Trade and Welfare Effects of Export Tax: Theory and Evidence from China's Incomplete Export VAT Rebate

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This Version: February, 2021

First Version: March, 2019

Abstract

While China was reducing tariffs as part of the WTO accession process, it was also effectively restricting exports in some sectors by reducing the rebates of the value added tax (VAT) for exporters. We use a multi-sector multi-country Ricardian model to examine the extent to which these de facto export tax changes benefited China and nullified the benefits to the rest of the world of China's trade liberalization. We show that trade liberalization benefited China's trade partners both through an improvement in their terms of trade and through a reallocation of resources from protected imported sectors to exportable sectors. We find that the partial rebate policy on VAT exports provided a small effect overall on the welfare of China and trading partners, although some countries lost as much as 2/3 of their gain from China's liberalization based on tariffs alone. We also use our model to solve for China's optimal export taxes and calculate the impact of optimal export taxes on China and the rest of the world.

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1 Introduction

One of the features of the General Agreement on Tariffs and Trade (GATT) that has puzzled trade economists is the asymmetric treatment of import policies and export policies. GATT and subsequently WTO negotiations have focused on the setting of tariff bindings that limit a country's ability to increase its tariffs. However, the use of export taxes is not limited by the WTO agreement. This is puzzling because according to the Lerner Symmetry theorem, the effect of an export tax is equivalent to an import tax, in that both have the effect of making production of import-competing goods relatively more attractive. Therefore, the failure to limit export taxes leaves open the possibility that a country that agrees to reduce tariffs might adjust export taxes or some other form of export sector policies to offset the effects of the tariff reductions.[1]

The potential for export sector policies to undo the effects of trade liberalization has recently been raised in relation to China's use of incomplete rebates of its Value Added Tax (VAT) to exporters. China's VAT is charged on a destination basis, which in principle means that China's VAT applies only to goods that are sold in the Chinese market.[2] A destination based VAT is implemented through border adjustments: goods that are imported into China must pay the applicable VAT rate and goods that are exported from China should receive a full rebate of the VAT. It then follows that the failure to provide a full rebate on exports will be equivalent to an export tax, while a rebate exceeding the VAT rate is equivalent to an export subsidy. Consistently with its treatment of export subsidies and taxes, the WTO allows countries to rebate an amount up to, but not exceeding, the VAT rate on export sales. Thus, China's use of differing rates of VAT rebates across sectors to exporters following China's accession to the World Trade Organization (WTO) was equivalent to increasing the export taxes.

Did China's use of differential rates of VAT rebates have the effect of undermining the effects of its trade liberalization and thus nullifying the benefits to trading partners of its tariff reductions? In this paper, we address this question using a multi-country general equilibrium trade model with sectoral production linkages (as in Caliendo and Parro [2015]) that incorporates the role of China's tariff and VAT policy. We begin by calibrating the model to 2000, the year before China's WTO accession, and impose on the model that China's import tariffs change from the levels in 2000 to those in 2007 while holding VAT export rebates and other countries' trade policies unchanged. This counterfactual exercise calculates the impact of China's trade liberalization if China had not made any adjustments in its VAT rebates. We then consider the case in which

[1]The WTO does allow non-violation complaints under Article XXIII. A non-violation complaint can be made against a trading partner if the partner has taken actions that result in the nullification of an expected benefit to the complainant from trade liberalization. However, such complaints are extremely rare in practice.

[2]Unless otherwise specified, China in this paper means China mainland and excludes Chinese Hong Kong, Taiwan, and Macao.

China makes both the tariff reductions and the adjustments in her VAT export rebates.

We decompose the effect of China's trade policy changes into terms of trade effects, trade volume effects, and VAT reallocation effects. We find that China's WTO tariff reductions (with VAT rebate policy held constant) would have resulted in a welfare gain of 1.89%. Although the tariff reductions result in a deterioration in China's terms of trade, as would be expected in light of China's size in world markets, the loss on terms of trade is dominated by the gain in welfare due to trade volume effects. The trade volume effect is primarily due to trade liberalization in the agricultural sector, where the average tariff was reduced from 64.9% to 13.7%.

China's tariff reductions led to substantial welfare gains for Brazil (1.08%) and Korea (.65%), and modest gains for most of the rest of the world in the range .01-.10%. A few countries (e.g. Mexico, Turkey, India) experience losses, but these are all less than .05%. Interestingly, for Brazil and Korea the trade volume effect from China's trade liberalization accounted for a substantial portion of the gain. The trade volume effect for trading partners reflects the fact that China's liberalization results in the reallocation of resources from protected import-competing sectors to sectors that export to the Chinese market. China's trade liberalization thus induced a more efficient resource allocation in trading partners.

When the welfare effect of trade liberalization is recalculated with the VAT rebate effects included, the effects of China's export policy changes are quite modest in overall impact. The use of partial VAT rebates to discourage exporting reduces the terms of trade loss from entry into the WTO. However, the overall effect on China is to raise the welfare gain from trade liberalization by .01%. The effects on the rest of the world of the increase in export barriers are also modest, but for some economies they nullify as much as 2/3 of the gains from trade due to reductions in China's applied tariffs. We find that the negative effects of China's export taxes are greater on countries that are part of the East Asian production network, as the effects of the export tax changes are transmitted through the global supply chain.

We also use the model to calculate the optimal export tax rates, and to compare these rates with the actual rates. We find that as a result of WTO tariff reduction, the optimal export taxes in 2007 were substantially higher than in 2000. Imposing these export taxes would have raised China's welfare by .43% in 2000 and by .88% in 2007. The imposition of optimal export taxes would have worsened the terms of trade of all economies in 2007, and all but Korea and Taiwan in 2000. We find that the difference between the optimal export taxes and the actual export taxes is positively correlated with the degree of upstreamness of the sector, which is consistent with the view that China's export tax policy is aimed at reducing returns in upstream sectors and shifting resources toward more downstream industries.

Our work is related to several strands of literature. Chandra and Long [2013] document the use of variation in average VAT rebate rates over the period 1994-2007, and discuss the role of the government budget situation on the level of rebates. Using a panel of firm level data for the period 2000-2006, they calculate that a $1 increase in rebate rate increases exports by $4.70 during that period, thus documenting that incomplete rebates play the role of an export tax. Garred [2018] shows that the variation in export tax equivalents of VAT rebate rates across sectors increased dramatically after China's entry into the WTO in 2002. He finds that four digit industries with higher tariffs prior to China's WTO entry were subject to smaller increases in export taxes during the period 2002-2012 following the WTO entry, and suggests that this could be an attempt to protect sectors that had initially high tariffs and sectors that were more upstream in the value chain. Our analysis differs from Garred in that we focus on the extent to which China's VAT rebate policy restored China's trade distortions to their pre-WTO accession levels. In that sense our work is related to theoretical results of Grossman [1980] and Feldstein and Krugman [1990] on the types of border adjustment policies that will be neutral in their effect on resource allocation and trade. We also differ in that we consider a general equilibrium model, which allows us to consider the welfare effects of changes in China's VAT rebate policy on China and its trading partners.

Our work is also related to recent studies that have assessed the impacts of China's WTO accession either on China itself or other countries (Aichele and Heiland, 2018; Amiti et al., 2020; Autor et al., 2013; Brandt et al., 2017; Caliendo et al., 2019; Erten and Leight, 2019; Handley and Limão, 2017). These works have focused primarily on China's tariff cuts or productivity improvement while ignoring the export tax changes. In contrast we focus on the relation of tariff policy and export tax policy and aim to quantify the welfare effect of export tax on China and other major economies. Bagwell and Staiger [2011] find that the tariff reductions of acceding countries negotiated with members of the WTO are largest in the sectors where they have the greatest market power, which supports the argument from the terms of trade theory that trade agreements are designed to neutralize terms of trade externalities resulting from the use of market power. Our approach is eclectic about the factors determining tariff reductions, but focuses on the extent to which the tariff reductions are neutralized by export tax policy. Finally, our work is related to work on optimal trade policy. Costinot et al. [2015] and Beshkar and Lashkaripour [2017] characterize optimal trade policies in gravity type trade models similar to the one we examine.

Section 2 discusses China's trade liberalization and VAT rebate policies following the entry into the WTO, and how these policy changes affected the ranking of industries by the degree of protection they were receiving. Section 3 presents the general equilibrium model that is used to discuss the policy exercises, and Section 4 discusses the data and solution method. Section 5 presents the results of the counterfactual analysis. Section

6 solves for the value of China's export taxes with the optimal rates and evaluates the effect of imposing those taxes.

2 China's Trade and VAT Rebate Policies during WTO Accession

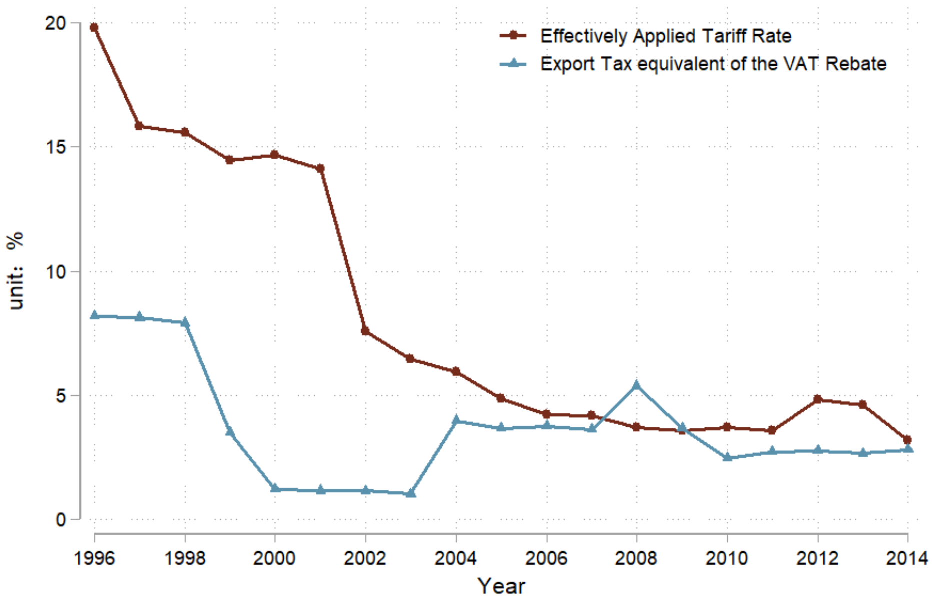
Before proceeding to the general equilibrium analysis, it is useful to provide a brief summary of the changes in trade and VAT policies that occurred during China's WTO accession. This will provide a first look at the extent to which China's adjustments in export rebate policy offset the effects of its tariff changes.

Figure 1 illustrates China's import-weighted average change in import tariffs over the period 1996-2014. Prior to China's WTO entry in 2001, China made unilateral tariff reductions that reduced the import weighted average applied tariff rate to around 14%. China's entry into the WTO resulted in a further reduction in China's average import tariff rate from 14.11% to 4.18% over the period 2001-2007. Import tariffs subsequently stabilized at these levels from 2007 to 2014. China was also required to eliminate some export taxes in its accession agreement.

Figure 1 also shows the export weighted average of the export tax equivalent of the VAT rebate rates. For the entire period, China had a VAT rate of 17% for almost all sectors except Agriculture, which had a rate of 13%. However, China did not rebate the full amount of the VAT on exports, so the difference between the VAT rate and the rebate is the export tax equivalent. Chandra and Long [2013] observe that the central and local governments could not afford full VAT rebates on exports in some years due to revenue shortfalls, as reflected in the reduction in rebates during the Asian financial crisis and the global financial crisis. The export tax equivalent also rose during the WTO accession process, with the export weighted average of the export tax equivalent of VAT rebates rising from 1.48% in 2000 to 3.76% in 2007. Garred [2018] notes that a significant difference between the rebates during this period and earlier periods is that the standard deviation of rates across sectors rose substantially compared with earlier periods. While the average export tax equivalents were relatively low, the individual export tax rates varied from .74% in Pharmaceuticals to 14.94% in Mining in 2007.[3] This increase in standard deviation suggests that differences in rebates across sectors could be related to differences in the degree of trade liberalization. [4]

[3] Please refer to Garred [2018] for a more detailed description of China's export rebate policies.

[4] Chandra and Long [2013] find that 87% of the products at the 6-digit harmonized system (HS6) product classification level have undergone at least one change in VAT rebate rate from 2002 to 2012 in China, either upwards or downwards.



Note: The effectively applied tariff rates at product level are from the WITS-TRAINS. We aggregate them into the data at national level by calculating the import-weighted averages. The export tax equivalent of the VAT rebate data are from Garred [2018] for 1996 to 2013, and are from China's Customs for 2014. We aggregate them into the data at national level by calculating the export-weighted averages.

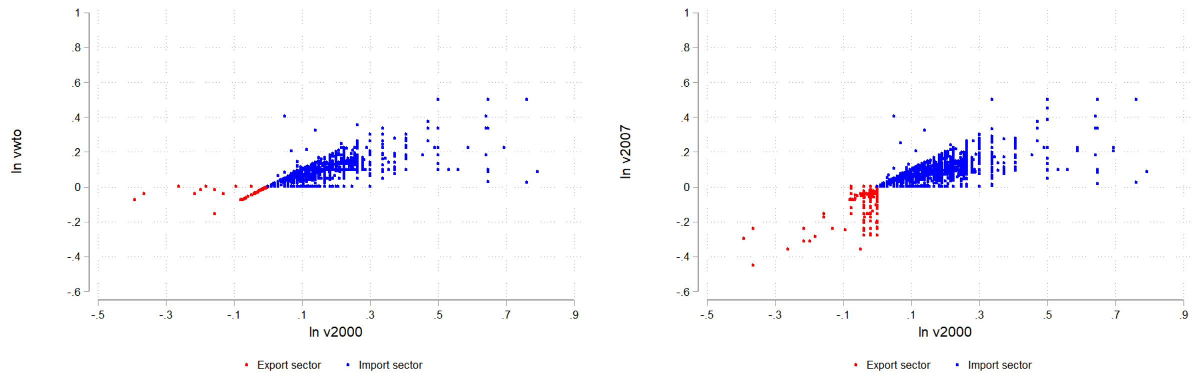
Figure 1: China's Tariff Rate and Export Tax Equivalents of VAT Rebate, 1996-2014

The impact of a change in trade policy on resource allocation will be related to how the sectoral "wedges" between the domestic price and world price, $v_i \equiv \frac{p_i}{p_i^*}$, change. For an imported sector i, $v_i = (1+\tau_i)$,where τ_i is the ad valorem tariff rate. For an exported sector i, $v_i = \frac{1}{\varphi_i}$, where φ_i is one plus the ad valorem export tax equivalent of the export policies. We can then construct a "chain of protection" as in Bond [1990] that ranks sectors in order of increasing v_i, and analyze how that ranking is affected by a change in trade policy. A change in trade policy from wedges v_i^0 to v_i^1 that satisfies $v_i^1 = \xi v_i^0$ for all i and $\xi > 0$ will keep all domestic relative prices constant. As an example, suppose that a country has tariffs of various amounts on its importable goods and no trade barriers on exports. A proportional reduction of amount $\xi = (1+\tau_i^1)/(1+\tau_i^0) < 1$ for all import tariffs accompanied by a common export tax of $\varphi_i^1 = 1/\xi$ would have no effect on the domestic wedges. If this change also keeps domestic resource allocation constant, then the trade policy change has no effect on trading partners. This is the many good generalization of the Lerner symmetry result.[5] In contrast, a change in

[5]The argument for the neutrality of a destination based VAT made by Grossman [1980] and Feldstein and Krugman [1990] uses the observation that a uniform VAT with a full rebate on exports will raise the prices of all traded goods by the same proportions, $v_i^1 = \xi v_i^0$, where ξ is one plus the VAT rate. In their models, this adjustment leaves domestic resource allocation unaffected and hence holds world prices constant. Costinot and Werning [2019] present sufficient conditions on technologies and asset holdings for this result to hold, which require independence of technology sets across countries and limits on cross border shopping and security holdings. Their

trade policy of the form $v_i^1 = (v_i^0)^\beta$ for $\beta < 1$ would represent a proportional reduction in all wedges, which is a policy that has been recommended as welfare improving for small open economies.

These results on the effect of trade liberalization on tariff wedges provide a means of illustrating the extent to which China's VAT rebate policy offset the tariff reductions resulting from WTO entry. The left panel in Figure 2 is a scatter plot of the log of the wedges for 4297 HS 6-digit products in 2000, denoted v_i^{2000}, against the log of the wedges that would have existed in 2007 on product i if China had kept its VAT rebates at the 2000 level, v_i^{WTO}. The tariff here is China's bound tariff, which is the maximum tariff level allowed by the WTO for China's imports from another member. For imported goods, the WTO accession agreement resulted in reductions in tariffs on most goods, which is shown by the fact that most of the points for which $v_i^{2000} > 0$ lie below the 45 degree line in Figure 1. For exported goods with $v_i^{2000} < 0$ in the left panel in Figure 1, the points above the 45 degree line reflect reductions in export taxes as part of China's accession agreement. The points on the 45 degree line for export sectors correspond to sectors that had less than full VAT rebates in 2000, and were not affected by the WTO agreement. A regression of $\ln v^{WTO}$ on $\ln v^{2000}$ for both importable and exportable wedges at the HS 6-digit level has a coefficient of .59 with a robust standard error of .01 (see Table 1). For importable sectors only, the coefficient is .47, indicating substantially more liberalization on importable sectors than on exportables. Thus, the WTO agreement resulted in significant trade liberalization on imported goods and a smaller degree of liberalization on the export side.



Note: ln v2000 is the log of the trade policy wedges in 2000 calculated using applied tariff rates, export duties and unrebated VAT export rates at HS6 product level in 2000; ln vwto is the log of import wedges at 2007 level calculated using the bound tariff rates and export wedges at 2000 level, ln v2007 includes both import and export wedges at 2007 levels.

Figure 2: Price Wedges before and after China's WTO Entry

sufficient conditions are satisfied by the general equilibrium model we consider below.

Table 1: The wedges before and after China's WTO entry

	$\ln v^{WTO}$ Exportable and importable sectors	$\ln v^{WTO}$ Exportable sectors	$\ln v^{WTO}$ Importable sectors	$\ln v^{2007}$ Exportable and Importable	$\ln v^{2007}$ Exportable sectors	$\ln v^{2007}$ Importable sectors
$\ln v^{2000}$	0.59***	0.58***	0.47***	0.67***	0.76***	0.42***
	(0.01)	(0.01)	(0.02)	(0.01)	(0.04)	(0.02)
Constant	-0.00***	-0.01***	0.22***	-0.03***	-0.04***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adjusted R^2	0.78	0.60	0.49	0.72	0.24	0.44
Observations	8255	4225	4030	8522	4225	4297

Note: The values in parentheses are the robust standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% significance level. $\ln v^{2000}$measure the price wedges between the domestic price and international prices caused by China's tariff and export tax in 2000. $\ln v^{WTO}$ measures the price wedges due to the tariff and export tax set by China's WTO accession agreement. $\ln v^{2007}$measure the price wedges caused by China's tariff and export tax in 2007. All regressions are run at the HS-6 digit level.

The right panel in Figure 2 is a scatter plot of $\ln v_i^{2000}$ against $\ln v_i^{2007}$, where v_i^{2007} is the wedge on product i based on the actual tariff and export tax/VAT rebate policies in 2007. The difference between v_i^{2007} and v_i^{WTO} is due to the changes in export taxes and sectoral VAT rebates that were outside the terms of the WTO accession agreement. The right panel shows that there were a substantial number of increases and decreases in export sector wedges between 2000 and 2007, resulting in a decrease in the mean export sector wedge and an increase in the standard deviation of the wedges.

For the unilateral actions by China to have completely offset the trade liberalization under the WTO, we would have to have $v_i^{2007} = \xi v_i^{2000}$. This would require that a regression of $\ln v_i^{2007}$ on $\ln v_i^{2000}$ have a coefficient of unity, which is strongly rejected by the data. The regression of $\ln v^{2007}$ on $\ln v^{2000}$ for all import and export wedges as a coefficient of .67, with a robust standard error of .01, which is significantly below 1 (see Table 1). However, it is also significantly higher than the coefficient from the regression without the change in VAT rebate policy, indicating that the rebate changes provided a partial offset to the liberalization of tariffs. Thus, the increase in wedges in the export sector due to unilateral actions by China did partially offset the reduction in import wedges resulting from tariff reductions from the WTO accession agreement.

In contrast to our exercise in Table 1, Garred [2018] tests the motivation for China's export tax policy by regressing the change in an HS-4 digit industry's export tax equivalent between 1999 and 2012 on its initial tariff in 2012 and other industry characteristics. He argues that the negative coefficient on the initial tariff level indicates that export tax changes were more favorable for industries that initially had a high level of protection, which would be consistent with a political economy model in which there are sector-specific resources that are mobile between exportable and import-competing activities in the sector. However, such a reduction is would not be neutral in its effect on the trade wedges. A complete offset of the effect of a tariff reduction on trade would require that the export taxes rise by the same amount as the import tariff reduction in order to keep the domestic relative price of the importable and exportable constant. More generally, our objective is not to explain why particular sectors received greater increases in export taxes, but to test whether they offset the effects of the tariff changes coming out of the WTO accession process.

Our results show that China's VAT export rebate policy partially offset the effect of trade liberalization on tariff wedges. In order to determine the impact of that offset on China and its trading partners, we now turn to a general equilibrium model to analyze the effects of the changes in wedges.

3 Model Setup

In this section, we present an N country J sector general equilibrium model that incorporates a production linkage as in Caliendo and Parro [2015] and a destination-based VAT system calculated using the credit invoice method.

3.1 Household

We assume L_n representative consumers in country n, whose preferences over the final goods from the J sectors take the Cobb-Douglas form,

$$U_n = \prod_j^J C_n^{j\,\alpha_n^j} \tag{1}$$

where $\alpha_n^j \geq 0$ are preference parameters satisfying $\sum_j^J \alpha_n^j = 1$ and C_n^j is the final consumption on sector j goods in country n. Consumers choose consumption of the final goods to maximize equation (1) subject to the budget constraint $\sum_j^J P_n^j C_n^j = I_n$, where P_n^j is the consumption price of sector j in country n and I_n is income. Household income consists of wage income w_n, the lump sum redistribution of revenues from the VAT, VAT_n, tariffs R_n, and the trade deficit D_n.

$$I_n = w_n L_n + R_n + VAT_n + D_n \tag{2}$$

Household expenditure on goods from sector j is $P_n^j C_n^j = \alpha_n^j I_n$, and the consumption price index in country n is

$$P_n = \prod_j^J (P_n^j / \alpha_n^j)^{\alpha_n^j} \tag{3}$$

3.2 Production and Value Added Tax

Labor is the only production factor, and moves freely across sectors within each country but cannot move across countries. Each sector produces a continuum of intermediate goods indexed by $\omega^j \in [0,1]$. The intermediate goods are produced using Cobb-Douglas technology by combining labor and a composite of intermediate goods from different sectors:

$$q_n^j(\omega^j) = z_n^j(\omega^j)[l_n^j(\omega^j)]^{\gamma_n^j} \prod_k^J [m_n^{k,j}(\omega^j)]^{\gamma_n^{k,j}} \tag{4}$$

where $z_n^j(\omega^j)$ is the production efficiency and varies across varieties, sectors and countries, $l_n^j(\omega^j)$ is the labor input and $m_n^{k,j}(\omega^j)$ is the composite intermediate goods from sector k used to produce ω^j in country n. The parameter γ_n^j is the share of labor input in total production cost, while $\gamma_n^{k,j} \geq 0$ is the share of intermediate goods from sector k used in production of sector j goods in country n with $\sum_k^J \gamma_n^{k,j} = 1 - \gamma_n^j$. Following Eaton and Kortum [2002], we assume that the production efficiency is a realization of Fréchet distribution $F_n^j(z_n^j) = exp(-\lambda_n^j z_n^{j\,-\theta^j})$, where the parameter λ_n^j varies by country and sector and governs the average productivity, and θ^j governs productivity variation with a larger value indicating lower variation.

All intermediate goods markets are assumed to be perfectly competitive. We consider a destination based VAT system that collects tax using the credit invoice method that prevails in virtually all countries applying a VAT (including China). Under the credit invoice method, a firm is taxed at the prevailing VAT rate on all of its sales, with a deduction given for any VAT paid on purchased inputs. The VAT creates a wedge between the consumer price of a variety (paid by households for final consumption or firms purchasing intermediate inputs), which we denote by $p_n^j(\omega^j)$, and the producer price, denoted $\tilde{p}_n^j(\omega^j)$. The firm's after-tax profit on sales of $q_n^j(\omega^j)$ in the domestic market under the credit invoice method will be

$$(1+\mu_n^j)\tilde{p}_n^j(\omega^j)q_n^j(\omega^j) - w_n l_n^j(\omega^j) - \sum_k^J (1+\mu_n^k)\tilde{P}_n^k m_n^{k,j}(\omega^j) - [\mu_n^j \tilde{p}_n^j(\omega^j)q_n^j(\omega^j) - \sum_k^J \mu_n^k \tilde{P}_n^k m_n^{k,j}(\omega^j)]$$
$$= \tilde{p}_n^j(\omega^j)q_n^j(\omega^j) - w_n l_n^j(\omega^j) - \sum_k^J \tilde{P}_n^k m_n^{k,j}(\omega^j).$$

where μ_n^j is the VAT rate levied on sector j goods in country n and $\tilde{P}_n^k$ the producer price of the composite intermediate input from sector k. Observe that with the credit invoice method, the existence of differential VAT rates across sectors does not distort the firm's input choice because the inputs are taxed at the rate in the sector where they are used, rather than the sector where they are produced.

Under a destination based system, the VAT is applied based on the location where goods are sold. Therefore, inputs from sector k that are imported into country are taxed at the sectoral VAT rate μ_n^k, and export sales of country of sector j receive a rebate at rate ρ_n^j. The tax rebate is incomplete if $\rho_n^j < \mu_n^j$ and is full if $\rho_n^j = \mu_n^j$. Hence, the F.O.B. price of sector j goods produced in country n and sold in country i $(i \neq n)$ is $(1+\mu_n^j - \rho_n^j)\tilde{p}_n^j(\omega^j)$. To simplify the notations, we define $\varphi_{in}^j = (1+\mu_{in}^j - \rho_{in}^j)$, where $\mu_{in}^j = \begin{cases} \mu_n^j & (i \neq n) \\ 0 & (i = n) \end{cases}$, $\rho_{in}^j = \begin{cases} \rho_n^j & (i \neq n) \\ 0 & (i = n) \end{cases}$. Hence, the F.O.B. price of variety ω^j that is produced in country n and sold in country i can be written as $\tilde{p}_{in}^j(\omega^j) = \varphi_{in}^j \tilde{p}_n^j(\omega^j)$. With a partial rebate of VAT for exports (i.e., $\rho_n^j < \mu_n^j$), the FOB price of exports will exceed the price at which the good is sold domestically, which is essentially a tax on exports. Henceforth, we use export tax and non-fully VAT export rebate interchangeably.

Given that the production is at constant returns to scales and markets are perfectly competitive, firms price at unit cost, $\tilde{p}_n^j(\omega^j) = \frac{c_n^j(\omega^j)}{z_n^j(\omega^j)}$, where $c_n^j(\omega^j)$ denotes the cost of an input bundle which minimizes the firm's production cost

$$c_n^j(\omega^j) = \Upsilon_n^j {w_n}^{\gamma_n^j} \prod_k {\tilde{P}_n^k}^{\gamma_n^{k,j}} \tag{5}$$

where $\Upsilon_n^j = \prod_k (\gamma_n^{k,j})^{-\gamma_n^{k,j}} (\gamma_n^j)^{-\gamma_n^j}$ is a constant.

There is a producer of final goods (composite intermediate goods) in each sector that purchases intermediate goods ω^j from the lowest cost suppliers across countries, and then costlessly assembles them together using the CES technology: $\bar{q}_n^j = \left[r_n^j(\omega^j)^{1-1/\sigma^j} d\omega^j \right]^{\sigma^j/(\sigma^j-1)}$, where $\bar{q}_n^j$ is output of the composite intermediate good, σ^j is the elasticity of substitution across varieties within sector j and $r_n^j(\omega^j)$ is the quantity of variety ω^j from the lowest cost supplies.

The purchases of intermediate goods will be subject to trade costs in the form of transport costs and tariffs, in addition to the value added tax. We assume iceberg transportation costs, i.e., delivering a unit of intermediate goods ω^j in sector j from country i to country n requires producing $d_{ni}^j \geq 1$ units in country i, with $d_{ii}^j = 1$, and an ad valorem tariff $\tau_{ni}^j \geq 0$ levied by country n on sector j goods from country i ($\tau_{ii}^j = 0$). Combining both trade costs, we define total bilateral trade costs as $\kappa_{ni}^j = (1+\tau_{ni}^j)d_{ni}^j$. Hence, the VAT-inclusive C.I.F price of ω^j sourced from country i is $\frac{\Psi^j_{ni}\kappa^j_{ni}(1+\mu^j_n)}{z^j_i}$ in country n, with $\Psi^j_{ni}=\varphi^j_{ni}c^j_i$ representing the cost of production bundle on the world market (that is, the cost of production bundle plus unrebated source country VAT). The consumer price of intermediate good ω^j in country n is $p^j_n(\omega^j)=min_i\{\frac{\Psi^j_{ni}\kappa^j_{ni}(1+\mu^j_n)}{z^j_i}\}$.

The composite intermediate goods are nontradable, used domestically as materials for downstream production as well as final consumption. Following an argument similar to that in Eaton and Kortum [2002], country n's expenditure share on goods of sector j from country i, denoted π^j_{ni}, when z is distributed according to a Fréchet distribution, is given by:

$$\pi^j_{ni}=\frac{\lambda^j_i(\Psi^j_{ni}\kappa^j_{ni})^{-\theta^j}}{\sum_h^J\lambda^j_h(\Psi^j_{nh}\kappa^j_{nh})^{-\theta^j}} \tag{6}$$

and the consumer price of the intermediate composite goods of sector j in country n is:

$$P^j_n=(1+\mu^j_n)\widetilde{P}^j_n=A^j_n(1+\mu^j_n)[\sum_i^N\lambda^j_i(\Psi^j_{ni}\kappa^j_{ni})^{-\theta^j}]^{-1/\theta^j} \tag{7}$$

where $A^j=\Gamma\left(1+(1-\sigma^j)/\theta^j\right)^{1/(1-\sigma^j)}$ is a constant and $\Gamma(.)$ is the Gamma function.[6] Observe that since the VAT is applied uniformly to purchase of imports and domestic goods, π^j_{ni} does not depend directly on μ^j_n. On the export side, country n's VAT policy affects π^j_{in} directly only in cases where $\mu^j_n-\rho^j_n\neq 0$.

Letting X^j_n denote the total expenditure on sector j in country n at consumer prices, the demand for output of sector j at producer prices can be expressed as the sum of the expenditure on composite intermediate goods as intermediate input by firms and as final consumption by household:

$$\frac{X^j_n}{1+\mu^j_n}=\sum_k^J\gamma^{j,k}_n\sum_i^N\frac{X^k_i\pi^k_{in}}{(1+\tau^k_{in})(1+\mu^j_i)\varphi^k_{in}}+\frac{\alpha^j_nI_n}{1+\mu^j_n} \tag{8}$$

The value received by country n from exports of sector j goods to country i is $E^j_{ni}=\frac{X^j_i\pi^j_{in}}{(1+\tau^j_{in})(1+\mu^j_i)}$, which deflates consumer expenditure in country i by tariffs and VAT applied by country i (but includes the unrebated portion of VAT). Similarly, the amount paid by country n to country i for imports in sector j is $M^j_{ni}=\frac{X^j_n\pi^j_{ni}}{(1+\tau^j_{ni})(1+\mu^j_n)}$, which deflates country n consumer expenditure by tariffs and VAT applied by country n. Aggregating across sectors, we obtain the trade deficit to be

$$D_n=\sum_i^N\sum_j^J\frac{X^j_n\pi^j_{ni}}{(1+\tau^j_{ni})(1+\mu^j_n)}-\sum_i^N\sum_j^J\frac{X^j_i\pi^j_{in}}{(1+\tau^j_{in})(1+\mu^j_i)\varphi^k_{in}}. \tag{9}$$

[6] For some nontradable intermediate sectors, equation (7) still holds but with $\kappa^j_{ni}=\infty$. Hence, the price index is given by $P^j_n=A^j(1+\mu^j_n)(\lambda^j_n)^{-1/\theta^j}c^j_n$.

We follow Caliendo and Parro [2015] and many of other trade literature, assuming that the national trade deficits are exogenous, while the sectoral trade deficits are endogenously determined.

Total VAT revenue can be calculated as the sum of VAT on consumption, $\sum_j^J \frac{\mu_n^j P_n^j C_n^j}{1+\mu_n^j}$, and the VAT levied on export goods, $\sum_i^N \sum_j^J (\mu_{in}^j - \rho_{in}^j) \frac{E_{ni}^j}{\varphi_{in}^j}$, which yields a total revenue of

$$VAT_n = I_n \sum_j^J \frac{\mu_n^j \alpha_n^j}{1+\mu_n^j} + \sum_i^N \sum_j^J (\mu_{in}^j - \rho_{in}^j) \frac{E_{ni}^j}{\varphi_{in}^j} \tag{10}$$

Putting equation (10) into equation (2), the household income is rewritten as:

$$I_n = \frac{1}{F_n}(w_n L_n + R_n + D_n + T_n) \tag{11}$$

where $R_n = \sum_i^N \sum_j^J \tau_{ni}^j M_{ni}^j$ is tariff revenue, $T_n = \sum_i^N \sum_j^J (\mu_{in}^j - \rho_{in}^j) \frac{E_{ni}^j}{\varphi_{in}^j}$ is the export tax revenue equivalent arising from the VAT, and $F_n = 1 - \sum_j^J \frac{\mu_n^j \alpha_n^j}{1+\mu_n^j}$. Note that F_n describes the fraction of income in country n actually spent on final goods after removing the spending on VAT. Therefore, $I_n F_n$ measures the VAT-exclusive household income that are used to purchase consumption goods.

For this model structure, we define an equilibrium for the world economy as follows:

Definition 1. *Given L_n, D_n, λ_n^j and d_{ni}^j, an equilibrium under tariff and VAT rebate structure $\left\{\tau_{ni}^j, \mu_n^j, \rho_n^j\right\}$ is a wage vector and prices of composite intermediate goods that satisfy equilibrium conditions (5), (6)-(9) for all j, n.*

3.3 VAT Distortions

It is straightforward to show that if the VAT rate is uniform across sectors and fully rebated to exporters, $\mu_n^j = \rho_n^j = \mu_n$ for all j, changes in μ_n will have no effect on resource allocation in this model. An increase in μ_n will increase all consumer prices proportionally, leaving $\frac{X_n^j}{1+\mu_n}$ constant for all j. The initial producer prices in country n will continue to be equilibrium prices, so that international trade flows would be unaffected by a change in the VAT. However, the VAT will be distorted if there are incomplete rebates to exporters and sectoral differences in VAT rates. Before turning to the calibration exercise, it is useful to formalize the first order effect of changes in parameters on welfare in the presence of VAT distortions.

The welfare of the representative consumer in country n is represented by her real income,

$$W_n = \frac{I_n}{P_n} \tag{12}$$

where I_n is given by equation (2), and P_n by equation (3). Up to a first-order approximation, the welfare change can be decomposed as:[7]

$$\begin{aligned} dlnW_n \approx & \underbrace{\sum_i^N \sum_j^J \frac{1}{I_n F_n}(E_{ni}^j dln\Psi_{in}^j - M_{ni}^j dln\Psi_{ni}^j)}_{terms\,of\,trade} + \underbrace{\sum_i^N \sum_j^J \frac{1}{I_n F_n}\tau_{ni}^j M_{ni}^j (dlnM_{ni}^j - dln\Psi_{ni}^j)}_{volume\,of\,import\,(tariff)} \\ & + \underbrace{\sum_i^N \sum_j^J \frac{1}{I_n F_n}(\frac{\mu_{in}^j - \rho_{in}^j}{\varphi_{in}^j})E_{ni}^j (dlnE_{ni}^j - dln\Psi_{in}^j)}_{volume\,of\,export\,(VAT)} - \underbrace{\frac{1}{I_n}\sum_j^J (1 + \mu_n^j - \frac{1}{F_n})[\frac{\alpha_n^j}{(1+\mu_n^j)} I_n] dlnP_n^j}_{adjustment\,for\,sectoral\,VAT\,differences}. \end{aligned} \tag{13}$$

The first term is the familiar terms of trade effect, which is a weighted-sum of changes in bilateral export prices and import prices at sector level with the weights being bilateral exports and imports, respectively. Changes in VAT rebate rates have two effects on the export prices Ψ_{in}^j: first, it directly enters the export prices, and second, it indirectly affects the unit production cost c_n^j through the general equilibrium condition. Meanwhile, changes in the VAT rebate rates also indirectly affect import prices Ψ_{ni}^j through the global production network. The second term is the import trade volume effect, which is the tariff weighted change in imports. Increases in import volumes have a favorable effect on welfare by mitigating the distortion from trade barriers when the domestic price is above the world price. The third term is the corresponding trade barrier weighted change in trade volumes for exports, where the trade barrier is the export tax equivalent of the incomplete VAT rebate. Increases in exports raise world welfare when the domestic price is below the world price due to an export tax. Observe that the first three terms are weighted by the inverse of $I_n F_n$, which is the VAT-excluded income used to purchase household consumption.

The fourth term exists because of the distortion caused by the heterogeneous VAT rates across industries within each country, and quantifies the re-allocation effect of final consumption due to the changes in import prices. Since $\frac{1}{F_n}$ reflects the average VAT rate across all sectors, a positive $(1 + \mu_n^j - \frac{1}{F_n})$ indicates a larger VAT rate in industry j than the national average in country n. For industries with positive $(1 + \mu_n^j - \frac{1}{F_n})$, increases in their prices will induce welfare because it exacerbates the distortion due to differential VAT rates by the

[7] Appendix A presents a detailed derivation of equation (13).

shifting consumption toward goods with lower VAT rates. In the case of uniform VAT and full export rebates, $\mu_n^j = \rho_n^j = \mu_n$, we have $1 + \mu_n^j - \frac{1}{F_n} = 0$ and the third and fourth terms disappear.

4 Data and Model Solving

Conditions (5) and (6)-(9) represent a system of equations in the unknowns that can be solved given a numeraire. To conduct counterfactual analysis, we use the Exact-Hat algebra approach following Dekle et al. [2007] to reduce the burdens of parameters calculation. Specifically, for each variable x in the original equilibrium, denote x' as its counterfactual value and $\hat{x} = \frac{x'}{x}$ as the proportional change. We now define the equilibrium of the model under the new policy $\left\{\tau_{ni}^{j\prime}, \mu_n^{j\prime}, \rho_n^{j\prime}\right\}$ relative to the original policy $\left\{\tau_{ni}^{j}, \mu_n^{j}, \rho_n^{j}\right\}$, by rewriting the equilibrium conditions in relative changes as a response to a change in model primitives.

Definition 2. *Let* $(\mathbf{w}, \mathbf{P})$ *be an equilibrium under policy* $\left\{\tau_{ni}^{j}, \mu_n^{j}, \rho_n^{j}\right\}$ *and let* $(\mathbf{w}', \mathbf{P}')$ *be an equilibrium under policy* $\left\{\tau_{ni}^{j\prime}, \mu_n^{j\prime}, \rho_n^{j\prime}\right\}$. *Using* (5) and (6)-(9)*, the equilibrium conditions in relative changes satisfy:*

Relative change in input cost:

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_j^J \left(\frac{\hat{P}_n^j}{\hat{\upsilon}_n^j} \right)^{\gamma_n^{k,j}} \tag{14}$$

Relative change in price index:

$$\hat{P}_n^j = \hat{\upsilon}_n^j \left\{ \sum_i^N \pi_{ni}^j (\hat{\Psi}_{ni}^j \hat{\kappa}_{ni}^j)^{-\theta^j} \right\}^{-1/\theta^j} \tag{15}$$

Relative change in bilateral trade shares:

$$\hat{\pi}_{ni}^j = \left(\frac{\hat{\upsilon}_n^j \hat{\Psi}_{ni}^j \hat{\kappa}_{ni}^j}{\hat{P}_n^j} \right)^{-\theta^j} \tag{16}$$

where $\hat{\upsilon}_n^j = \frac{1+\mu_n^{j\prime}}{1+\mu_n^j}$*; the new equilibrium should also satisfy the equations (8) and (9) with fixed* D_n*.*

The above equations are sufficient to solve the new equilibrium given the exogenous changes in tariffs and/or VAT rebate rates. Importantly, the productivity parameter λ_n^j, iceberg transportation costs d_{ni}^j, and total labor supply L_n are absent from these expressions. This significantly simplifies the estimation of the model.

4.1 Data

For our empirical analyses, we calibrate the model for three years 2000, 2007, and 2014. Data on bilateral expenditure (X_{ni}^{j}), value added ratio (γ_n^j), the share of each input in gross production ($\gamma_n^{k,j}$), bilateral tariff rate (τ_{in}^{k}) , the VAT rate (μ_n^j), export rebate rate (ρ_n^j), and dispersion of productivity (θ^j), all at sector level, are required for each country and each sector. Most of these data are sourced from the World Input-Output Database (WIOD, Timmer et al. [2015]). In more detail, the WIOD provides the international input-output tables for major economies from 2000 to 2014, providing the output, value added, intermediate inputs from each sector, as well as the bilateral trade flows across countries and industries. It allows us to calibrate our model to 30 economies plus the rest of the world (ROW), and 36 sectors including 19 tradable sectors and 17 nontradable sectors. The 30 economies, presented in Table 3, account for approximately 85.5% of world GDP in our time period.[8] The sectors are further presented in Table 10 in Appendix B.

Another important element is the VAT rates and export rebate rates at country and industry level. For China, these data are sourced from Garred [2018], which provides the product-level tax data at the HS10-digit level from 1993 to 2013. The product-level export rebate data for 2014 are from the China Customs. We aggregate the product-level data to the 36 sectors in the Input-Output tables by calculating the export-weighted averages. The corresponding product-level exports are from China's Customs. For other countries, however, we fail to access this kind of product-level tax data like China, and thus use the VAT rates at industry level. We collect the information from many different sources. The VAT rates for European Union (EU) countries mainly come from the "Taxes in Europe" database.[9] They provide the standard VAT rates for EU countries. For most of the other economies, we refer to the KPMG's Corporate and Indirect Tax Survey for the standard VAT rates.[10] For the VAT rates of the ROW, we take the average of the standard VAT rates in Africa and Oceania countries reported by the KPMG.[11] This is because these countries are major members of the ROW. Due to the lack of export rebate rates for each country, we assume that the VAT in all economies but China is fully rebated. This assumption, however, will have a minor influence on the counterfactual results since seldom countries have unrebated VAT on exports like China and moreover we exclusively focus on the welfare effect of China's (instead of other countries') VAT rebate policy.

The ad valorem tariff is another essential piece of data. They are sourced from the WITS-TRAINS, which

[8]The figure is calculated by using the world input-output table in 2014. The other EU countries include Belgium, Cyprus, Czech Republic, Estonia, Lithuania, Luxembourg, Latvia, Malta, Poland, Slovakia, and Slovenia.

[9]Please see http://ec.europa.eu/taxation_customs/tedb/taxSearch.html

[10]Please refer to http://world.salestaxhandbook.com. We also carefully check the data with that from the IMF, the OECD, and from Bird and Gendron [2007] when the VAT rates are available.

[11]Please refer to https://home.kpmg/xx/en/home/services/tax/tax-tools-and-resources/tax-rates-online/indirect-tax-rates-table.html

provides the bilateral effective applied tariff rate at 4-digit ISIC Rev.3 industries. We then aggregate these tariff data into the data of the 19 tradable sectors, by calculating the averages weighted by the bilateral import value.[12]

The adjustments required to adjust this data to match the variables in the model are detailed in Appendix B. The values for the sectoral trade elasticities, θ^j, are borrowed from Caliendo and Parro [2015]. The values of these elasticities and the sectoral definitions are shown in Table 10 in Appendix B. We also conduct exercises with alternative sets of estimates for θ to analyze the sensitivity of our results with respect to this choice in section 7.

4.2 Calibration Procedure and Solution Algorithm

We follow the approach of Caliendo and Parro [2015] to solve the model given parameter values. We consider an imaginary change in tariff from τ to the new tariff τ' or change in VAT rebate from ρ to the new policy ρ'. To solve the model, we first guess a vector of changes in wages $\hat{\mathbf{w}} = (\hat{w}_1, ..., \hat{w}_n)$, e.g. $\hat{\mathbf{w}}$=1, based on which together with the parameters calibrated to 2000, the equilibrium conditions allow us to solve for the prices in each sector and each country by using equations (14) and (15). Plugging this solution into equation (16), we obtain the new bilateral expenditure $\pi_{ni}^{j\prime}$. Using the new shares, together with the solved price, the guess of wages, as well as the VAT policy shocks, we calculate the total expenditure at both sector and country level $X_n^{j\prime}$ according to equation (8). Finally, substituting the corresponding variables into equation (9), we verify if the trade balance holds. If not, we adjust our guess of $\hat{\mathbf{w}}$ until equilibrium condition (9) is finally obtained.

Recall that our calibration strategy determines that our model exactly matches the base year, which suggests that if countries have an aggregate trade deficit, the model is also going to account for the trade deficit in the base year, which is exogenous to our framework. Therefore, before conducting counterfactuals, we eliminate all national trade deficits by first calibrating the model with trade deficits and then solving the model imposing zero national deficit, namely, $D_n' = 0$. We then use the implied zero-deficit world economy as our baseline equilibrium.

5 How Much Do Export Taxes Counteract Import Tariffs?

To empirically investigate and quantify how much VAT export rebates counteract import tariff reductions in the accession agreement, we perform 2 counterfactual exercises. First, we calculate the welfare effect on

[12] Following Caliendo and Parro [2015] and Blanchard et al. [2017], when the tariff data for the target years are not available, we input this value with the closest value available, searching for the four previous years

China and the rest of the world due to WTO tariff reductions from 2000 to 2007, assuming that the VAT export rebate policy remained at its 2000 level. The first two columns of Table 2 report China's import tariffs for 2000 and 2007, aggregated to the 19 traded goods sectors in our data as described in Section 4.1. The accession process resulted in a reduction in the tariff in all sectors, with the biggest reductions taking place in the Agriculture, Automobile, and Food sectors.

Second, we calculate the equilibrium with changes in the VAT export rebate levels from 2000 to 2007 as well as the tariff changes. The export tax equivalents of the VAT rebates in 2000 and 2007 for the 19 tradable goods sectors are shown in the last two columns of Table 2. There were substantial variations across sectors in the change in export tax equivalents, with the largest increases taking place in Mining, Basic Metals, and Paper. The comparison between these two exercises provides an assessment of the extent to which the change in VAT export rebates affected the payoff that the economies would have obtained with China's accession agreement.

Table 2: China's Tariff Rates and Export Tax Rates by Sector (unit:%)

Sectors	Tariff 2000	Tariff 2007	Export tax 2000	Export tax 2007
Agriculture	64.9	13.7	5.28	5.84
Mining	4.1	0.2	2.00	14.94
Food	25.2	10.0	7.02	6.22
Textile	22.0	8.9	0.88	4.49
Wood	9.4	1.6	4.01	6.52
Paper	11.5	2.8	4.00	10.55
Printing	11.1	4.5	3.87	4.00
Chemicals	13.2	6.3	1.71	5.61
Pharmaceuticals	10.1	4.5	0.05	0.74
Plastic	16.2	8.1	1.65	5.33
Minerals	15.0	11.5	2.82	6.80
Basic metals	9.3	4.5	2.32	8.94
Metal products	11.3	8.8	2.28	4.02
Electronics	10.5	0.9	0.00	0.45
Electrical	13.7	4.4	0.03	3.40
Machinery	13.8	6.4	0.48	2.92
Autos	35.3	15.8	0.00	1.21
Other Transport	7.3	3.6	0.01	1.64
Other Manufacture	10.7	6.6	2.85	7.05
Simple Average	16.6	6.5	2.17	5.30

Notes: The raw tariff data are sourced from the WITS-TRAINS, and the raw export tax data are from the Garred [2018]. We aggregate them into the data at sector level by using the method described in Section 4.

5.1 Welfare Effects of Import Tariff Cuts

We first quantify the economic effects of the import tariff cuts due to China's WTO entry. Specifically, we calibrate the model to 2000, the year before China's WTO accession, and impose on the model that China's import tariffs change from the levels in 2000 to those in 2007 while fixing her VAT export rebates and other economies' trade policies unchanged.[13] Table 3 presents the welfare effects for individual economies in this counterfactual exercise and Table 4 describes the bilateral trade and aggregated trade growth for major economies.

5.1.1 The Effect on China

China obtains a 1.89% of welfare gains due to the import tariff cuts upon the WTO accession. The number aligns well with the existing literature (Ghosh and Rao, 2010; Aichele and Heiland, 2018). Further decomposition shows that the major source of China's welfare gain comes from the volume of import channel. This is intuitive as import tariffs cuts directly lower import prices, and therefore, expand the import volume. It also indirectly affects the import prices and import volume through the global production network. This is further supported by Table 4, China's total imports increase by 75.43% due to the tariff cuts.[14] The terms of trade effect is negative as the increase in Chinese import demand raises wages and product prices in foreign economies. The import tariff cuts have alleviated the distortions from the unequal VAT rates across sectors, although the overall magnitude is small due to the relatively small differences in VAT rates across sectors.

Table 5 presents sectoral contributions to the welfare gains of import tariff cuts.[15] To save space, we focus on the results of tradable sectors, as these are where tariff reductions were implemented. The first finding is that sectoral contributions show considerable variations across sectors. The top two sectors that contribute to the deterioration of China's terms of trade are Textiles and Electronics, which combined explains nearly half of the reduction. As shown in column 5, these sectors have a large share of exports, which explains their importance in the calculation of the terms of trade. Second, Agriculture dominates the volume of imports effect. This is mainly due to its significant reduction in the tariff level, i.e., from 71.15% in 2000 to 13.15% in

[13] Here, we follow existing literature (Aichele and Heiland, 2018), and take China's tariff changes from 2000 to 2007 to represent the tariff cuts due to the WTO accession, since China's tariff rate was quite stable since 2007 as suggested by Figure 1. Besides tariffs, China's pre-WTO import policy regime also includes non-tariff barriers (NTBs), some of which are also required to be removed according to China's WTO accession agreement.

[14] Note that Chinese actual imports saw a more than threefold increase from 2000 to 2007, much larger than the tariff effect in Table 4. This is because there are other factors that would influence trade flows besides import tariffs, such as changes in non-tariff barriers (NTB) and productivity. Levchenko & Zhang (2016) demonstrated that the evolution of relative sectoral productivities had an appreciable impact on global trade patterns.

[15] Based on equation (13), the sectoral terms of trade effect is $dlntot_n^j = \frac{1}{I_n F_n}\sum_{i=1}^{N}(E_{ni}^j dln\Psi_{in}^j - M_{ni}^j dln\Psi_{ni}^j)$, and its contribution to aggregate terms of trade effect is $dlntot_n^j / \sum_{k=1}^{J} dlntot_n^k$. The sectoral contributions to volume of import, volume of export, and distortion can be arrived by analogy.

Table 3: Welfare Effect from China's Tariff Cuts (unit:%)

Economies	Welfare				
	Total (1)	Term of Trade (2)	Volume of Import (3)	Volume of Export (4)	Distortion (5)
China	1.89	-1.25	10.30	0.17	0.06
Germany	0.04	0.01	0.00	0.00	0.00
Japan	0.05	0.02	0.01	0.00	0.00
Korea	0.64	0.04	0.51	0.00	0.00
Taiwan, China	0.16	0.08	0.03	0.00	0.00
U.S.	0.10	0.07	0.01	0.00	0.00
Australia	0.04	0.00	0.02	0.00	0.00
Austria	0.02	0.01	0.00	0.00	0.00
Brazil	1.08	0.59	0.43	0.00	0.00
Canada	0.11	0.06	0.03	0.00	0.00
Switzerland	0.00	-0.01	0.00	0.00	0.00
Denmark	0.03	0.02	0.00	0.00	0.00
Spain	0.01	0.00	0.00	0.00	0.00
Finland	0.01	0.00	0.00	0.00	0.00
France	0.07	0.05	0.01	0.00	0.00
The UK	0.01	0.00	0.00	0.00	0.00
Greece	0.03	0.01	0.00	0.00	0.00
Hungary	0.00	-0.01	0.00	0.00	0.00
Indonesia	0.09	0.02	0.03	0.00	0.00
India	-0.02	-0.02	-0.01	0.00	0.00
Ireland	-0.01	-0.02	0.00	0.00	0.00
Italy	-0.01	-0.02	0.00	0.00	0.00
Mexico	-0.05	-0.04	-0.02	0.00	0.00
Netherlands	0.03	0.00	0.00	0.00	0.00
Norway	0.06	0.03	0.02	0.00	0.00
Portugal	-0.03	-0.03	0.00	0.00	0.00
Russia	0.15	0.06	0.04	0.00	0.00
Sweden	0.02	0.01	0.00	0.00	0.00
Turkey	-0.02	-0.03	0.00	0.00	0.00
Other EU	0.02	-0.01	0.01	0.00	0.00
ROW	0.21	0.12	0.01	0.00	0.00

Note: Column (1) shows the percentage changes in national welfare resulting from China's tariff cuts. Columns (2)-(5) show the elements of the welfare decomposition in equation (13) calculated using a linear assumption, so elements will not add to the total.

2007. Third, Agriculture, Food, and Textile are the top three contributors to the improvement in the volume of export effect, which explains about 47.28%. This accords with the rapid growth of exports in these sectors as shown in the second last column in Table 5.

Table 4: Bilateral Trade Effect from China's Tariff Cuts (Between Major Economies) (%)

	China	U.S.	Germany	Japan	Korea	Taiwan	Brazil
China's imports	-	429.3	9.52	15.22	17.87	18.02	3697.00
US's imports	75.89	-	2.98	4.71	3.42	1.68	-24.67
Germany's imports	74.56	-5.37	-	0.54	-1.06	-2.80	-34.34
Japan's imports	72.65	-7.5	-2.17	-	-3.10	-4.03	-36.57
Korea's imports	75.79	-6.25	-0.88	0.63	-	-2.10	-40.08
Taiwan's imports	72.00	-4.47	-0.14	1.16	0.69	-	-29.17
Brazil's imports	147.90	23.51	29.91	35.21	30.61	29.85	-
Total imports	75.43	5.10	0.17	2.97	2.06	1.40	35.94

Table 5: Sectoral Contribution to Welfare Effect from China's Tariff Cuts (unit:%)

Sectors	Term of Trade	Volume of Import	Volume of Export	Export Share 2000	Import Share 2000	Export Growth	Import Growth
Agriculture	2.90	95.90	15.22	2.41	3.04	119.39	2073.90
Mining	3.18	-0.11	10.80	3.30	6.61	163.07	-30.50
Food	6.10	0.09	12.30	4.50	2.38	32.10	4.96
Textile	27.51	1.53	19.76	24.91	8.20	83.93	51.24
Wood	0.98	-0.01	5.82	0.88	0.76	166.46	-11.50
Paper	0.60	0.13	5.66	0.51	2.51	283.87	10.43
Printing	0.47	0.00	4.48	0.49	0.28	241.82	-13.45
Chemicals	3.97	0.06	2.42	4.34	12.43	26.53	1.61
Pharmaceuticals	0.75	-0.01	0.01	0.72	0.59	31.05	-10.87
Plastic	4.46	0.04	1.55	4.52	1.48	13.91	11.46
Minerals	1.50	-0.02	1.17	1.65	0.98	19.36	-8.32
Basic metals	3.90	0.01	4.28	4.51	7.10	35.76	0.09
Metal products	3.05	-0.10	5.34	3.46	2.65	63.45	-23.38
Electronics	18.93	1.21	0.00	20.17	26.45	87.94	26.95
Electrical	7.40	0.51	0.33	8.21	6.89	143.50	33.82
Machinery	3.72	0.05	0.90	4.17	10.55	38.77	1.91
Autos	0.74	0.78	0.00	0.81	2.00	41.44	60.77
Other Transport	1.88	0.00	0.00	2.03	1.47	2.73	-5.73
Other Manufacture	7.97	-0.06	9.95	8.40	3.61	36.24	-11.11

Note: The sectoral contribution for the terms of trade effect is the linearized value of the terms of trade effect for that sector over the sum of terms of trade effects for all sectors. The sectoral contributions to volume of import and volume of export are similarly calculated. The sectoral contribution of the VAT distortion is not reported due to the small magnitude of the aggregate distortion.

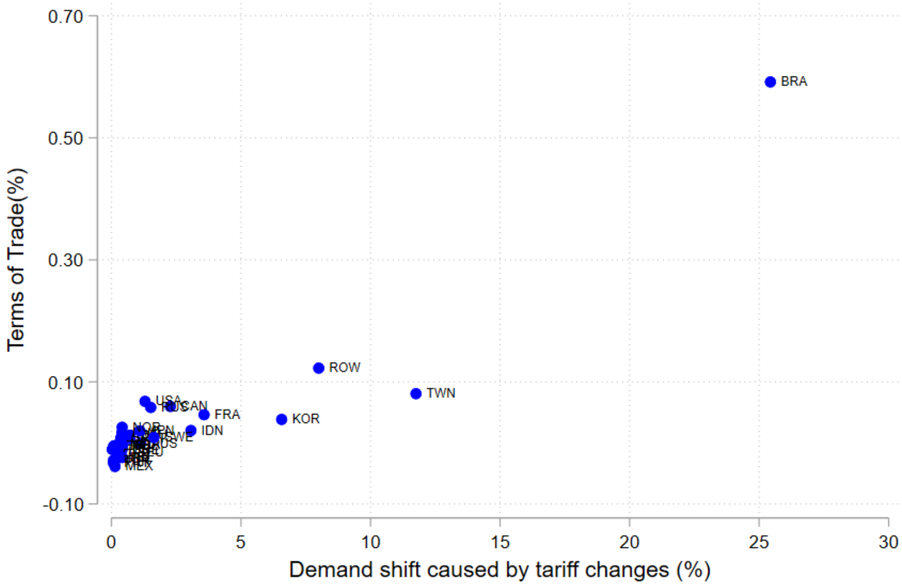
5.1.2 The Effect on Foreign Economies

Most of the economies gain from import tariffs reduction upon China's WTO accession, and enjoy an improvement in the terms of trade and the volume of imports effect. However, there are considerable variations in welfare consequences across economies, with a range from -0.05% for Mexico to 1.08% for Brazil. To provide some insight into the reason for this variation, we focus on the decomposition of the first order welfare decomposition into terms of trade effects and import volume effects.

The tariff reduction shifts Chinese import demand toward sectors where the tariff reductions are the largest. The impact of this demand shift on China's trading partners will depend on the composition of its exports to China and the magnitude of these exports. To illustrate how this demand shift varies across trading partners, we calculate the tariff reduction of country i's products to China as $(\sum_{j=1}^{J} \hat{\tau}_{Ci}^{j\ -\theta^j} M_{Ci}^{j})/GDP_i$, where $\hat{\tau}_{Ci}^{j}$ is the relative change in the tariff wedge (i.e. $\widetilde{\tau}_{Ci}^{j} = 1 + \tau_{Ci}^{j}$) for sector j goods from country i to China, M_{Ci}^{j} is the corresponding import value in 2000, and GDP_i is the gross domestic product of country i. We impose power of $-\theta^j$ on tariff changes to reflect its effect on trade flows, so that our measure of tariff reduction is an approximation of the increase in demand for country $i's$ exports (at initial world prices) as a fraction of $i's$ GDP. We expect that countries experiencing the largest demand shift toward their products will experience the greatest improvement in their terms of trade, and this is borne out in the fact that the correlation between our tariff reduction measure and the improvement in the terms of trade is .98.

We plot the relation between our measure of average tariff reductions and the changes in terms of trade in the left panel of Figure 3. Brazil stands out for Chinese sharp tariff decline against it as well as its large welfare gains. From the WIOD data, Chinese imports from Brazil are dominated by agricultural products, accounting for around one third of the total imports from Brazil in 2000. Chinese tariffs on Brazilian agricultural products were reduced dramatically, from 105.41% in 2000 to 3.18% in 2007. Significant demand increase also occurred for both Taiwan and Korea, reflecting both the magnitude of the tariff reductions and the importance of exports to China as a share of their respective GDPs. The positive correlation between the tariff reduction measure in Figure 3 reflects the impact of the shifts in Chinese demand on the terms of trade for its trading partners.

The import volume effect is the product of the trading partner's import tariff and the change in import volumes. Observe that the two trading partners that gain the most from China's tariff reduction, Brazil and Korea, are also the countries with the largest trade volume effects. The import volume effect, which accounts for about 45% of the welfare gain for Brazil and more than 90% of the welfare gain for Korea, captures the effect that increased trade with China shifts resources out of protected import-competing sectors. The resource reallocation toward export markets results in a more efficient allocation of resources.



Note: The x-axis in the left panel captures the demand shift effect caused by China's tariff changes, measured by $\sum_{j=1}^{J}(\hat{\tau}_{Ci}^{j\;-\theta^j}-1)M_{Ci}^{j}/GDP_i$. The x-axis in the right panel measures the dependence of country i's production on Chinese products. The samples exclude China itself.

Figure 3: The Welfare Changes from China's Tariff Cuts

5.2 The Role of Export Taxes

To investigate how much the changes in VAT export rebates (which is equivalent to export taxes) offset the changes in import tariff reduction, we next allow both China's import tariffs and VAT export rebates to change from actual levels in 2000 to those in 2007 (while keeping trade policies in other economies constant at the 2000 level). Then we compare the equilibrium results with the counterfactual in which only import tariffs change in the previous subsection, to examine the role of VAT export rebates. Table 6 presents the welfare effects for individual economies in this counterfactual exercise and Tables 11 and 12 in Appendix C describe the bilateral trade and aggregated trade growth for major economies and sectoral welfare contributions.

5.2.1 The Effect on China

With both import tariff cuts and VAT export rebate changes, there is a 1.90% welfare gain for China. Compared with the welfare gains from only import tariff cuts, the change in VAT export rebates adds only .01 to China's welfare. One possible reason is that the changes in VAT export rebates during China's WTO were relatively small compared with the cuts in tariff rates as shown in Figure 1. Specifically, from 2000 to 2007, China's export-weighted-average export tax equivalent of the VAT rebate increased by 2%, while the import-weighted-average tariffs declined by around 10%. Another potential reason is the sectoral heterogeneity in the changes of export tax rates relative to their optimal levels. That is, changes in VAT export rebates may lead the rates in some sectors closer to their optimal levels while driving away others from the optimal levels. Consequently, the different welfare effects from the changes of sectoral VAT export rebates offset each other and result in an overall small welfare effect.

Comparing the decomposition results in Table 6 with those in Table 3, we find that the changes in VAT export rebates have slightly improved the terms of trade but reduced the volume of import effect. The average unrebated VAT export rate increased from 2000 to 2007, which effectively increased export prices, and therefore generates a welfare gain through improving the terms of trade. However, the increased export prices raise the costs of production in foreign economies through the production network, which negatively affects the volume of imports effect.

The inclusion of VAT export rebate changes also changes China's trade structure, as exhibited in Table 12 (Appendix C) and Figure 4. Specifically, in the left panel of Figure 4, the y-axis measures the difference of sectoral export growth between the counterfactual with both import tariffs and VAT export rebate changes and the counterfactual with only import tariff cuts. The x-axis measures the changes of export tax rates, i.e., $\hat{\varphi}_n^j = (1+\mu_n^{j\prime} - \rho_n^{j\prime})/(1+\mu_n^j - \rho_n^j)$. A negative value indicates a decline in export volume caused by rebate changes, and Figure 4 illustrates a significant negative relationship between the amount of the export tax increase and the growth in export volume. There is a positive relationship between the amount of increase in the export tax on an industry and the "upstreamness" of the industry in the global value chain according to the measure developed by Antràs et al. [2012], with a correlation coefficient of 0.70 with a p value of .001. In particular, the industries that are most upstream according to that measure, Mining, Paper, Basic Metals, and Chemicals, experienced the largest declines in exports. A significantly negative relation is observed, indicating that sectors with higher increases in export tax rate suffered larger drops in export volume.

Our results echo the empirical research that highlights the impact of export rebates on trade [Sharma, 2020]. In this domain, the existing literature has empirically explored the role of China's export rebate policy by using CGE or reduced form econometric equations, such as Chao et al. [2006], Chen et al. [2006], Chandra and Long [2013], and An et al. [2017].[16] They all consistently find a significant and large effect of VAT rebates

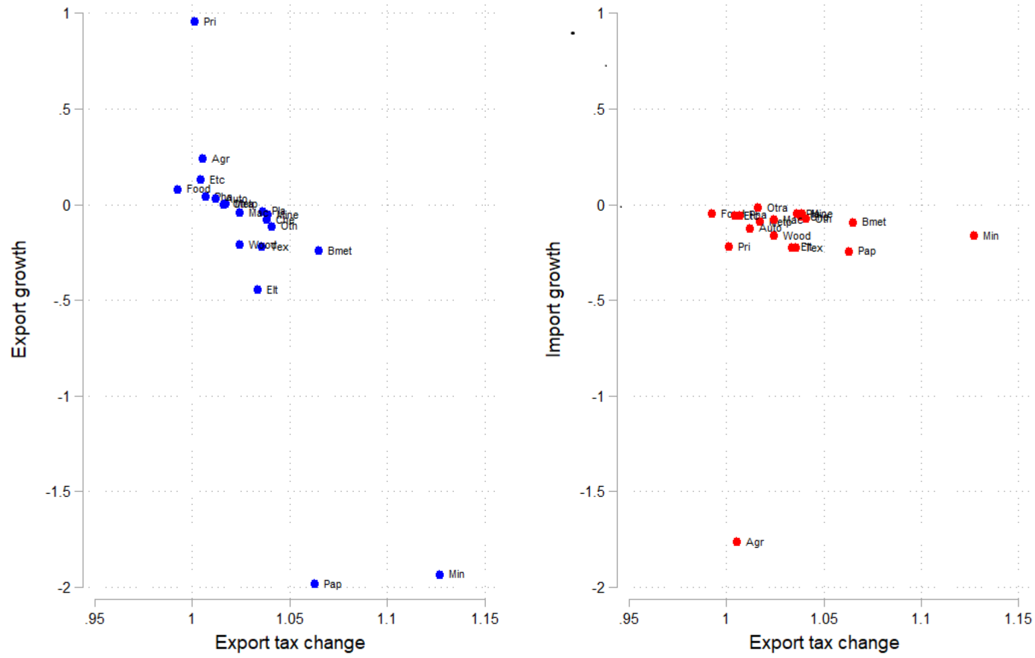
[16]Chao et al. [2006] has investigated the welfare effect of reductions in tariffs and domestic taxes on imported inputs used for export processing by utilizing CGE model. They also find that raising the export tax rebate rate significantly boosts export quantity. Another related study Liu and Lu [2015] find that China's 2004 value-added tax pilot reform has significantly increased the likelihood of exporting through promoting firm investment.

Table 6: Welfare Effect from China's Tariff and VAT Rebate Policy (%)

Economies	Welfare					Relative Welfare Changes
	Total	Terms of Trade	Volume of Import	Volume of Export	Distortion	
	(1)	(2)	(3)	(4)	(5)	(6)
China	1.90	-1.05	9.25	0.13	0.05	0.53
Germany	0.03	0.01	0.00	0.00	0.00	-25.00
Japan	0.04	0.01	0.01	0.00	0.00	-20.00
Korea	0.65	-0.01	0.57	0.00	0.00	1.56
Taiwan, China	0.06	0.01	0.02	0.00	0.00	-62.50
The U.S.	0.08	0.06	0.01	0.00	0.00	-20.00
Australia	0.04	0.01	0.01	0.00	0.00	0.00
Austria	0.01	0.00	0.00	0.00	0.00	-50.00
Brazil	1.01	0.56	0.40	0.00	0.00	-6.48
Canada	0.09	0.05	0.02	0.00	0.00	-18.18
Switzerland	-0.01	-0.02	0.00	0.00	0.00	-
Denmark	0.03	0.01	0.00	0.00	0.00	0.00
Spain	0.01	0.00	0.00	0.00	0.00	0.00
Finland	0.01	0.00	0.00	0.00	0.00	0.00
France	0.06	0.03	0.00	0.00	0.00	-14.29
The UK	0.01	-0.01	0.00	0.00	0.00	0.00
Greece	0.03	0.01	0.00	0.00	0.00	0.00
Hungary	0.01	0.00	0.00	0.00	0.00	-
Indonesia	0.09	0.03	0.02	0.00	0.00	0.00
India	-0.02	-0.02	-0.01	0.00	0.00	0.00
Ireland	-0.04	-0.04	0.00	0.00	0.00	300.00
Italy	-0.01	-0.02	0.00	0.00	0.00	0.00
Mexico	-0.04	-0.03	-0.02	0.00	0.00	-20.00
Netherlands	0.02	-0.01	0.00	0.00	0.00	-33.33
Norway	0.06	0.03	0.01	0.00	0.00	0.00
Portugal	-0.02	-0.02	0.00	0.00	0.00	-33.33
Russia	0.12	0.05	0.04	0.00	0.00	-20.00
Sweden	0.01	0.00	0.00	0.00	0.00	-50.00
Turkey	-0.01	-0.02	0.00	0.00	0.00	-50.00
Other EU	0.02	-0.01	0.01	0.00	0.00	0.00
ROW	0.17	0.11	0.01	0.00	0.00	-19.05

Note: Column (1) shows the percentage changes in national welfare resulting from China's tariff cuts. Columns (2)-(5) show the elements of the welfare decomposition in equation (13) calculated using a linear assumption, so elements will not add to the total. The relative welfare changes in column (6) are calculated by first dividing the welfare changes in the counterfactual having both changes of import tariffs and export taxes by the welfare changes with only import tariff cuts and then minus 1.

on export volume.



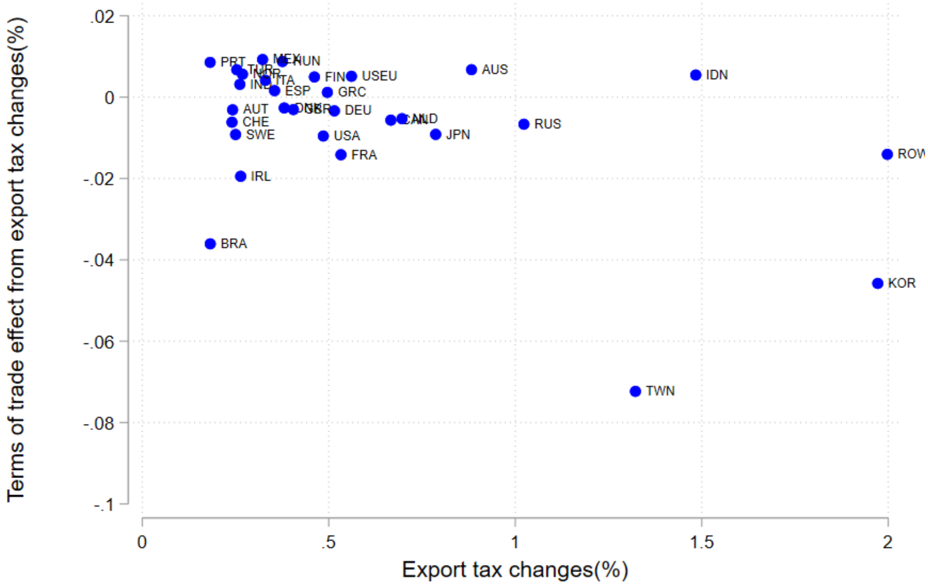
Note: The y-axis measures the differences of sectoral export growth between the counterfactual with both import tariffs and export tax changes and the counterfactual with only import tariff cuts. The x-axis measures the changes of export tax rates. The samples here only include tradable sectors.

Figure 4: Trade Effect of the Export Tax Changes (%)

5.2.2 The Effect on Foreign Economies

The overall effect of adding the change in export taxes is to reduce the gains that foreign economies earn from China's tariff reductions. Brazil, Korea, Taiwan, Russia, Canada, Indonesia, and the U.S. are still the top beneficiaries from China's WTO-entry. With the exception of Hungary, the countries that suffered from China's tariff cuts still suffer welfare losses when also considering the rebate changes. For most economies, China's increasing export taxes increase their consumption prices and decreased their imports, which is shown in the terms of trade effect and the volume of import effect in Table 6.

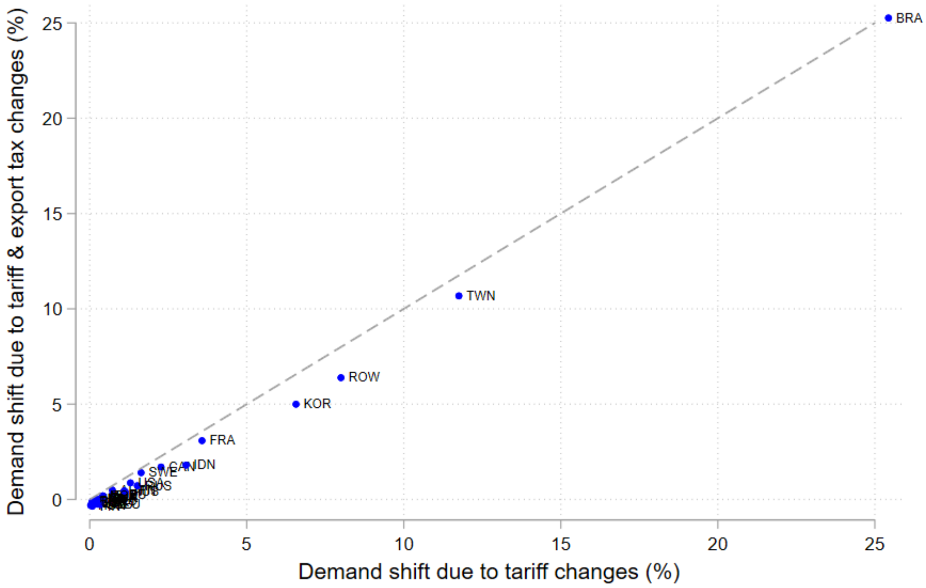
In order to measure the degree to which China's export taxes affect its trading partners, we can construct a measure of the impact of the export tax changes on the supply of exports to country i as a percentage of $i's$ GDP as $(\sum_{j=1}^{J} \hat{\varphi}_{iC}^{j}{}^{-\theta^j} M_{iC}^{j})/GDP_i$, where $\hat{\varphi}_{iC}^{j}$ is the relative change in unrebated VAT rate for sector j goods from China to country i from 2000 to 2007, and M_{iC}^{j} is the corresponding trade value in 2000. Figure 5 shows the relationship between the magnitude of the supply shift to a country caused by China's export tax policy and the deterioration in a country's terms of trade as a result of China's imposition of export taxes. As expected, countries that experienced a larger supply effect from China's export tax change tended to have a larger worsening in their terms of trade.



Note: The y-axis measures the differences of terms of trade effect between the counterfactual with both import tariffs and export tax changes and the counterfactual with only import tariff cuts. The x-axis in the left figure measures the changes of export tax rates. The x_axis in the right figure measures the importance of an economy as an supplier to China's export production. The samples here only include tradable sectors.

Figure 5: Welfare Effect of the Export Tax Changes (%)

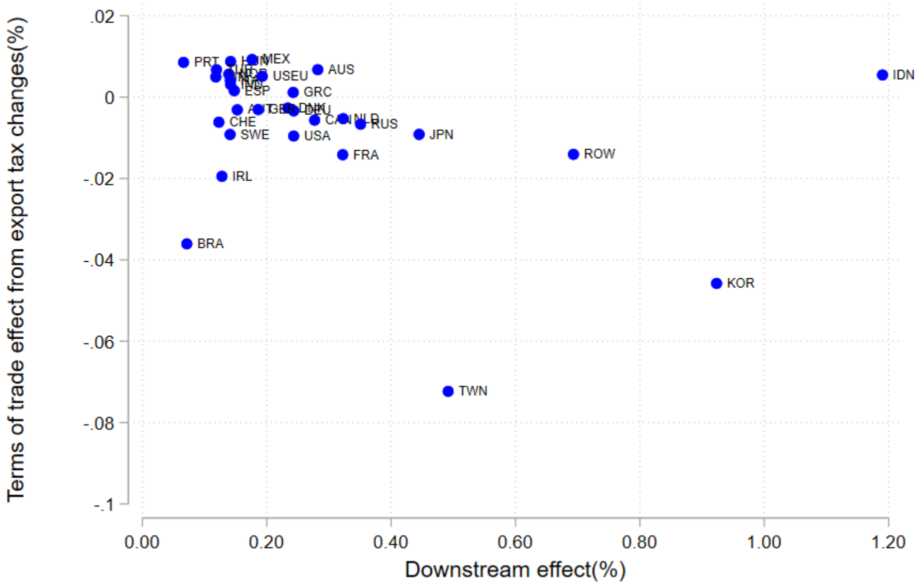
Column 6 of 6 shows that while the welfare of some countries is relatively unaffected by the incomplete VAT rebates, other countries lose a substantial portion of the gains they received from trade liberalization. Brazil, which benefits from China's substantial cuts in agricultural tariffs, only loses a minimal portion of that gain from incomplete rebates. In contrast, Taiwan loses more than 60% of the gain from WTO trade liberalization due to the VAT rebate policy. One factor that contributes to the differential effect across countries is differences in the extent to which the export rebate policy offset the effect on labor demand of the WTO trade liberalization. The net effect of the combination of tariff cuts and export tax increases on demand for country $i's$ labor is given by the difference between our measure of the demand shift from trade liberalization, and the supply shift from export tax changes, $\sum_{j=1}^{J}(\hat{\tau}_{Ci}^{j}{}^{-\theta^j} M_{Ci}^j - \hat{\varphi}_{iC}^{j}{}^{-\theta^j} M_{iC}^j)/GDP_i$. To illustrate the extent to which the export tax increases offset the effects of the tariff cuts for country i, we plot the welfare effect of the combined tariff cuts and export taxes on the horizontal axis of Figure 7, and the welfare effect of tariff cuts alone on the vertical axis. For the countries lying close to the 45^o line, the increase in export taxes has minimal effect on supply to the trading partners, which we expect to lead to a smaller loss in the terms of trade. For example, the impact of the export rebates on supply to Brazil is minimal, whereas the impact on Taiwan and Korea is much larger.



Note: The y-axis measures the demand shift of each economy caused by the combination effect of Chinese export tax and tariff change. The x-axis measures the demand shift caused by Chinese tariff changes.

Figure 6: Demand Shift: Tariff Changes vs Export Tax Changes (%)

One difference between the sectoral impact of trade liberalization and the sectoral impact of export tax increases is the extent to which they are correlated with the "upstreamness" of the sector's production. Recall that the correlation between upstreamness and the export tax changes is .7 with a p value of .001. However, the correlation between upstreamness and the WTO trade liberalization is not significant at the 10% level. This suggests that the export tax measures raised input costs for industries of trading partners downstream in the production chain. China's export taxes on rare earth minerals, which play a key role as inputs in a variety of high-tech products, are an example of this effect. To see this, we construct a measure $\sum_{j=1}^{J} \hat{\varphi}_{iC}^{j}{}^{-\theta^j} \Upsilon_{iC}^{j}$ to capture the downstream effect, which measures the dependence of country i's production on Chinese products. A larger value indicates a higher dependence on the intermediate input provided by China. Here Υ_{iC}^{j} is the output of industry j in China required to produce per unit output of country i, by taking all production linkages across countries and sectors into account. [17]The more downstream countries are primarily countries that participate in the East Asian production network. Figure (7)illustrates shows the relationship between the a country's downstreamness and the terms of trade effect, and shows that the negative terms of trade effect is larger in countries with greater dependence on inputs from China.



Note: The x-axis measures the dependence of country i's production on Chinese products. A larger value indicates a higher dependence on the intermediate input provided by China.

Figure 7: The welfare effect of China's Export Tax Changes: Downstream Effect(%)

6 Design of China's Export Taxes

The results have shown that China's export taxes did relatively little to improve China's terms of trade and had a relatively small impact on China's overall welfare. In this section we address two related questions. The first is to solve for China's optimal export taxes for 2000, 2007, and 2014 and calculate their impact on the welfare of China and trading partners. This exercise illustrates the magnitude of China's market power, and

[17] Υ^{j}_{iC} is calculated by using input-output technique: $\Upsilon^{j}_{iC} = \sum_{k=1}^{J} b^{jk}_{Ci} x^{k}_{i}$. b^{kj}_{iC} is the element of the so-called Leontief Inverse $(\mathbf{I}-\mathbf{A})^{-1}$, and measures the output of industry j in China required to produce per unit output of industry k in Country i . $\mathbf{I}$is the identity matrix, and $\mathbf{A}$ is the matrix of the world input-output coefficients. x^{k}_{i} is the output share of industry k in country i. Please see with Antràs and Chor [2018]as reference.

the potential impact of the exercise of that market power when export policies are unconstrained.

The second exercise is to compare the difference between the optimal export taxes and the actual export taxes with a measure of "upstreamness" of industries using a measure developed by AntrÃ s et al. [2012]. If one interprets the difference between the optimal tax and the actual export tax as the degree to which the sector is favored by the government, as in Ossa[2014, 2016], this provides a test of whether the export taxes were being used to encourage more downstream industries.

6.1 Optimal Export Tax Schedule

We compute China's optimal export tax using the mathematical programming with equilibrium constraints (MPEC) algorithm of Su and Judd [2012], following Ossa [2014, 2016]. Specifically, for given trade policies of foreign economies, we search for China's sectoral optimal export taxes to maximize China's welfare (13) subject to the equilibrium conditions. That is, we solve $min_{\rho_n^j}\left\{-\hat{W}_n = -\frac{\hat{I}_n}{\hat{P}_n}\right\}$ subject to the conditions (15)-(12). We compute China's optimal export taxes for three years, i.e., 2000 (the year before China's WTO accession), 2007 (the year that China completed its promised tariff reduction and just before the financial crisis), and 2014 (the most updated year with available data). Table 7 lists the actual and estimated optimal export taxes.

Sectors such as Agriculture, Mining, Wood, Paper, Printing are always over-protected with larger actual export taxes than the optimal levels. In contrast, China sets higher VAT rebate rates for the sectors such as Food, Chemicals, Pharmaceuticals, Plastic, Minerals, Basic metal, Machinery, Autos, Other Transportation, and Other Manufacture, to encourage their exports. For sectors such as Textile, Metal products, Electronic, and Electrical, China has restricted exports before its WTO entry but encouraged their exports after the WTO entry. Meanwhile, in 2000, the optimal taxes for some sectors are negative, indicating that the government should provide export subsidies instead of taxes for these sectors. For those optimal export taxes exceeding the maximum rate that could be obtained by eliminating the export rebate entirely (in most cases 17%), an explicit export tax would be required on top of the elimination of export rebate. The combined use of export taxes and elimination of VAT rebates is a reasonable policy tool for China, since Eisenbarth [2017] note that VAT rebates have been eliminated in virtually all of the sectors in which export taxes have been imposed.

To provide some intuition for these results, we can use the formula for optimal tariffs in Beshkar and Lashkaripour [2017]. They show that in a two-country model with a uniform tariff rate τ_n across sectors that sectoral optimal export tax ($\bar{\phi}_n^j$) satisfies the relation that $(1+\bar{\phi}_n^j)(1+\tau_n) = 1+1/\theta^j\pi_{ff}^j$, where π_{ff}^j is foreign countries' expenditure share on foreign products in sector j and θ^j is the elasticity of foreign expenditure share with respect to the price of good j. Smaller values of θ^j indicate a greater role for comparative advantage, and hence a higher optimal export tax.[18] Similarly, a smaller foreign expenditure share on the foreign good implies more market power in the export market for China. Finally, a lower tariff on imports leads to a larger optimal export tax, a result which is due to Lerner symmetry.

Although China's import tariffs are not uniform, our calculated optimal tariffs for 2000 match those using Beshkar and Lashkaripour [2017]'s formula very closely when τ_n is calculated as the national import-weighted tariff rate of China in 2000. The higher optimal export tax rates in 2007 and 2014 compared with 2000 are consistent with the fact that the average import tariff was substantially lower in the later years.

Table 7: The Optimal Export Tax (unit:%)

	2000		2007		2014	
Sector	Actual Export Tax	Optimal Export Tax	Actual Export Tax	Optimal Export Tax	Actual Export Tax	Optimal Export Tax
Agriculture	5.28	-4.03	5.84	5.72	7.83	6.73
Mining	2.00	-6.99	14.94	2.53	13.93	3.47
Food	7.02	19.12	6.22	31.68	3.76	33.08
Textile	0.88	-1.86	4.49	10.13	1.35	11.22
Wood	4.01	-5.60	6.52	4.08	7.21	5.60
Paper	4.00	-7.88	10.55	1.37	10.57	3.24
Printing	3.87	-7.59	4.00	1.51	3.94	3.70
Chemicals	1.71	14.38	5.61	25.68	8.05	27.70
Pharmaceuticals	0.05	14.25	0.74	26.20	0.46	27.64
Plastic	1.65	38.92	5.33	53.71	5.28	56.55
Minerals	2.82	22.99	6.80	35.74	7.89	38.32
Basic metals	2.32	6.51	8.94	17.53	6.93	19.00
Metal products	2.28	-0.32	4.02	9.62	8.15	11.45
Electronic	0.00	-1.80	0.45	9.07	0.04	10.39
Electrical	0.03	-5.78	3.40	4.10	1.17	5.62
Machinery	0.48	6.45	2.92	17.75	1.05	19.51
Autos	0.00	5.62	1.21	16.46	0.41	17.73
Other Transport	0.01	220.16	1.64	247.59	0.79	259.85
Other Manufacture	2.85	9.00	7.05	20.49	8.57	21.90

[18]The extremely high optimal export tax for other transportation equipment is a result of the fact that $\theta = .4$ for that sector, whereas the values for the other sectors range from 1.7 to 16.5 as shown in Table 10. Like other quantitative trade literature, there is always an aggregation bias issue. For example, within a sector, the trade elasticities for different products may vary. When we use a uniform trade elasticity for all products in this sector, it may impact the estimation of optimal export tax. We are prevented from doing a more disaggregated analysis by the lack of more disaggregated input-output data,

6.2 Welfare Effects of Optimal Export Tax Schedule

Table 8 shows the effects on China and the rest of the world if China imposed the optimal export taxes in 2000, 2007, and 2014.[19] By setting optimal export taxes, China gains 0.42% compared with the benchmark level in 2000, gains 0.88% in 2007, and gains 0.70% in 2014. They are mainly due to positive terms of trade effect. From equation (13), Chinese increasing export tax would directly increase the export price and therefore would improve China's terms of trade. The sectoral sources of these gains however differ between 2000 and the later years. As shown in Table 7, 9 of the 19 sectors have export tax equivalents in 2000 that exceed the optimal export tax. Table 14 in Appendix C shows that half of the sectors would have enjoyed positive export growth if optimal export taxes were imposed in 2000, half of the sectors would have negative growth, and the overall export growth and import growth would have been positive. Therefore, China has a positive volume of trade effect in 2000 from the optimal export tax. In contrast, the tariff reductions from WTO entry in 2007 result in substantially higher optimal export taxes than in 2000. Table 16 in Appendix C shows that a larger fraction of the sectors experience negative export growth in the presence of optimal export taxes, and the overall growth rate of export and import growth for China are both negative. This results in a negative volume of trade effect of China in 2007. The results on the optimal export taxes for 2014 are similar to those for 2007.

Almost all foreign economies suffer welfare losses when China set their export taxes at optimal levels, with varying magnitude. Chinese increasing export tax would raise the import price of foreign economies, which deteriorates their terms of trade. The variation in national welfare changes can be partly explained by the export tax changes experienced by each economy and its trade pattern with China. According to equation (13), we construct a measure of the impact of the export tax changes on the import price to country i as $(\sum_{j=1}^{J} \hat{\varphi}_{iC}^{j} M_{iC}^{j})/GDP_i$, Figure 8 displays the relation between this measure and terms of trade effect experienced by each economy. In general, economies that undergo larger China's export tax increases and import more from China suffer more from China's optimal export taxes. Two interesting observations are Korea and Taiwan. Korea is a large gainer from optimal /export taxes in 2000 but loses in 2007, and Taiwan goes from a marginal gainer to a big loser in 2007. These changes can be explained by the volume of trade effect. Korea had a high dependency on imports of Agriculture, Mining, Textile, and Wood from China in 2000, which would enjoy export subsidy under optimal export tax policy in 2000 from Table 7. This would increase Korea's imports from China (see Table 13 in Appendix C), and therefore would improve Korea's volume of import effect. The effect is quite large given the high tariff level of Korea against China, especially in agricultural goods. In contrast, since almost all sectors suffer increasing export taxes under the optimal export tax policy

[19] The results for 2014 are similar to those in 2007, and are reported in Appendix C.

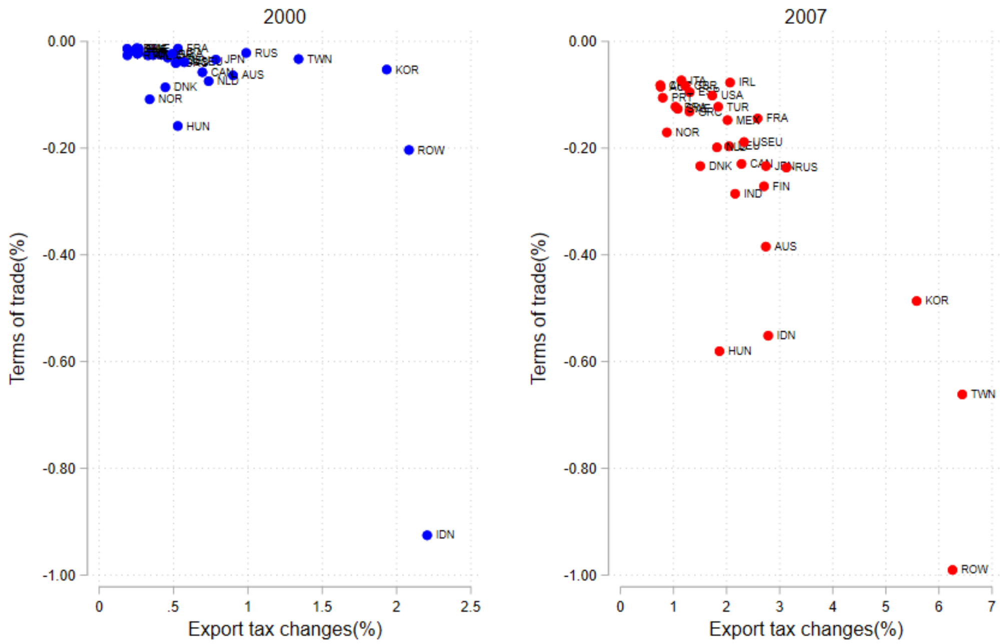
Table 8: Welfare Effect from China's Optimal Export Tax (%)

Economies	2000			2007			2014		
	Welfare	Terms of Trade	Volume of import	Welfare	Terms of Trade	Volume of import	Welfare	Terms of Trade	Volume of import
China	0.42	1.30	0.28	0.88	3.71	-0.20	0.70	2.84	-0.13
Germany	-0.02	-0.04	0.00	-0.12	-0.20	-0.01	-0.02	-0.23	-0.02
Japan	-0.01	-0.03	0.00	-0.14	-0.23	-0.01	-0.01	-0.32	-0.02
Korea	0.41	-0.05	0.40	-0.24	-0.49	-0.01	0.41	-0.79	-0.12
Taiwan, China	0.02	-0.03	0.01	-0.49	-0.66	-0.06	0.02	-1.06	-0.09
The US	-0.01	-0.02	0.00	-0.06	-0.10	-0.01	-0.01	-0.16	-0.01
Australia	-0.03	-0.06	0.00	-0.30	-0.38	-0.03	-0.03	-0.66	-0.04
Austria	-0.01	-0.02	0.00	-0.06	-0.08	-0.01	-0.01	-0.11	-0.01
Brazil	-0.01	-0.01	0.00	-0.11	-0.12	-0.04	-0.01	-0.32	-0.11
Canada	-0.03	-0.06	0.00	-0.16	-0.23	-0.01	-0.03	-0.43	-0.02
Switzerland	-0.01	-0.01	0.00	-0.03	-0.08	0.00	-0.01	-0.05	0.00
Denmark	-0.04	-0.09	0.00	-0.14	-0.23	-0.02	-0.04	-0.31	-0.03
Spain	-0.02	-0.03	0.00	-0.06	-0.09	-0.01	-0.02	-0.14	-0.02
Finland	-0.02	-0.03	0.00	-0.20	-0.27	-0.02	-0.02	-0.59	-0.04
France	0.00	-0.01	0.00	-0.09	-0.14	-0.01	0.00	-0.21	-0.02
The UK	-0.01	-0.02	0.00	-0.05	-0.08	-0.01	-0.01	-0.13	-0.02
Greece	-0.02	-0.04	0.00	-0.08	-0.13	-0.01	-0.02	-0.29	-0.03
Hungary	-0.09	-0.16	-0.02	-0.29	-0.58	-0.03	-0.09	-0.64	-0.04
Indonesia	-0.56	-0.93	-0.29	-0.33	-0.55	-0.05	-0.56	-0.54	-0.02
India	-0.01	-0.02	0.00	-0.24	-0.29	-0.07	-0.01	-0.38	-0.07
Ireland	0.00	-0.01	0.00	-0.03	-0.08	-0.01	0.00	-0.17	-0.02
Italy	-0.01	-0.02	0.00	-0.04	-0.07	-0.01	-0.01	-0.12	-0.02
Mexico	-0.02	-0.03	0.00	-0.11	-0.15	-0.03	-0.02	-0.33	-0.04
Netherlands	-0.04	-0.07	0.00	-0.11	-0.20	-0.02	-0.04	-0.55	-0.05
Norway	-0.05	-0.11	0.00	-0.12	-0.17	0.00	-0.05	-0.29	0.00
Portugal	-0.02	-0.03	0.00	-0.06	-0.11	-0.01	-0.02	-0.17	-0.02
Russia	-0.01	-0.02	0.00	-0.23	-0.24	-0.05	-0.01	-0.48	-0.07
Sweden	-0.01	-0.01	0.00	-0.07	-0.13	-0.01	-0.01	-0.15	-0.02
Turkey	-0.01	-0.02	0.00	-0.06	-0.12	0.00	-0.01	-0.34	0.01
Other EU	-0.02	-0.04	0.00	-0.12	-0.19	-0.01	-0.02	-0.29	-0.03
ROW	-0.09	-0.20	-0.02	-0.65	-0.99	-0.12	-0.09	-1.50	-0.15

Note: The welfare effects are calculated by imposing Chinese optimal export tax in each year. We do not list the volume of export effect in this table, because they are 0 for all economies other than China. The volume of export effect for China is 0.02% in 2000, -0.14% in 2007, and -0.07% in 2014.

in 2007, Korea loses. A similar story also applies to Taiwan.

Moreover, notice that Indonesia suffers most from China's optimal export tax in 2000. This is mainly due to its high dependency on imports of *Other Transport* from China, which occupied about 26% of its total expenditure on this sector in 2000. This sector would experience a significant increase of export tax under the optimal export taxes setting in 2000.



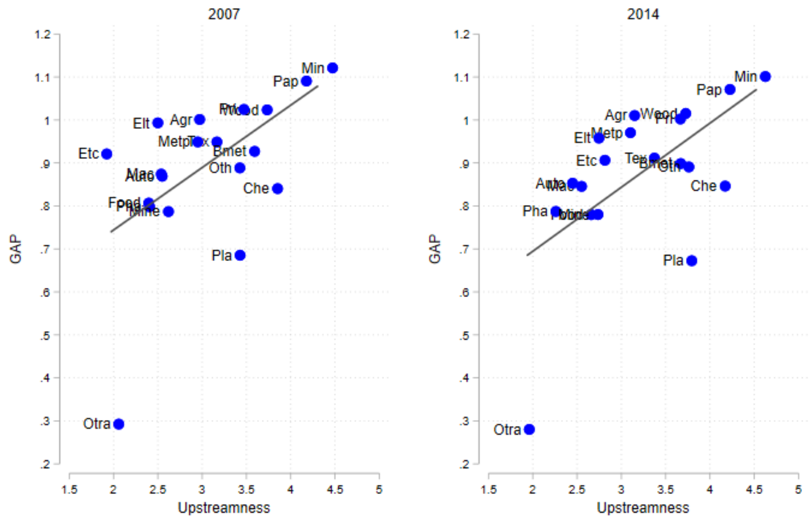
Note: The x-axis is the change of export taxes imposed by China facing each economy and calculated as $(\sum_{j=1}^{J} \hat{\varphi}_{iC}^{j} M_{iC}^{j})/GDP_i$. The y-axis is the terms of trade effect of optimal export tax calculated using equation (13). The samples in this figure exclude China itself.

Figure 8: Optimal Export Tax: Welfare Effect and Export Tax Changes

6.3 Export Taxes and Upstreamness

As shown in Table 7, there are significant deviations of actual export taxes from their optimal levels. Previous authors (e.g. Eisenbarth, 2017; Gourdon et al., 2016) have used regressions of export tax rates at the HS-6 digit level on industry characteristics as a test of hypotheses concerning the role of factors such as pollution intensity, terms of trade, and resource intensity in explaining the government's choice of export taxes. The relatively high level of aggregation in our data, which is required by our use of the WIOD, prevents us from doing an analysis of this type. However, the use of the WIOD does allow us to construct a measure of upstreamness suggested by Antràs et al.[2012]. This upstreamness measure captures the extent to which an industry's output is removed from the final consumer, with a higher value of the measure reflecting an industry that is more upstream. The average industry measure for China is 2.95, with a standard deviation of .68, which places it among the most upstream countries in the WIOD as noted by Antràs and Chor [2018].

Figure 9 shows the relationship between GAP, which is the difference between the optimal industry export tax and the actual export tax measure, and upstreamness for 2007 and 2014. The positive correlation between the two measures indicates that the deviation of the actual export tax from the optimal level is largest in the most upstream industries. This is consistent with a policy whose goal is to move up the global value chain. By restricting the exports of upstream industries, China may attract more downstream production activities inside the border, which further generates more domestic value added. In particular, the actual export tax rate in Mining is 9.0% higher than the optimal level in 2000 and 12.4% higher in 2007. The large gap suggests that the VAT rebate tax are meant to restrict the exports of mineral resources. This result is also consistent with the evidence from the WTO case that China's export taxes and quotas on rare earth minerals were related to a desire to attract downstream industries that used rare earth minerals to China (Bond and Trachtman, 2016) .



Note: The upstreamness in x-axis is calculated following the method of Antràs et al. [2012]. The y-axis is the actual export tax level relative to the optimal export tax level.

Figure 9: The Protection Level and Upstreamness

7 Sensitivity Analysis

7.1 Alternative Trade Elasticity

In this sub-section, we analyze the sensitivity of our findings with regard to the calibration of the sectoral trade elasticity θ^j. Our main specification uses the structural estimates of Caliendo and Parro [2015]. The extant literature provides ample alternative estimates for trade elasticity. In particular, we follow Bartelme et al. [2018] and Shapiro [2019] to use the median of sector-specific trade elasticities from the prior studies that have estimated these parameters: Bagwell et al. [2018], Caliendo and Parro [2015], Giri et al. [2018], and Shapiro [2016].[20] Besides, we also follow Ossa [2014] to use scaled versions of the original elasticity estimates reported in Table 10. The scaling is such that the elasticities for tradable sectors average to the aggregate elasticity (denoted by $\bar{\theta}$) that suggested by the literature (Recall that the original elasticity estimates reported in Table 10 average to 7.08). In particular, we use commonly used rule-of-thumb value 5 as the average elasticity, which is a middle value of the estimations from a large number of literature, such as Donaldson [2018], Parro [2013], Broda and Weinstein [2006], and Burstein and Vogel [2017] (also see Head and Mayer [2014] for a review). Moreover, we also try a uniform trade elasticity of 5 for all sectors.

Based on the different groups of trade elasticities, we re-calibrate the model and recalculate the related results reported above. Table 9 explore the sensitivity of the main results to alternative assumptions on the trade elasticities, presenting China's welfare gains from the trade policy after the WTO-entry and from the optimal export taxes. Though the trade elasticity is important to the degree of the welfare effect of trade policy, as clearly documented in previous studies [Arkolakis et al., 2012, Caliendo and Parro, 2015], we find qualitatively very similar results with our benchmark ones. In summary, China's export tax changes after her WTO-accession bring additional gains for China compared with the case with only tariff cuts. In particular, the use of partial VAT rebates reduces China's terms of trade loss from entry into the WTO.

Table 9: The Welfare Effect for China: Sensitivity Analysis (unit:%)

Robust Tests	Tariff cuts		Tariff cuts & Export tax changes		Optimal export tax 2000	Optimal export tax 2007	Optimal export tax 2014
	Welfare	Terms of Trade	Welfare	Terms of Trade	Welfare	Welfare	Welfare
Median Trade Elasticity	1.84	-1.26	1.85	-1.06	0.13	0.45	0.38
$\bar{\theta}$=5	0.53	-1.21	0.63	-0.90	0.49	1.26	0.98
θ^j=5 for all j	0.25	-0.95	0.38	-0.70	0.05	0.51	0.45
Treatment for Processing trade	1.76	-1.02	1.81	-0.81	0.41	0.95	0.73
Production Subsidy & Export Duty	1.82	-1.25	1.83	-1.05	0.41	0.91	0.73
Non-zero Trade deficit	1.49	-1.25	1.51	-1.03	0.42	1.17	0.88

Note: $\bar{\theta}$ is the average trade elasticity for tradable sectors. The "Median Trade Elasticity" row provides the results by using the median of sector-specific trade elasticities from the prior studies; The "$\bar{\theta}$=5" row provides the results by using the scaled version of elasticities by forcing the average elasticity equal to 5. The "θ^j=5" row provides the results by setting an uniform trade elasticity of 5 for all sectors. The "Treatment for Processing Trade" row considers the zero tariff policy for China's processing imports. The "Production Subsidy & Export Duty" row takes China's production subsidy and export duty into consideration. Finally, the last row provides the results when we hold countries' aggregate trade deficits constant in all counterfactuals.

[20]Within a study, we follow Shapiro [2019] to aggregate multiple estimates for a sector using inverse variance weighted average.

7.2 Special Treatment for China's Processing Trade

One of the important features of China's international trade is the large share of processing trade. In 2000, China's processing imports accounted for 41.9% of her total merchandise imports, and this share decreased to 38.9% in 2007. The materials imported into China were exempted from tariffs if they were used for production of processing exports. Therefore, without any special treatment for these processing imports, it may bias the actual degree of China's tariff cuts from 2000 to 2007, and therefore bias our empirical results. To avoid this influence, we re-calculate China's tariff rates against each economy by setting China's tariff rates on processing imports to be zero. In more detail, China's Customs provide detailed import data at the HS 8-digit level, by trade mode (e.g., processing trade and non-processing trade), and by trade partner. We aggregate China's import data into the data of the 19 tradable sectors, and calculate the shares of non-processing imports in China's imports of each sector from each economy. The new tariff levels are obtained by multiplying the non-processing import shares by the original tariff levels. Based on the new tariff levels in 2000, 2007, and 2014, we re-calibrate the model and re-calculate all the counterfactuals. Table 9 lists the related results on China's welfare effects, which are quite similar to our baseline results.

7.3 Production Subsidy and Export Duty

In many industries, Chinese government provides financial subsidies to encourage firm's production activity. Meanwhile, besides the export tax equivalent of VAT rebate, some Chinese exported goods, though with a narrow range, are also subject to export duties. Both production subsidy and export duty will impact export price and have a potential to influence our empirical results. We now accommodate these forces and show that they do not change our main findings. Denote s_n^j as the production subsidy rate, i.e., the firm in sector j of country n received for one dollar of its output, and denote t_n^j as the export duty rate. In an economic system with VAT, production subsidy, and export duty, the VAT-inclusive F.O.B. price of variety ω^j that is produced in country n and sold in country i now changed to $p_{in}^j(\omega^j) = (1-s_n^j)(1+\mu_i^j)(1+\mu_{in}^j-\rho_{in}^j+t_n^j)\tilde{p}_n^j(\omega^j)$. To be simple, we define $\bar{\varphi}_{in}^j = 1+\mu_{in}^j-\rho_{in}^j+t_n^j$, and $\widetilde{\varphi}_{in}^j = \bar{\varphi}_{in}^j(1-s_n^j)$. Replacing φ_{in}^j with the new $\widetilde{\varphi}_{in}^j$ in the benchmark model (in equations (5), (6)-(9)) generates the new model that incorporating the production subsidy as well as the export duty. The household income now is $\widetilde{I}_n = \frac{1}{F_n}(w_nL_n+R_n+D_n+\widetilde{T}_n+\widetilde{S}_n)$, where $\widetilde{S}_n$ is the government's expenditure to finance the production subsidy. We have $\widetilde{T}_n = \sum_{i=1}^N\sum_{j=1}^J \frac{(\bar{\varphi}_{in}^j-1)E_{ni}^j}{\widetilde{\varphi}_{in}^j}$ and $\widetilde{S}_n = -\sum_{i=1}^N\sum_{j=1}^J \frac{s_n^jE_{ni}^j}{\widetilde{\varphi}_{in}^j}$.[21] The sectoral subsidy rates are sourced from Chinese firm-level industrial enterprise

[21]Note that $\widetilde{T}_n+\widetilde{S}_n = \sum_{i=1}^N\sum_{j=1}^J \frac{(\widetilde{\varphi}_{in}^j-1)E_{ni}^j}{\widetilde{\varphi}_{in}^j}$, and the welfare decomposition in equation (13) still holds by simply replacing φ_{in}^j with $\widetilde{\varphi}_{in}^j$.

statistics and calculated as the subsidy revenue divided by the sum of subsidy revenue and output. The export duty data are from Garred [2018], which are at HS 8-digit commodity level and further aggregated to the sector level by using exports as weights.[22] We then calibrate the new model and conduct all counterfactual analysis. Table 9 lists the related results on China's welfare effects, which are quite similar to the baseline results.

7.4 Alternative Method to Treat Trade Deficit

Recall that we calibrate the model by eliminating the trade deficit in our main specifications. In this subsection, we use an alternative way to treat the trade deficit. That is, we calibrate the model with each country's aggregate trade deficit to the actual level in the base year, and then calculate all counterfactuals holding countries' aggregate trade deficits constant. The last row in Table 9 lists the corresponding results. They show that all the results in sections 5 and 6 are robust to including trade deficits or not.

8 Conclusion

Our analysis has focused on the extent to which China's use of partial VAT rebates offset the effects of China's trade liberalization on China and its trading partners from improved market access. The Lerner symmetry result suggests that there is a set of export taxes that could offset the effects of tariff cuts and leave world welfare unaffected. Our analysis of sectoral price wedges indicated that the VAT rebates had the effect of significantly increasing price wedges in the exportable sector, although they were not sufficiently large to satisfy the condition for Lerner symmetry. However, they could still be sufficiently large to have a significant effect on world prices and trade patterns.

We used a performed two counterfactual exercises to indicate the extent to which China's VAT rebate policy affected the benefits of trade liberalization. Our first counterfactual exercise showed that China's trade liberalization under the WTO would have resulted in a gain of 1.89% for China, assuming no change in VAT rebate policy. Although the unilateral liberalization by China worsened its terms of trade, this was more than offset by the gains from positive trade volume gains in imports. China's liberalization benefited most economies in the rest of the world by improvements in the terms of trade, with the gains being largest for economies that experienced the largest improvement in market access as a result of Chinese liberalization.

[22]The production subsidies here are general production related subsidies and does not include export tax rebate data. The subsidy data in 2014 are from the annual tax survey by China's Ministry of Finance and State Administration of Taxation. The export duty data are not available in 2014, so we use the data of 2013 as a substitute.

The largest gainers among China's trading partners obtained a significant portion of their gains from the trade volume effect, which captures the efficiency gains from moving resources out of protected import-competing sectors and into exportable sectors.

The second counterfactual exercise examined the effects of China's trade liberalization combined with the VAT rebate policy, and found that the effect of the export taxes was to raise the gain from the WTO liberalization process for China by .01%. This small gain was due to the fact that the export tax changes were not as large as the effects of tariff reductions, and that some of the export tax changes were moving the export taxes away from their optimal values. The choice of export tax rates seems to have been driven more by a desire to shift resources into more downstream export activities. Although the effects of tax reductions on China's trading partners were small, they did have the effect of eliminating as much as 2/3 of the gains from China's trade liberalization for some trading partners. These offsets were generally associated with countries involved in the East Asian production network. Thus, the failure of the WTO to restrict the use of partial VAT rebates cum export taxes has the potential to nullify some of the benefits of trade liberalization.

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Online Appendices - Not Intended for Publication

Appendix A. The changes in welfare due to changes in VAT:

In this sub-section, we present a detailed derivation of the expression for the changes in welfare due to changes in tariff or VAT rebate expressed in equation (13).

According to equation 11, the welfare is given by $W_n = \frac{I_n}{P_n} = \frac{w_nL_n+R_n+D_n+T_n}{F_nP_n}$. Now, totally differentiating welfare and assuming fixed trade deficit as well as fixed iceberg cost, namely, $dD_n = 0$,we have:

$$dlnW_n = \frac{1}{I_nF_n}(w_nL_ndlnw_n + dR_n + dT_n) - dlnP_n \tag{17}$$

In the following, we will totally differentiate every terms in RHS of equation (17), and finally obtain a simple expression on welfare changes. In more detail, combining with equation 10, we totally differentiate tariff revenue and obtain,

$$dR_n = \sum_j \sum_i \tau_{ni}^j dM_{ni}^j + \sum_j \sum_i M_{ni}^j d\tau_{ni}^j \tag{18}$$

Totally differentiating T_n, we get:

$$dT_n = \sum_j \sum_i [\frac{\varphi_{in}^j - 1}{\varphi_{in}^j} dE_{ni}^j + \frac{E_{ni}^j}{\varphi_{in}^j} dln\varphi_{in}^j] \tag{19}$$

Totally differentiating the consumption price index in equation (3) we obtain:

$$dlnP_n = \sum_j \alpha_n^j dlnP_n^j = \sum_j \frac{1}{I_n}(X_n^j - Q_n^j)dlnP_n^j \tag{20}$$

where $Q_n^j = (1+\mu_n^j)\sum_k \sum_i \gamma_n^{j,k} \frac{E_{ni}^k}{\varphi_{in}^k}$. In order to get the equation (20), we have utilized the equation (8), and have $\alpha_n^j = \frac{1}{I_n}(X_n^j - Q_n^j)$. Further based on equations (6) and (7), it is straightforward that $dlnP_n^j = \sum_i \pi_{ni}^j (dln\varphi_{ni}^j + dlnc_i^j + dln\widetilde{\tau}_{ni}^j)$ with $\widetilde{\tau}_{ni}^j = 1 + \tau_{ni}^j$.

Then, summing the total expenditure equation over sectors and plugging it into the equation for trade balance, we can solve for the labor market clear condition:

$$w_n L_n = \sum_k \sum_i \gamma_n^k \frac{E_{ni}^k}{\varphi_{in}^k} \tag{21}$$

Then we can get the expression for wages,

$$\begin{aligned} w_n L_n dlnw_n &= \sum_j w_n L_n^j dlnw_n \\ &= \sum_j w_n L_n^j \frac{1}{\gamma_n^j}(dlnc_n^j - \sum_k \gamma_n^{k,j} dlnP_n^k) \\ &= \sum_j \sum_i \frac{E_{ni}^j}{\varphi_{in}^j} dln\Psi_{in}^j - \sum_j \sum_i \frac{E_{ni}^j}{\varphi_{in}^j} dln\varphi_{in}^j - \sum_k \frac{Q_n^k}{(1+\mu_n^k)} dlnP_n^k \end{aligned}$$

Plugging above equations into equation(17) and after some algebra work, welfare change could be written as:

$$\begin{aligned} dlnW_n = \frac{1}{I_n}\{ &\frac{1}{F_n}\sum_j \sum_i \frac{E_{ni}^j}{\varphi_{in}^j} dln\Psi_{in}^j + \frac{1}{F_n}\sum_j \sum_i \tau_{ni}^j dM_{ni}^j + \frac{1}{F_n}\sum_j \sum_i M_{ni}^j \widetilde{\tau}_{ni}^j dln\widetilde{\tau}_{ni}^j \\ &+ \frac{1}{F_n}\sum_j \sum_i \frac{\varphi_{in}^j - 1}{\varphi_{in}^j} dE_{ni}^j - \sum_j (1+\mu_n^j) \sum_i \widetilde{\tau}_{ni}^j M_{ni}^j (dln\Psi_{ni}^j + dln\widetilde{\tau}_{ni}^j) \\ &+ \sum_j (1+\mu_n^j - \frac{1}{F_n}) \frac{Q_n^j}{(1+\mu_n^j)} \sum_i \pi_{ni}^j (dln\Psi_{ni}^j + dln\widetilde{\tau}_{ni}^j)\} \end{aligned}$$

We want to further decompose the above equation by splitting the following terms: $\frac{E_{ni}^j}{\varphi_{in}^j} dln\Psi_{in}^j = E_{ni}^j dln\Psi_{in}^j - (\frac{\varphi_{in}^j - 1}{\varphi_{in}^j}) E_{ni}^j dln\Psi_{in}^j$,and $(1+\mu_n^j)\widetilde{\tau}_{ni}^j M_{ni}^j = \frac{1}{F_n}\tau_{ni}^j M_{ni}^j + \frac{1}{F_n} M_{ni}^j + [1 - \frac{1}{F_n(1+\mu_n^j)}] X_n^j \pi_{ni}^j$. Then after some algebra work, we have:

$$dlnW_n = \underbrace{\sum_j \sum_i \frac{1}{I_n F_n}(E^j_{ni} dln\Psi^j_{in} - M^j_{ni} dln\Psi^j_{ni})}_{terms\,of\,trade} + \underbrace{\sum_j \sum_i \frac{1}{I_n F_n}\tau^j_{ni} M^j_{ni}(dlnM^j_{ni} - dln\Psi^j_{ni})}_{volume\,of\,import\,(tariff)}$$

$$+ \underbrace{\sum_j \sum_i \frac{1}{I_n F_n}(\frac{\varphi^j_{in}-1}{\varphi^j_{in}})E^j_{ni}(dlnE^j_{ni} - dln\Psi^j_{in})}_{volume\,of\,export\,(VAT)} - \underbrace{\frac{1}{I_n}\sum_j [1 - \frac{1}{F_n(1+\mu^j_n)}]\alpha^j_n I_n dlnP^j_n}_{adjustment\,for\,distortion}$$

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Appendix B: Variable Construction and Sector Description

According to Dietzenbacher et al. [2013], all the transactions in the WIOD Input-Output Tables are accounted in basic price, which suggests that all the transaction values ($\widetilde{X}^j_{ni}$) are excluding VAT, export VAT rebate, as well as the tariff. Several steps should be conducted in order to obtain the variables consistent with the variable definitions in our model. First, the bilateral expenditures in the model (X^j_{ni}) include both the non-rebated VAT levied by the exporting country and VAT levied by importing country, while the data from the WIOD are not. Therefore, to obtain X^j_{ni}, we multiply the bilateral trade flows ($\widetilde{X}^j_{ni}$) first by one plus VAT rates minus rebate rates in exporting country, and then by tariffs and VAT rate in importing country, namely, $X^j_{ni} = \widetilde{X}^j_{ni}\varphi^j_{ni}(1+\tau^j_{ni})(1+\mu^j_n)$. Then the bilateral imports and exports of sector j goods is immediately calculated as $E^j_{ni} = X^j_{in}/(1+\tau^j_{in})(1+\mu^j_i)$ and $M^j_{ni} = X^j_{ni}/(1+\tau^j_{ni})(1+\mu^j_n)$. Second, we sum up the bilateral trade (E^j_{ni}) over destination countries and obtain the sectoral output for each country ($\sum_i^N E^j_{ni}$). Then dividing the output by value added immediately yields the desired value added share (γ^j_n). Third, summing up the bilateral expenditure over the source countries yielding the sector expenditure in each country, that is, $X^j_n = \sum_i^N X^j_{ni}$. Further, based on the expenditure data, we compute the bilateral expenditure share as π^j_{ni}=X^j_{ni}/X^j_n. Fourth, the share of sector k's spending on sector j's goods is calculated from the Input-Output matrix as the share of intermediate consumption of sector j in sector k over the total intermediate consumption of sector k. Finally, we use equation (8) to calculate the final consumption shares α^j_n. To this end, the total income I_n is firstly calculated as the sum of total value added ($\sum_j V^j_n$), trade deficit (D_n), tariff revenue (R_n) as well as the VAT revenue (VAT_n). In particular, D_n,R_n, and VAT_n are given by $D_n = \sum_i^N \sum_j^J M^j_{ni} - \sum_i^N \sum_j^J E^j_{ni}$, $R_n = \sum_i^N \sum_j^J \tau^j_{ni} M^j_{ni}$, and $VAT_n = \sum_j^J \mu^j_n [X^j_n/(1+\mu^j_n) - Q^j_n] + \sum_i^N \sum_j^J (\mu^j_{in} - \rho^j_{in})\frac{E^j_{ni}}{\varphi^j_{in}}$ respectively, where $Q^j_n = \sum_k^J \gamma^{j,k}_n \sum_i^N \frac{X^k_i \pi^k_{in}}{(1+\tau^k_{in})\varphi^k_{in}}$ is country n's total intermediate expenditure on sector j goods. After that, we take the total expenditure of sector j goods, subtract the intermediate goods expenditure and divide by total final absorption, which generates our desired α_n^j. That is, $\alpha_n^j = \frac{1}{I_n}[X_n^j - Q_n^j(1+\mu_n^j)]$.

The sectoral descriptions and sectoral elasticities are reported in Table 10.

Table 10: Sector Description and Trade Elasticity

ID	Industry	Short name in Figures	Description	Corresponding sectors in WIOD	Trade elasticity
1	Agriculture	Agr	Agriculture, Forestry, and Fishing	A01-A03	9.1
2	Mining	Min	Mining and quarrying	B	13.5
3	Food	Food	Food products, beverages and tobacco products	C10-C12	2.6
4	Textile	Tex	Textiles, wearing apparel and leather products	C13-C15	8.1
5	Wood	Wood	Wood and of products of wood and cork, except furniture	C16	11.5
6	Paper	Pap	Paper and paper products	C17	16.5
7	Printing	Pri	Printing and reproduction of recorded media	C18	16.5
8	Chemicals	Che	Chemicals and chemical products	C20	3.1
9	Pharmaceuticals	Pha	Basic pharmaceutical products and pharmaceutical preparations	C21	3.1
10	Plastic	Pla	Rubber and plastic products	C22	1.7
11	Minerals	Mine	Other non-metallic mineral products	C23	2.4
12	Basic metals	Bmet	Basic metals	C24	4.5
13	Metal products	Metp	Fabricated metal products, except machinery and equipment	C25	7.0
14	Electronics	Etc	Computer, electronic and optical products	C26	8.5
15	Electrical	Elt	Electrical equipment	C27	12.9
16	Machinery	Mac	Machinery and equipment n.e.c.	C28	4.5
17	Autos	Auto	Motor vehicles, trailers and semi-trailers	C29	4.5
18	Other Transport	Otra	Other transport equipment	C30	0.4
19	Other Manufacture	Oth	Furniture, Coke, refined petroleum products, and other Manufacturing	C19,C31_C32	4.0
20	Electricity		Electricity, gas, steam and air conditioning supply;	D	8.28
21	Water and Waste		Water collection, treatment and supply, Sewerage; waste collection, treatment and disposal activities; other waste management services	E36-E39	8.28
22	Construction		Construction	F	8.28
23	Retail		Wholesale and retail trade	G45_G47	8.28
24	Land transport		Land transport and transport via pipelines	H49	8.28
25	Water transport		Water transport	H50	8.28
26	Air transport		Air transport	H51	8.28
27	Aux Trans. and Post		Warehousing and support activities for transportation; Postal and courier	H52_H53	8.28
28	Accommodation		Accommodation and food service activities	I	8.28
29	Media		Publishing, Motion picture, video and television program production, sound recording and music publishing; programming and broadcasting	J58_60	8.28
30	Information		Telecommunications,Computer programming, consultancy and related activities; information service activities	J61_J63	8.28
31	Finance		Financial services and insurance activities	k64_66	8.28
32	Real State		Real estate activities	L68	8.28
33	Tech and Business		Business, Professional, scientific and technical activities; veterinary	M	8.28
34	Education		Education	P85	8.28
35	Health		Human health and social work activities	Q	8.28
36	Other services		Administrative and support service activities; Public administration and defense; Other service activities	N_O,R_U	8.28
	Average for tradable sectors				7.08

Appendix C: Additional Results

Appendix C provides additional results. Tables 11 and 12 provide the trade effect and sectoral contributions to welfare effect of China's export changes and tariff changes after the WTO entry. Tables 13-18 provide the trade effect and sectoral contributions to welfare effect of China's optimal export tax in 2000, 2007 and 2014.

Table 11: Bilateral Trade Effect of China's Tariff and VAT Rebate Policy (Between Major Economies) (%)

	China	U.S.	Germany	Japan	Korea	Taiwan	Brazil
China's imports	-	384.30	0.20	3.88	7.53	8.70	3465.00
US's imports	65.12	-	2.75	4.39	3.58	2.29	-23.38
Germany's imports	65.85	-5.01	-	0.57	-0.71	-2.10	-32.63
Japan's imports	56.12	-6.93	-1.95	-	-2.36	-3.10	-34.73
Korea's imports	53.12	-6.31	-1.02	0.49	-	-1.63	-37.92
Taiwan's imports	53.88	-4.61	-0.54	0.90	0.50	-	-27.78
Brazil's imports	132.80	22.16	28.05	33.14	29.10	28.85	-
Total imports	59.91	4.49	0.16	2.06	1.26	0.57	33.44

Table 12: Sectoral Contribution to Welfare Effect of China's Tariff and VAT Rebate Policy (%)

Sectors	Terms of Trade	Volume of Import	Volume of Export	Distortion	Export Share 2000	Import Share 2000	Export Growth	Import Growth
Agriculture	3.86	97.95	23.55	195.21	2.41	3.04	143.33	1897.60
Mining	-1.18	-0.21	-2.75	6.01	3.30	6.61	-30.42	-46.78
Food	8.63	0.04	19.64	145.28	4.50	2.38	40.06	0.08
Textile	25.51	0.97	18.94	73.09	24.91	8.20	61.80	28.74
Wood	1.07	-0.03	6.58	2.30	0.88	0.76	145.16	-28.03
Paper	0.40	0.00	2.23	3.56	0.51	2.51	85.21	-14.12
Printing	0.66	-0.02	8.07	1.84	0.49	0.28	337.35	-35.62
Chemicals	3.53	-0.11	2.20	10.05	4.34	12.43	18.54	-4.63
Pharmaceuticals	1.00	-0.02	0.02	11.23	0.72	0.59	35.25	-16.50
Plastic	3.97	0.03	1.50	6.31	4.52	1.48	10.36	6.74
Minerals	1.28	-0.03	1.08	8.61	1.65	0.98	13.78	-13.16
Basic metals	1.72	-0.10	1.80	1.95	4.51	7.10	11.41	-9.26
Metal products	3.63	-0.16	6.94	10.70	3.46	2.65	63.79	-32.64
Electronics	25.11	1.06	0.00	68.08	20.17	26.45	100.88	21.06
Electrical	6.79	0.20	0.29	29.62	8.21	6.89	98.79	11.47
Machinery	4.10	-0.15	1.04	80.61	4.17	10.55	34.47	-6.02
Auto	0.95	0.71	0.00	34.81	0.81	2.00	44.26	48.30
Other Transport	2.22	-0.01	0.00	15.07	2.03	1.47	2.82	-7.57
Other manufacture	6.72	-0.12	8.86	22.03	8.40	3.61	24.83	-18.79
Nontradable sectors	0.00	0.00	0.00	-628.38	0.00	0.00	-	-

Note: The sectoral contribution for the terms of trade effect is the linearized value of the terms of trade effect for that sector over the sum of terms of trade effects for all sectors. The sectoral contributions to volume of import, volume of export, and distortion are calculated similarly. The results for nontradable sectors are the aggregate contributions for all 17 nontradable sectors.

Table 13: Bilateral Trade Effect from China's Optimal Export Tax 2000 (Between Major Economies, %)

	China	U.S.	Germany	Japan	Korea	Taiwan	Brazil
China's imports	-	11.00	9.88	10.75	9.36	8.32	18.21
US's imports	-0.82	-	-0.01	0.15	-0.15	-0.84	0.05
Germany's imports	5.15	-0.05	-	-0.04	-0.20	-0.86	-0.03
Japan's imports	16.41	-0.56	-0.35	-	-0.36	-1.14	-0.69
Korea's imports	22.91	-0.57	0.32	0.64	-	-0.47	-1.67
Taiwan's imports	11.39	0.15	0.35	0.48	0.26	-	0.72
Brazil's imports	8.06	-0.14	-0.14	0.01	-0.25	-0.79	-
Total's imports	11.19	0.00	0.04	0.93	0.94	0.57	5.26

Table 14: Sectoral Contribution to Welfare Effect of China's Optimal Export Tax 2000 (Unit:%)

Sectors	Term of Trade	Volume of Exports	Volume of Import	Distortion	Export Share 2000	Import Share 2000	Export Growth	Import Growth
Agriculture	-2.14	22.43	106.08	-105.81	2.41	3.04	91.52	20.35
Mining	-2.88	3.89	98.21	-5.45	3.30	6.61	163.94	24.11
Food	7.52	2.37	-108.28	-103.98	4.50	2.38	-28.02	6.64
Textile	-3.48	16.24	17.57	-48.70	24.91	8.20	7.96	15.19
Wood	-0.84	1.13	44.86	-1.85	0.88	0.76	141.55	26.60
Paper	-0.61	6.15	79.95	-2.57	0.51	2.51	445.57	36.36
Printing	-0.59	0.65	63.82	-1.65	0.49	0.28	382.67	35.36
Chemicals	7.75	3.97	-31.24	-7.68	4.34	12.43	-33.83	4.10
Medical	1.46	0.25	-0.17	-9.72	0.72	0.59	-37.49	7.08
Plastic	21.97	0.39	-52.48	-5.16	4.52	1.48	-41.62	2.84
Minerals	4.47	0.50	-23.73	-8.11	1.65	0.98	-37.51	5.69
Basic metals	3.29	3.20	-25.19	-1.71	4.51	7.10	-22.00	8.23
Metal products	-0.41	2.26	5.16	-9.49	3.46	2.65	6.55	12.87
Electronics	-1.19	13.13	0.00	-26.98	20.17	26.45	4.03	7.96
Electrical	-4.43	11.60	1.49	-20.72	8.21	6.89	71.93	20.79
Machinery	4.02	6.42	-6.36	-62.83	4.17	10.55	-28.06	7.40
Auto	0.76	3.49	0.00	-26.05	0.81	2.00	-27.22	8.41
Other Transport	57.07	0.02	-0.36	-13.09	2.03	1.47	-35.09	0.47
Other Manufacture	8.25	1.92	-69.32	-19.09	8.40	3.61	-25.79	8.26
Nontradable sectors	0.00	0.00	0.00	580.62	0.00	0.00	-	-

Note: The sectoral contribution for the terms of trade effect is the linearized value of the terms of trade effect for that sector over the sum of terms of trade effects for all sectors. The sectoral contributions to volume of import, volume of export, and distortion are calculated similarly. The results for nontradable sectors are the aggregate contributions for all 17 nontradable sectors.

Table 15: Bilateral Trade Effect from China's Optimal Export Tax 2007 (Between Major Economies, %)

	China	U.S.	Germany	Japan	Korea	Taiwan	Brazil
China's imports	-	-20.23	-15.80	-18.45	-17.43	-16.74	-25.07
US's imports	-25.22	-	1.52	2.09	2.96	5.10	2.70
Germany's imports	-22.81	1.91	-	3.18	5.25	7.04	1.89
Japan's imports	-14.72	0.11	0.66	-	2.15	4.57	0.25
Korea's imports	-8.38	-0.58	0.74	1.44	-	4.25	-1.10
Taiwan's imports	-20.38	-1.54	-0.92	-0.83	0.21	-	-1.27
Brazil's imports	-22.32	-0.44	-0.23	0.02	1.72	2.44	-
Total's imports	-19.51	-0.68	0.16	-2.12	-2.20	-3.04	-0.99

Table 16: Sectoral Contribution to Welfare Effect of China's Optimal Export Tax 2007 (unit:%)

Sectors	Term of Trade	Volume of Import	Volume of Export	Distortion	Export Share 2007	Import Share 2007	Export Growth	Import Growth
Agriculture	-0.24	20.52	-3.87	-58.43	1.01	4.76	34.04	-25.74
Mining	-0.46	1.21	-91.32	0.00	0.65	16.54	561.42	-26.62
Food	4.50	3.16	20.04	-101.94	3.15	2.45	-37.64	-9.83
Textile	3.10	6.39	22.43	-28.05	17.29	2.17	-13.53	-25.32
Wood	-0.24	0.25	-6.57	-0.81	0.67	0.42	80.64	-29.02
Paper	-0.11	1.83	-11.64	-0.74	0.11	1.43	558.91	-35.01
Printing	-0.03	0.52	-0.92	-0.99	0.09	0.23	135.92	-38.53
Chemicals	5.38	11.41	25.72	-5.83	4.96	10.22	-35.94	-13.33
Medical	1.50	0.49	0.91	-5.05	0.99	0.71	-44.90	-11.45
Plastic	11.41	1.79	31.04	-2.29	3.84	1.29	-42.71	-12.73
Minerals	2.54	0.92	11.44	-1.21	1.53	0.65	-39.08	-9.33
Basic metals	1.86	4.98	19.58	-2.29	5.24	6.16	-19.11	-13.75
Metal products	0.70	3.06	4.81	-6.46	3.81	1.24	-14.70	-21.21
Electronics	12.14	6.80	9.90	-7.73	27.94	25.65	-35.58	-21.33
Electrical	-1.02	9.16	-13.27	-21.59	7.40	5.64	27.44	-27.79
Machinery	7.39	11.81	24.07	-50.92	9.42	10.26	-36.52	-13.42
Auto	2.02	10.08	2.85	-39.84	2.47	3.40	-39.05	-14.07
Other Transport	45.00	0.61	22.39	-14.42	2.75	1.76	-35.68	-6.91
Other Manufacture	4.58	5.02	32.41	-14.44	6.68	4.99	-29.61	-11.78
Nontradable sectors	0.00	0.00	0.00	463.02	0.00	0.00	-	-

Note: The sectoral contribution for the terms of trade effect is the linearized value of the terms of trade effect for that sector over the sum of terms of trade effects for all sectors. The sectoral contributions to volume of import, volume of export, and distortion are calculated similarly. The results for nontradable sectors are the aggregate contributions of all 17 nontradable sectors.

Table 17: Bilateral Trade Effect from China's Optimal Export Tax 2014 (Between major economies, %)

	China	U.S.	Germany	Japan	Korea	Taiwan	Brazil
China's imports	-	-23.60	-19.37	-23.84	-23.02	-22.04	-28.38
US's imports	-27.05	-	2.58	3.05	3.65	6.52	5.13
Germany's imports	-22.83	2.29	-	4.67	4.70	8.41	4.41
Japan's imports	-23.34	0.75	2.04	-	3.11	7.62	1.87
Korea's imports	-24.91	0.01	2.21	2.76	-	7.24	1.52
Taiwan's imports	-26.29	-1.88	1.10	0.72	0.53	-	-1.67
Brazil's imports	-29.02	-0.43	0.37	0.57	2.40	3.74	-
Total imports	-23.98	-0.83	0.43	-2.74	-3.35	-4.18	-3.45

Table 18: Sectoral Contribution to Welfare Effect of China's Optimal Export Tax 2014 (unit:%)

Sectors	Welfare Contribution				Export Share 2014	Import Share 2014	Export Growth	Import Growth
	Terms of Trade	Volume of Import	Volume of Export	Distortion				
Agriculture	-0.32	23.34	-6.46	-58.79	0.67	6.23	53.36	-29.29
Mining	-0.56	0.26	-77.45	-0.24	0.57	21.39	469.01	-31.18
Food	4.18	4.48	16.11	-144.79	2.92	3.24	-41.82	-11.60
Textile	5.52	6.08	15.76	-38.37	14.44	1.97	-29.17	-32.59
Wood	-0.24	0.10	-9.86	-1.56	0.83	0.63	72.78	-33.20
Paper	-0.31	1.31	-42.82	-0.67	0.48	1.29	399.34	-39.29
Printing	-0.04	0.45	-1.15	-1.29	0.17	0.16	72.77	-45.77
Chemicals	4.47	6.96	43.49	-5.28	5.37	7.72	-32.28	-14.76
Pharmaceuticals	1.44	0.71	0.78	-9.55	1.07	1.10	-45.70	-13.40
Plastic	8.96	1.42	34.01	-1.54	3.38	1.24	-42.77	-12.69
Minerals	3.93	1.03	28.30	-1.39	2.69	0.76	-38.14	-11.17
Basic metals	2.21	3.84	25.34	-1.45	4.82	7.66	-26.94	-16.14
Metal products	0.00	3.31	-3.01	-10.91	4.29	1.20	4.25	-24.48
Electronics	10.97	5.31	1.11	-16.54	26.19	21.66	-36.51	-27.59
Electrical	0.73	6.81	2.28	-32.46	9.71	4.15	-7.20	-38.57
Machinery	8.40	8.69	13.19	-69.17	9.72	6.77	-41.75	-17.60
Autos	2.23	20.37	1.56	-92.24	3.02	5.00	-41.26	-17.56
Other Transport	44.89	0.50	15.46	-31.58	3.03	1.81	-35.36	-7.48
Other Manufacture	3.55	5.02	43.38	-16.35	6.60	5.99	-26.92	-13.91
Nontradable sectors	0.00	0.00	0.00	634.17	0.00	0.00	-	-

Note: The sectoral contribution for the terms of trade effect is the linearized value of the terms of trade effect for that sector over the sum of terms of trade effects for all sectors. The sectoral contributions to volume of import, volume of export, and distortion are calculated similarly. The results for nontradable sectors are the aggregate contributions for all 17 nontradable sectors.