)	(0.025)	
L.Profits	−0.001	0.003	
	(0.003)	(0.003)	
L.ΔOutput	0.972***	2.574*	
	(0.280)	(1.518)	
L.Labour Intensity	0.008	−0.008	
	(0.008)	(0.014)	
L.Export Intensity	−14.743***	−43.109**	
	(4.171)	(20.783)	
L.SOE share	0.348	0.417	
	(0.726)	(0.996)	
L.Foreign share	0.220	−0.051	
	(0.454)	(0.844)	
L.Income tax	0.008	−0.003	
	(0.011)	(0.009)	
L.VAT tax	0.173*	0.193***	
	(0.095)	(0.062)	
Tariff	−0.008	−0.021	
	(0.008)	(0.019)	
Observations	11373	16954	
r2	0.138	0.224	
F	219.560	438.393	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007–2009 sample compared to the 2005–2006 sample. No entry means that there is no statistically significant difference.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

Table 8
Predicted change in the export tax.

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	−0.425	−0.111
COD Int	0.010	−0.052
Ammonium N. Int	0.159	0.020
Soot Reg_gap*Int	0.077	0.052
SO2 Reg_gap*Int	0.030	−0.339
Waste Int	0.236	0.711
Recycling Ratio	0.241	0.533
Energy Int	−0.590	−0.610
Observations	11373	28327

Change from the 25th percentile to the 75th percentile.

output value. Furthermore, the Chinese government seems to grant more protection to large industries. The VAT tax is significantly lower for industries with a larger number of employees in the period from 2007 on.[27]

The results also reveal that a high export tax is accompanied by a high VAT tax. An increase in the export tax by one percentage point is associated with an increase in the VAT tax of 0.33 percentage points in the 2007–2009 sample. This reflects the fact that the rebate rate is zero for almost all products for which the Chinese governments levies an export tax and suggests that the export tax is not set in a way which offsets the effect of the VAT tax.

The tariff is not significantly correlated with the VAT tax in the 2007–2009 sample. To the best of our knowledge, the Chinese government does not link import tariffs to environmental concerns. While our results suggest that the VAT rebate rates reflect concerns about pollution, energy use and resource conservation, protection on the import side may be driven by other motives. This could explain why there is no statistically significant relationship between the tariff and the VAT tax.

Export tax as dependent variable

According to the WTO trade policy report (WTO, 2008, p. 73–74) not only the VAT rebates but also China's export taxes are motivated by environmental concerns. This section examines whether the data support this claim.

The export tax is modelled as a function of the pollution intensities, the resource dummies and the control variables as in Eq. (8). In order to ovoid an omitted variables bias, we also include the lag of the VAT tax as a control variable. As explained in the Control variables section, the Chinese government only implements export taxes which exceed the export tax allowed under the WTO Accession Protocol once it has exhausted the VAT tax as a policy instrument. This is similar to a situation in which the regulator chooses the VAT tax first and then chooses the export tax. Therefore, we are not concerned about reverse causality from the export tax to the VAT tax. Furthermore, using the lag of the VAT tax guarantees that the regressor is not influenced by the dependent variable. The model is estimated using an OLS regression.

The estimated relationships between the export tax, the environmental variables and the control variables are shown in Table 7. Column 1 of Table 7 displays the results for an OLS regression using data for the years 2005–2006. Column 2 of the same table shows the results for a sample covering the years 2007–2009.

The results show little evidence of an environmental motive behind China's export taxes. Neither the pollution intensities nor the control variables are significantly positively correlated with the export tax. One notable exception is the solid waste intensity. Table 7 reveals a statistically significant positive relationship between the solid waste intensity and the export tax throughout the sample period. The relationship between the waste intensity and the export tax is significantly larger from 2007 on (see column 3 of Table 7) indicating that the introduction of export taxes could be geared towards a reduction in the generation of solid waste. However, even from 2007 on, the economic effect of a change in the solid waste intensity on the export tax is small. Table 8 displays the predicted change in the export tax as the pollution intensities increase from the 25th to the 75th percentile. Such an increase in the solid waste intensity is predicted to raise the export tax by no more than 0.24 percentage points prior to 2007 and by 0.71 percentage points in the 2007–2009 sample.

The results indicate that the export tax is significantly lower for SO_2 and energy intensive products as well as wood products and precious stones. This is contrary to the actions of a regulator who uses trade policy as second-best instrument to reduce pollution and conserve resources.

The finding that the export tax is not motivated by environmental concerns is not surprising if we bear in mind that the Chinese government is restricted in its choice of export taxes due to its commitment under the WTO Accession Protocol. When we derive the equation of the second-best export tax in the Second-best export taxes as environmental policy section, we assume that the regulator can choose trade policy to its liking. According to its WTO Accession protocol, China is only allowed to levy export taxes on 84 products. Hence, its ability to use export taxes as secondary environmental policy

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[27] Table 15 in Appendix A shows the results for an unconditional correlation between the VAT tax and the pollution intensities. The result that the VAT tax is significantly higher for waste water and energy intensive products follows through.

Table 9
Sensitivity analysis I.

	(1) VAT tax Manufacturing	(2) VAT tax Small	(3) VAT tax No Reg_gap	(4) VAT tax 2007	(5) Overall export tax
Water Reg_gap*Int	0.014***	0.009**		0.009**	0.013**
	(0.005)	(0.005)		(0.004)	(0.005)
Water Int			−0.001		
			(0.001)		
COD Int	−1.841	−0.483	4.886	−0.311	−1.634
	(1.130)	(1.180)	(2.996)	(1.089)	(1.279)
Ammonium N. Int	47.438**	53.242*	76.304**	5.020	50.258**
	(22.014)	(27.713)	(37.108)	(19.319)	(22.880)
Soot Reg_gap*Int	−4.002	−5.654		−10.528	−3.902
	(5.297)	(6.809)		(6.433)	(6.432)
Soot Int			−8.958		
			(6.584)		
SO2 Reg_gap*Int	7.331***	4.696*		4.916**	0.825
	(2.608)	(2.638)		(2.323)	(1.718)
SO2 Int			5.561*		
			(2.945)		
Waste Int	0.003	−0.007**	−0.002	−0.008*	0.004
	(0.017)	(0.004)	(0.002)	(0.004)	(0.003)
Recycling Ratio	2.968	7.686	12.775**	8.604	12.884**
	(7.952)	(7.279)	(5.598)	(5.625)	(5.014)
Energy Int	0.038***	0.035***	0.024**	0.031***	0.033***
	(0.013)	(0.008)	(0.010)	(0.007)	(0.009)
Mineral	5.565***	5.329***	5.970***	4.186***	7.906***
	(0.818)	(0.733)	(0.812)	(0.683)	(0.826)
Wood	7.523***	6.448***	6.692***	4.913***	6.271***
	(1.111)	(0.921)	(0.802)	(0.712)	(0.942)
Stones	2.040*	4.082***	3.951***	2.167*	3.334***
	(1.140)	(0.709)	(0.862)	(1.115)	(1.188)
Metal	2.720	4.571***	4.381***	3.690***	6.932***
	(1.720)	(1.556)	(1.445)	(1.318)	(2.119)
Primary	0.595	0.558	1.356	1.232	2.482*
	(0.732)	(0.927)	(0.975)	(0.812)	(1.281)
L.Exp share [5–15)	−0.170		−0.224	0.278	−0.429
	(0.193)		(0.182)	(0.172)	(0.269)
L.Exp share 15+	−0.103		−0.197	0.252	0.242
	(0.371)		(0.370)	(0.280)	(0.502)
L.Employees	−0.684**	−0.939***	−0.488	−0.330	−0.616**
	(0.287)	(0.358)	(0.392)	(0.267)	(0.268)
L.Firm No	−0.056	−0.051	−0.074	−0.188***	−0.120**
	(0.064)	(0.065)	(0.056)	(0.062)	(0.052)
L.Profits	−0.003	0.005	−0.000	0.016**	0.005
	(0.006)	(0.006)	(0.007)	(0.007)	(0.005)
L.ΔOutput	−0.496	2.369	4.756	6.668*	7.823*
	(3.323)	(3.395)	(3.634)	(3.448)	(4.577)
L.Labour Intensity	0.075	0.161*	0.056	0.060	0.045
	(0.056)	(0.090)	(0.067)	(0.044)	(0.057)
L.Export Intensity	−11.054	127.290***	57.141	60.581*	−6.481
	(44.969)	(46.096)	(43.726)	(33.979)	(36.773)
L.SOE share	−10.559***	−8.569**	−12.719***	−9.976***	−11.228***
	(3.017)	(3.783)	(3.530)	(2.205)	(3.691)
L.Foreign share	0.553	−3.569	−1.512	−5.259***	−1.070
	(3.359)	(3.217)	(2.323)	(1.782)	(2.643)
L.Income tax	0.098***	0.090**	0.117***	0.098***	0.111**
	(0.030)	(0.038)	(0.039)	(0.031)	(0.044)
Export tax	0.441***	0.361***	0.267***	0.256**	
	(0.126)	(0.122)	(0.098)	(0.107)	
Tariff	−0.043	−0.031	−0.031	−0.046**	−0.068*
	(0.027)	(0.022)	(0.021)	(0.018)	(0.036)
Observations	14990	10787	17022	5700	16954

Cluster robust standard errors in parentheses.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

instrument is limited.

Discouraging exports of primary products seems to be a motivation for the introduction of export taxes. Prior to 2007, primary products are taxed 0.6 percentage points more than processed products. Between 2007 and 2009, the export tax is 1.25 percentage points higher for primary products. This suggests that the Chinese government may have introduced export taxes for a range of products in an attempt to attract downstream producers to China where they have access to primary products at a lower price.

Sensitivity analysis

This section analyses the sensitivity of our results. Since China's WTO Accession protocol constrains the use of export taxes and the Chinese government only levies export taxes on less than 300 out of more than 5700 products, most of the variation in trade policy results from variation in the VAT rebate rates. The sensitivity analysis therefore focuses on regressions with the VAT rebate rate as dependent variable. Regression results for the same sample period with the export tax as dependent variable can be found in Table 17 in Appendix A. Moreover, the sensitivity analysis focuses on the time period from 2007 onwards, since the Chinese authorities link trade policy to environmental concerns during this time period.

No extractive industries

Our sample contains a broad spectrum of industries. In this section, we restrict the sample to manufacturing industries and exclude extractive industries like *Mining and Washing of Coal*, *Extraction of Petroleum and Natural Gas* and Mining and Processing of Metal and Non-Metal Ores. Moreover, the sectors *Recycling and Disposal of Solid Waste* and *Production and Supply of Energy* are removed from the sample. All of the extractive industries as well as power generation and supply are classified as resource intensive and Table 16 in Appendix A shows that they are amongst the most polluting industries. Therefore, we investigate whether the positive correlation between the VAT tax and the pollution intensities follows through in a sample without the above-mentioned resource- and pollution-intensive industries.

The regression results are presented in Column 1 of Table 9. The results are very similar to those we obtained for the entire sample. The VAT tax is significantly higher for minerals, wood products and precious stones as well as waste water, ammonium nitrogen, SO_2 and energy intensive products. The magnitude of the coefficient estimates is similar to the magnitude of the coefficient estimates in the baseline regression.

No market power

The theoretical model shows that the second-best export tax is also driven by an incentive to manipulate the world market price of exports. This terms of trade motive is difficult to measure. In the main analysis we proxy the terms of trade motive using dummy variables for the lag of China's share in global exports. However, we want to scrutinize the terms of trade motive further.

As a robustness check, we only look at observations for which China is a small producer in the world market. There is no incentive to set an export tax or a VAT tax in order to manipulate the terms of trade if the industry is small on the world market. Hence, we look at a sample of products for which China exports less than 15% of global exports. The results are presented in Column 2 of Table 9. They are similar to the results for the unrestricted sample.[28]

No measure for the regulatory gap

In our baseline regression, we interact the waste water intensity, the soot intensity and the SO_2 intensity with the share of emissions meeting discharge standards. The latter variable is a proxy for the difference between marginal damage and the pollution tax in the theoretical model.

In order to investigate whether this measure for the regulatory gap drives our results, we include the waste water, soot and SO_2 intensities as regressors without interacting them with the measure for the regulatory gap. As mentioned above, the relevant Five Year Plans foresee reductions in SO_2 and soot emissions as well as water consumption, indicating that the pollution tax is lower than marginal damage. Moreover, the share of emissions exceeding discharge standards is positive for all industries and all years in the sample. With the pollution tax not internalizing the environmental distortion to the desired extent, we would expect a positive relationship between soot, SO_2 and waste water intensities and the VAT tax.

The regression results for a model which does not interact the pollution intensities with a measure for the regulatory gap are displayed in Column 3 of Table 9. As in the baseline regression, the VAT tax is significantly higher for SO_2 intensive products and not significantly related to the soot intensity. The coefficient estimate for the waste water intensity, however, is not statistically significant, indicating that the positive relationship between the waste water intensity and the VAT tax only holds if we consider differences in the industries' compliance with discharge standards.

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[28] The results also follow through if we drop all primary products from the sample.

This result highlights the importance of using economic theory to guide the empirical analysis. Based on the theory, the correct specification requires an interaction term between the pollution intensity and the regulatory gap. Omitting the regulatory gap can be considered a misspecification and the misspecified model would suggest that the Chinese government does not have reductions in waste water emissions in mind when it sets the VAT rebate rates.

Effects of the economic and financial crisis?

The sample period includes the years of the economic and financial crisis which had a large negative impact on Chinese exports in some product categories. When Chinese exports plummeted, the Chinese government tried to support some of its export industries via increases in VAT rebate rates.[29] The summary statistics in Table 4 show that, as a consequence, the average VAT tax declined in 2009.

In order to demonstrate that our results are not driven by VAT rebate adjustments in response to the economic and financial crisis, we restrict the sample to the year 2007 instead of using observations for the years 2007–2009.

The results presented in Column 4 of Table 9 corroborate our findings. The VAT tax is significantly positively correlated with the waste water intensity, the SO_2 intensity and the energy intensity and the coefficient estimates are of a similar magnitude as in the baseline regression, indicating that the VAT tax may aim at reducing pollution along those dimensions.

Overall export tax

The results suggest that the VAT tax and the export tax are driven by different factors, in particular with respect to the pollution intensities and the resource dummy variables. The Chinese government uses VAT rebate rates to discourage exports of natural resources, waste water, SO_2 and energy intensive products and natural resources. The export tax, on the other hand, is lower for SO_2 and energy intensive products as well as the wood products and precious stones in the 2007–2009 sample.

The fact that the coefficient estimates for some of the environmental variables have opposite signs in the regression using the VAT tax or the export tax as dependent variables means that the export tax could potentially offset the effect of the VAT tax and vice versa. In order to investigate whether this poses a problem, we add the VAT tax and the export tax to generate a variable called “Overall export tax”. This variable is used as the dependent variable in the regression presented in Column 5 of Table 9.

A comparison between Column 1 of Table 9 and Column 2 of Table 5 reveals great similarities between the determinants of the overall export tax and the VAT tax. This is not surprising if we bear in mind that no more that 252 out of more than 5700 products in our sample were subject to an export tax.

The export tax does not seem to offset the positive correlation between the pollution intensities and the VAT tax. The overall export tax is significantly higher for waste water, ammonium nitrogen intensive and energy intensive products as well as natural resources. The results confirm the hypothesis that Chinese trade policy is motivated by environmental concerns.

Conclusion

From 2007 on, the Chinese government repeatedly emphasised that it uses export taxes as well as VAT rebates as second-best environmental policy instruments. This paper investigates whether, in practice, concerns about pollution drive Chinese trade policy reforms.

Environmental issues are of increasing importance on the Chinese policy agenda. However, the decentralized implementation and a lack of enforcement of pollution regulation pose a challenge to internalizing the environmental distortion. Given this constraint on the use of domestic pollution taxes, partial export VAT rebates and export taxes can be used as a second-best policy instrument to protect the environment.

Extending Copeland's (1994) model to the large country case, we solve for the second-best export tax in a situation in which the regulator cannot adjust trade policy. Under certain assumptions, it is possible to show that the second-best export tax increases in a product's pollution intensity. This relationship guides our empirical analysis.

This paper investigates whether the difference between the VAT and the VAT rebate and the export tax are positively correlated with a product's air, water, solid waste and energy intensity. The analysis is based on product-level trade policy data as well as data on Chinese pollution emissions and energy use spanning the years 2005–2009.

The results presented in this paper lend support to the Chinese authorities' claim that the export VAT rebate adjustments are driven by environmental concerns. The VAT rebate rates are set in a way which discourages exports of waste water, ammonium nitrogen, SO_2 and energy intensive and products. Moreover, the conservation of natural resources such as minerals, metals, wood products and precious stones seems to be a key determinant of China's VAT rebate rates.

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[29] From the end of 2008 on, there were several VAT rebate reforms in which the Chinese government increased the VAT rebate rates for particular industries. See Table 13 in Appendix A for details on the dates of the reforms.

However, there is no evidence that the export tax is used as a secondary instrument to reduce pollution or conserve natural resources. The export tax seems to be motivated by an attempt to protect downstream producers in China, since the export taxes are higher for primary products.

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Appendix A

Theoretical model

This appendix shows how to derive the welfare maximising export tax in a situation in which the regulator cannot adjust pollution policy. The Second-best export taxes as environmental policy section defines the following equilibrium conditions for the economy:

$$E(1, q, z, u) = G(1, q, s, v) + s'z + t'X \tag{11}$$

$$X = G_q(1, q, s, v) - E_q(1, q, z, u) \tag{12}$$

$$z = -G_s \tag{13}$$

$$-E_q(1, q, z, u) + G_q(1, q, s, v) - E_p^*(1, p) + G_p^*(1, p) = 0_N \tag{14}$$

In this framework, changes in welfare can be measured by $\mathrm{E_u d_u}$ since E_u is the marginal utility of income. The first step in solving for the welfare maximising policy is to totally differentiate Eq. (11). Since we consider a large economy which can affect the price level, $dq = dp - dt$.[30] The technology set is assumed to be constant ($dv=0$).

Using Eqs. (12) and (13), the total differential of Eq. (11) simplifies to

$$E_u du = -(E_z - s)'dz + t'dX + X'dp \tag{15}$$

For the purpose of this paper, the regulator is assumed to be unable to change pollution policy ($ds=0$). However, export taxes can be adjusted. In order to solve for a change in welfare as a function of changes in the export tax t it is necessary to use the total differentials of Eqs. (12)–(14). Total differentiation of Eqs. (12) and (13) yields

$$dX = (G_{qq} - E_{qq})d(p - t) - E_{qz}dz - E_{qu}du. \tag{16}$$

$$dz = -G_{sq}d(p - t) \tag{17}$$

The goods market equilibrium condition allows us to solve for the change in the international price vector as a function of changes in the export tax. Throughout the paper, we assume that income effects attach to the numeraire. In other words, we assume that $E_{qu} = 0_N$. With this assumption, the total differential of the goods market equilibrium condition (14) is given by

$$\left(X_q + X_p^* + E_{qz}G_{sq}\right)dp - \left(X_q + E_{qz}G_{sq}\right)dt = 0 \tag{18}$$

where $X_q = G_{qq} - E_{qq}$ and $X_p^* = G_{pp}^* - E_{pp}^*$ are the response of domestic exports and foreign exports to changes in the domestic and world market price, respectively.

We define $\Lambda = -X_q - X_p^* - E_{qz}G_{sq}$ and assume that Λ is of full rank and hence invertible. The variable Λ captures the complete effect of changes in the world market price on production and consumption including the effects which work though changes in pollution.

With this notation, the relationship between the export tax and the world market price can be expressed by the following equation:

$$dp = -\Lambda^{-1}\left(X_q + E_{qz}G_{sq}\right)dt \tag{19}$$

Substituting Eqs. (16), (17) and (19) into Eq. (15) and manipulating terms yields

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[30] In the small country case, as in Copeland (1994), this simplifies to $dq=dt$, since the small country does not affect the international price level.

Table 10
Emission reduction targets.

Pollutant	10th FYP (2001–2005)	11th FYP (2006–2010)
Water consumption	–	Reduction in water consumption per unit of industrial value by 30%
COD	10% reduction	10% reduction
Ammonium nitrogen	10% reduction	–
SO_2	10% reduction	10% reduction
Soot	9% reduction	–
Dust	17% reduction	–
Generation of solid waste	10% reduction	–
Recycling	Recycle 50% of solid waste by 2005	Recycle 60% of solid waste by 2010
Energy	–	Reduce energy consumption per unit of GDP by 20%

Emission reduction targets are defined as a reduction in emissions at the end of the FYP period compared to emissions at the beginning of the FYP period unless otherwise specified.

Table 11
List of sectors.

Sectors in the dataset
Mining and Washing of Coal
Extraction of Petroleum and Natural Gas
Mining and Processing of Ferrous Metal Ores
Mining and Processing of Non-Ferrous Metal Ores
Mining and Processing of Nonmetal Ores and Other Ores
Processing of Food from Agricultural Products
Manufacture of Foods
Manufacture of Beverages
Manufacture of Tobacco
Manufacture of Textile
Manufacture of Textile Wearing Apparel, Footwear, and Caps
Manufacture of Leather, Fur, Feather and Related Products
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
Manufacture of Furniture
Manufacture of Paper and Paper Products
Printing, Reproduction of Recording Media
Manufacture of Articles For Culture, Education and Sport Activity
Processing of Petroleum, Coking, Processing of Nuclear Fuel
Manufacture of Raw Chemical Materials and Chemical Products
Manufacture of Medicines
Manufacture of Chemical Fibres
Manufacture of Rubber
Manufacture of Plastics
Manufacture of Non-metallic Mineral Products
Smelting and Pressing of Ferrous Metals
Smelting and Pressing of Non-ferrous Metals
Manufacture of Metal Products
Manufacture of General Purpose Machinery
Manufacture of Special Purpose Machinery
Manufacture of Transport Equipment
Manufacture of Electrical Machinery and Equipment
Manufacture of Communication Equipment, Computers and Other Electronic Equipment
Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
Manufacture of Artwork and Other Manufacturing
Recycling and Disposal of Waste
Production and Distribution of Electric Power and Heat Power

$$E_u du = -\left[\delta_z G_{sq} + t' X_q\right] dt - \left(\delta_z G_{sq} + t' X_q + X'\right) \Lambda^{-1} \left(X_q + E_{qz} G_{sq}\right) dt. \tag{20}$$

The term $\delta_z = E_z' + t' E_{qz} - s'$ is the gap between the marginal damage caused by pollution $E_z' + t' E_{qz}$ and pollution tax s. Marginal damage consists of the direct effect of pollution E_z and the indirect effect $t' E_{qz}$. The direct effect represents the consumer's marginal willingness to pay for a one unit reduction in pollution. The indirect effect of pollution on the consumer, $t' E_{qz}$, works through the trade distortion.

The second best export tax satisfies $E_u du / dt = 0$ or

Table 12
Data source.

Variables	Data Source
VAT tax	China Customs, State Administration of Taxation, Ministry of Finance (see Table 13 for details)
Export tax	China Customs Homepage
Tariff	WITS TRAINS database
Waste Water Vol	China Statistical Yearbook on Environment
COD Vol	China Statistical Yearbook on Environment
Waste Gas	China Statistical Yearbook on Environment
Soot Emission	China Statistical Yearbook on Environment
Soot Stand_Rat	China Statistical Yearbook on Environment
SO_2 Emission	China Statistical Yearbook on Environment
SO_2 Stand_Rat	China Statistical Yearbook on Environment
Dust Emission	China Statistical Yearbook on Environment
Dust Stand_Rat	China Statistical Yearbook on Environment
Solid Waste	China Statistical Yearbook on Environment
Energy Consumption	China Statistical Yearbook, Energy Chapter
Output Value	China Statistical Yearbook, Industry Chapter
PPI	China Statistical Yearbook, Industry Chapter
Primary	UN Broad Economic Categories
Exp share	BACI Trade Database
Firm No	China Statistical Yearbook, Industry Chapter
Employees	China Statistical Yearbook, Industry Chapter
Δ Output	China Statistical Yearbook, Industry Chapter
Labour Intensity	China Statistical Yearbook, Industry Chapter
Export Intensity	BACI Trade Database and China Statistical Yearbook, Industry Chapter
SOE share	China Statistical Yearbook, Industry Chapter
Foreign share	China Statistical Yearbook, Industry Chapter
Income Tax	China Statistical Yearbook, Industry Chapter

Table 13
VAT rebate reforms and data source.

Policy reform	Effective date	Data source
Cai Shui (2006) No. 139	15th September 2006	China Customs*
Cai Shui (2007) No. 64	15th April 2007	State Administration of Taxation**
Cai Shui (2007) No. 90	1st July 2007	State Administration of Taxation
Cai Shui (2007) No. 169	20th December 2007	State Administration of Taxation
Cai Shui (2008) No. 77	13th June 2008	China Customs
Cai Shui (2008) No. 111	1st August 2008	Ministry of Finance***
Cai Shui (2008) No. 138	1st November 2008	China Customs
Cai Shui (2008) No. 144	1st December 2008	State Administration of Taxation
Cai Shui (2008) No. 177	1st January 2009	State Administration of Taxation
Cai Shui (2009) No. 14	1st February 2009	State Administration of Taxation
Cai Shui (2009) No. 43	1st April 2009	China Customs
Cai Shui (2009) No. 88	1st June 2009	China Customs

* http://china-customs.com/. **http://www.chinatax.gov.cn/. ***http://szs.mof.gov.cn/zhengwuxinxi/zhengcefabu/200808/t20080801_60216.html.

$$\left[\delta_z G_{sq} + t' X_q\right]\Lambda^{-1} X_p^* - X'\Lambda^{-1}\left(X_q + E_{qz} G_{sq}\right) = 0. \tag{21}$$

Assuming that X_p^* is invertible and using the definition of Λ and δ_z we can solve for the second-best export tax as

$$t' = X'\left(X_p^*\right)^{-1} - \left(E_z' - s'\right) G_{sq}\left(X_q + E_{qz} G_{sq}\right)^{-1} \tag{22}$$

The pollution intensities are defined as the elements of the matrix $G_{sq} = -\partial z/\partial q$. In order to be able to make a statement about the relationship between the export tax and the pollution intensities, we assume that compensated demand E_q is

Table 14

Correlation between trade policy variables, overall pollution intensities and resource dummy variables.

	(1)													
	VAT tax	Export	Water Int	COD Int	Am. Int	Soot Int	SO2 Int	Waste Int	Recy.	Energy Int	Mineral	Metal	Wood	Stones
VAT tax	1.00													
Export	0.28***	1.00												
Water Int	0.17***	−0.04***	1.00											
COD Int	0.20***	−0.04***	0.92***	1.00										
Am. Int	0.01	−0.06***	0.66***	0.56***	1.00									
Soot Int	0.00	−0.05***	0.40***	0.27***	0.42***	1.00								
SO2 Int	0.06***	−0.02***	0.38***	0.20***	0.39***	0.94***	1.00							
Waste Int	0.14***	0.20***	0.05***	−0.07***	−0.01	0.31***	0.46***	1.00						
Recy.	0.23***	−0.03***	0.22***	0.25***	0.15***	−0.12***	−0.24***	−0.55***	1.00					
Energy Int	0.11***	0.01**	0.25***	0.04***	0.36***	0.81***	0.88***	0.47***	−0.21***	1.00				
Mineral	0.30***	0.13***	−0.03***	−0.07***	−0.06***	0.18***	0.23***	0.28***	0.01	0.17***	1.00			
Metal	0.21***	0.20***	−0.08***	−0.11***	−0.13***	0.08***	0.20***	0.41***	−0.36***	0.35***	−0.08***	1.00		
Wood	0.19***	−0.00	−0.04***	−0.01*	−0.03***	0.01	−0.03***	−0.05***	0.06***	−0.05***	−0.03***	−0.03***	1.00	
Stones	0.08***	−0.01*	−0.03***	−0.03***	−0.04***	0.03***	0.04***	0.05***	−0.07***	0.04***	−0.03***	−0.03***	−0.01*	1.00

Export = Export tax, Am. = Ammonium Nitrogen, Recy. = Recycling Ratio.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Table 15
Dependent variable: VAT tax.

	(1) 2005–06	(2) 2007–2009
Water Reg_gap*Int	0.002	0.012**
	(0.002)	(0.005)
COD Int	1.675***	−0.278
	(0.421)	(1.508)
Ammonium N. Int	−15.869**	−37.182
	(6.126)	(22.093)
Soot Reg_gap*Int	−3.731*	−6.843
	(1.842)	(15.538)
SO2 Reg_gap*Int	1.430	5.343
	(0.970)	(4.373)
Waste Int	0.006***	0.003
	(0.002)	(0.004)
Recycling Ratio	8.258**	11.467
	(4.061)	(9.509)
Energy Int	0.001	0.036***
	(0.005)	(0.008)
Observations	11527	17147
r2	0.266	0.313
F	22.834	13.048

Cluster robust standard errors in parentheses.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

Table 16
VAT tax, export tax and pollution ranks at the industry level for the year 2007.

	VAT tax	export tax	Water	COD	A_N	Soot	SO2	Waste	Recycling	Energy
Artwork	6.7	0.0	13	21	22	11	15	19	10	22
Beverages	5.6	0.0	30	34	29	20	13	13	33	6
Chemical Fibres	6.3	0.0	32	32	31	26	26	18	31	27
Chemicals	7.7	0.1	31	26	35	30	28	26	21	34
Clothing	5.0	0.0	29	25	24	8	8	4	25	11
Coal	13.7	0.8	23	17	11	23	22	33	18	30
Communication Equipment	2.9	0.0	4	7	7	4	3	9	11	4
Culture, Sports	7.5	0.0	3	3	4	3	4	3	15	10
Electrical Equipment	3.8	0.0	9	12	15	15	21	27	4	17
Food Manufacturing	5.2	0.0	28	30	30	14	10	8	29	9
Food Processing	6.9	0.3	26	33	26	9	6	6	32	3
Furniture	6.7	0.0	10	18	21	12	11	16	14	12
General Machinery	2.6	0.0	6	4	5	13	17	24	5	19
Leather/Fur/Feather	11.2	0.0	27	29	34	6	5	5	20	5
Measuring Instruments	4.3	0.0	8	11	13	5	7	15	12	7
Medicine	5.4	0.0	24	28	25	17	14	7	27	8
Metal Products	8.1	0.2	15	14	12	25	25	29	6	29
Mining: Ferrous Metal Ores	13.0	10.0	22	10	6	29	31	35	1	26
Mining: Non-Ferrous Metal Ores	11.7	11.3	34	27	20	27	34	36	2	20
Mining: Nonmetal/ Other Ores	12.4	1.1	20	15	14	32	27	30	19	28
Natural Gas	15.9	0.7	2	2	3	7	12	11	13	18
Non-metallic Mineral Products	9.5	0.0	14	19	18	35	35	25	34	35
Paper	15.3	0.0	36	36	36	33	30	21	36	23
Petroleum, Nuclear Fuel	9.7	0.4	21	16	23	34	33	28	23	33
Plastic	8.7	0.0	19	23	32	24	24	17	22	24
Printing Media	5.2	0.0	35	35	33	21	18	12	30	13
Recycling/Disposal of Waste	13.9	6.0	1	1	1	1	1	1	17	1
Rubber	7.6	0.0	18	20	27	22	23	20	16	25
Smelting Ferrous Metals	11.9	1.6	16	9	16	31	29	32	7	36
Smelting Non-ferrous Metals	12.5	1.2	17	13	17	28	32	34	3	32
Special Machinery	3.0	0.0	7	6	9	16	19	23	9	21
Supply of Electricity	4.0	0.0	25	5	2	36	36	31	35	31
Textiles	5.8	0.0	33	31	28	18	20	10	28	16
Timber/Wood	14.7	0.3	11	22	19	19	16	14	24	14
Tobacco	8.7	0.0	12	24	8	2	2	2	26	2
Transport Equipment	1.4	0.0	5	8	10	10	9	22	8	15
Total	8.2	0.9	19	19	19	19	19	19	19	19

Columns 1 and 2 show the average VAT tax and export tax at the industry level. Averages are taken across HS8 digit codes for the year 2007. Columns 3–8 rank the industries according to their pollution intensities with respect to a particular pollutant. A higher rank indicates a higher pollution intensity. A_N represents the rank for the ammonium nitrogen intensity.

Table 17
Sensitivity analysis: dependent variable export tax.

	(1) Manufacturing	(2) Small	(3) No Reg_gap	(4) 2007
Water Reg_gap*Int	0.000	−0.004**		−0.003*
	(0.001)	(0.002)		(0.002)
Water Int			0.001*	
			(0.000)	
COD Int	−0.240	0.229	−1.744*	−0.495
	(0.294)	(0.359)	(1.025)	(0.406)
Ammonium N. Int	−10.947	−0.984	−3.784	15.878
	(8.826)	(14.432)	(11.749)	(12.925)
Soot Reg_gap*Int	−0.828	1.007		4.547
	(2.577)	(3.805)		(3.739)
Soot Int			4.890	
			(3.241)	
SO2 Reg_gap*Int	−2.478**	−2.874***		−1.421*
	(1.000)	(0.997)		(0.829)
SO2 Int			−3.396**	
			(1.395)	
Waste Int	0.004	0.011***	0.007***	0.007***
	(0.007)	(0.001)	(0.001)	(0.001)
Recycling Ratio	2.553	8.534**	1.095	2.749
	(2.149)	(3.401)	(1.749)	(1.988)
Energy Int	−0.002	−0.010	−0.002	−0.012**
	(0.003)	(0.006)	(0.007)	(0.005)
Mineral	0.910**	−0.101	0.758*	−0.252
	(0.441)	(0.357)	(0.418)	(0.347)
Wood	−0.999	−1.392*	−1.738**	−1.675**
	(1.059)	(0.792)	(0.663)	(0.718)
Stones	−1.322**	−1.062**	−1.200**	−1.391**
	(0.625)	(0.449)	(0.456)	(0.657)
Metal	0.489	1.713	1.647	1.480
	(0.550)	(1.358)	(1.322)	(1.306)
Primary	0.102	1.592***	1.032**	1.162**
	(0.410)	(0.478)	(0.422)	(0.546)
L.Exp share [5–15)	−0.012		−0.128	−0.233
	(0.064)		(0.130)	(0.159)
L.Exp share 15+	0.462*		0.328	0.015
	(0.244)		(0.272)	(0.187)
L.Employees	0.095	0.197	0.124	0.083
	(0.084)	(0.129)	(0.118)	(0.148)
L.Firm No	−0.036*	−0.010	−0.025	0.041
	(0.021)	(0.030)	(0.027)	(0.037)
L.Profits	0.008**	0.002	0.001	−0.008
	(0.004)	(0.003)	(0.004)	(0.006)
L.ΔOutput	0.441	3.948**	2.843**	0.412
	(1.607)	(1.677)	(1.399)	(2.053)
L.Labour Intensity	−0.001	−0.011	−0.015	−0.017
	(0.011)	(0.031)	(0.015)	(0.013)
L.Export Intensity	−33.425*	−55.282*	−53.555*	−33.589*
	(16.611)	(32.083)	(27.773)	(17.264)
L.SOE share	1.162	0.952	1.891	1.108
	(0.958)	(1.405)	(1.456)	(0.924)
L.Foreign share	−0.787	1.796	0.073	1.400*
	(0.982)	(1.234)	(0.892)	(0.811)
L.Income tax	−0.013	−0.006	−0.011	−0.001
	(0.010)	(0.011)	(0.010)	(0.011)
Tariff	−0.017	−0.017	−0.026	−0.015
	(0.022)	(0.023)	(0.020)	(0.011)
Observations	14990	10787	17022	5700

Cluster robust standard errors in parentheses.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

independent of pollution, i.e. $E_{qz} = 0$. Moreover, we simplify the notation used in Eq. (22). Based on the goods market equilibrium condition (14), domestic exports X equal foreign imports $M^* = G_p^* - E_p^*$. Moreover, foreign exports X^* can be considered negative imports $-M^*$ and we can write $X_p^* = -M_p^*$. These changes in notation yield the second-best export tax presented in Eq. (7) in the main text.

$$t^{*'} = -M^{*'}\left(M_p^*\right)^{-1} + \left(E_z' - s'\right)\frac{\partial z}{\partial q}X_q^{-1} \tag{23}$$

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