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Is it in China's interest to implement an export carbon tax?

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HIGHLIGHTS

THE SICGE MODEL Considering the dual context of China's domestic willingness to have a cleaner export structure and the widespread concern among developed countries that carbon leakage from developing countries, particularly China, could threaten their own climate policy effectiveness, this paper uses the SICGE model to investigate the economic rationale of taxing direct CO_2 emissions of export in China.

THREE SCENARIOS OF TAX REVENUE With an export carbon tax set at 200 Yuan/t CO_2 (roughly 22 euro/t CO2), three policy scenarios were studied, where the tax revenue is: undistributed; redistributed neutrally to stimulate investment; and redistributed neutrally to stimulate consumption. According to the model, the economic and climate effects of the different policy scenarios are not particularly distinguishable.

ECONOMIC AND CLIMATE IMPACTS The economic impacts are slightly negative while the effect on the export structure is significant: the export of major energy-intensive products decreased and the export of certain sectors (labour-intensive or with higher value-added) increased, resulting in a cut of 3.6% in total direct CO_2 emissions from exports. Given that major CO_2 emissions reduction is generated from iron and steel, basic chemical, glass and non-ferrous metal sectors, the export carbon tax could also be implemented on these sectors in order to reduce the tax management cost.

RELEVANCE OF AN EXPORT CARBON TAX The revenue redistribution to stimulate consumption is shown to be the optimal scenario choice, which was confirmed by further sensitivity tests. By reviewing related WTO laws, this paper concludes that a clearly designed export carbon tax with a comparable carbon price is in China's own interest, while lessening the carbon leakage concerns of developed countries.

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Introduction

There is a political willingness in China to restructure its economy to enlarge its value-added and technology product component, and to reduce the overcapacity of energy-intensive (EI) sectors, in order to sustain its economic development while guaranteeing energy and environmental security. In this context, frequently implemented policies, such as the closure of outdated installations and the establishment of stricter market entrance criteria for EI sectors, are likely to be strengthened in the future. In addition, restrictive policies on EI exports (such as export tax, export VAT refund rebate, export quotas, licenses, etc.) have been implemented on a large scale since 2007. However, while these policies initially claimed to encourage environmental protection and address resource conservation concerns, they have been temporarily modified and thus generate neither a unique and clear carbon price nor send out a predictable political signal (Wang and Voituriez, 2010). This provides an opportunity to raise the subject of the implementation of an explicit and comprehensive export carbon tax (ECT) in China, which could provide at least three advantages.

First, at the domestic level, it could contribute towards China's above-mentioned central development goal. In particular, given the significant proportions of China's total primary energy consumption and CO_2 emissions that are induced by exports, it could facilitate the achievement of vital energy intensity and carbon intensity targets[1] (see for example, Lin and Sun, 2010; Yan and Yang, 2010; Guan et al., 2008; Kahrl and Roland-Holst, 2008; Weber et al., 2008).

Second, at the global level, an ECT could provide China, as a non-Annex 1 country under the Kyoto Protocol, with a proactive and responsible international image. Given that a domestic carbon price would probably be low when implemented (Su et al., 2009), a higher export carbon price could be introduced and would serve as a transitional measure before the domestic carbon price in China attains a comparable level.

Finally, at the bilateral level, carbon leakage and competitiveness concerns have become widespread among developed countries during recent years and act as both an obstacle to (further) implementation of climate policies and a potential threat to policy efficiency. Since China is one of the biggest exporters of EI products, it has become the most cited source of carbon leakage. The implementation of an ECT in China could therefore lessen carbon leakage concerns and facilitate the tightening of climate policies in developed countries, particularly the European Union and the United States.

Most of the recent literature on carbon border measures has mainly focused on the implementation of carbon tariffs in developed countries (for example, Mattoo et al., 2009; Kuik and Hofkes, 2009; McKibbin and Wilcoxen, 2009; Peterson and Schleich, 2009). Only a few studies have examined the feasibility of establishing an ECT policy in major EI exporting countries,

1. China has set a mandatory target to reduce its unit GDP energy consumption by 20% by the end of 2010, compared to its 2005 level. China also pledged to cut its unit GDP carbon dioxide emission by 40-45% by 2020, again compared to the 2005 level.

particularly China. Wang and Voituriez (2010) studied the equivalent CO_2 quota price generated by China's export tax and VAT refund rebate policies on steel, cement and aluminium sectors. Müller and Sharma (2005) discussed the role of China's export tax in fighting against climate change. Wang et al. (2010) proposed the introduction of a unique carbon cost on the export of EI sectors which already receive an export tax and/or export VAT refund rebate, without a further increase of export tax burden. However, none of these studies provide a detailed economic analysis on the climate and economic impacts of an ECT, which is the objective of this paper in order to answer the question on whether it is in China's interest to implement a comprehensive and comparable ECT, given its domestic development needs. The paper is structured as follows: part 1 introduces the SICGE model with a particular focus on its export module; part 2 presents a method for calculating the ECT rate and integrating it into the SICGE (State Information Center General Equilibrium) model; part 3 presents data; part 4 analyses the related results; and part 5 presents an overview of related WTO laws on export tax before concluding.

1. Model

1.1. General presentation

Co-developed by the State Information Center (SIC) of China and the Monash University of Australia, the SICGE model is used by the Chinese government as an auxiliary tool for the preparation of public policies. Based on China's 2002 input-output table, SICGE includes 137 sectors, 5 labour types as well as parameters of technology, consumption preference and market distortion, etc. The core and dynamic modules of SICGE are based respectively on the ORANI model (Dixon et al., 1982) and the Monash model (Dixon and Rimmer, 2002).

1.2. Labour market specificity

Labour market isolation remains pervasive in China. There exists a certain degree of non-competitiveness among different labour markets and labour mobility is relatively low (Hertel and Zhai, 2006; Knight and Li, 2005; Knight and Yueh, 2004). The labour market is still binary despite the fact that the factors hindering labour mobility among regions and sectors are diminishing. In general, unskilled labour forces with a relatively high degree of mobility and competitiveness are dominant in labour intensive sectors (for example, textiles and toys), while skilled and well-trained labour forces with low unemployment rates and high salaries still account for only a minor share.

Based on actual sectoral labour force components, the SICGE model divides the labour force into peasants, employees of township enterprises, migrant workers *(nong min gong)*, urban unskilled labour forces and urban skilled labour forces. It also sets a mobility mechanism among peasants, employees of township enterprises and migrant labour forces in order to integrate China's oversupply of low skilled labour forces. Importantly, such labour module settings enable a detailed analysis on the impact of an ECT on labour markets, given that a significant number of unskilled labour forces, particularly migrant workers, are employed in China's export-oriented industries. If an ECT affects export-oriented industries it could generate an oversupply of unskilled labour, which may not be easily absorbed by other sectors due to labour immobility.

1.3. Export module of SICGE

The SICGE model's export module comprises two equations: the export demand and the free on board (FOB) prices of export products. The export demand x_i^{FR} given by equation (1) is given as a function of the FOB price of the export products (see Dixon and Rimmer [2002] for details)

$$x_i^{FR} = \theta_i[pex_i^{FOB} - fep_i] + feq_i + feq_g \qquad (1)$$

where x_i^{FR} is the percentage change in the export demand of product i, θ_i is the foreign demand price elasticity of product i, pex_i^{FOB} is the FOB price of product i, fep_i and $[feq_i + feq_g]$ are respectively the parameters of vertical and horizontal changes of the export demand curve.

The FOB price of an exported product i is given by equation (2)

$$VEX_i^{FOB} pex_i^{FOB} = [VEX_i^{bas} + VTEX_i] \times pex_i^{bas} + t_i^{EX} + \sum_m VMAR_{m,i}^{EX} \times (p_m^{dom}) \qquad (2)$$

where, for a product i, VEX_i^{FOB}, VEX_i^{bas}, VTEXi and $VMAR^{EX}_{m,i}$ are parameters which denote respectively the value calculated according to the FOB price (domestic currency), the base price (production cost), the total tax revenue and the mth margin cost. For variables given in the form of percentage change in equation (2), pex_i^{FOB} is the FOB price, pex_i^{bas} is the base price, t_i^{EX} is the power of the tax rates[2] (including export tax rate changes) and p_m^{dom} is the base price of the mth margin.

According to equation (2), the export FOB price of product i is a weighted average of manufacturer price and costs. The manufacturer price is the sum of the base price and the tax costs (including the export tax). The policy impact is obtained by modifying the export tax rates t_i^{EX} as shown in this paper (see section 2.2).

1.4. Recursive dynamic

The dynamic impact analysis is obtained in the recursive form with the SICGE model. Two options are generally available when simulating the dynamic effect of a policy impact: firstly, a short-term analysis can be conducted, which usually requires data on the rigid real wage, capital stocks, flexible employment and the rate of capital return; and secondly, a long-term analysis is possible using data on rigid employment, the capital return rate, the flexible real income and capital stocks. This paper adopts the method used by Dixon and Rimmer (2002) that integrates the two options.

For the labour market, the real wage figure used is quasi-rigid, while employment is defined as flexible during the first measured period of the policy impact (one year). In the year-on-year recursive form, the real wage is adjusted based on total employment changes in the former period in order to take account of such changes. The real wage adjustment terminates when the total employment returns to its baseline level. As a result, the policy impact on employment changes is zero and the real wage is flexible in the long term.

For the capital market, this paper adopts a conventional recursive dynamic: the capital stocks at the beginning of year t are equal to the capital stocks at the end of year t-1. The capital stocks at the end of year t are the sum of the capital stocks of the beginning of year t and the total investment in year t minus the depreciations in year t. In year t there is no policy impact on the capital stocks of the same year, but the expectation of the investment return rate is affected, and changes in capital stocks are therefore generated in the following year.

2. i.e. if the tax rate is 20% for a given sector, the power is 1+20%=120%.

2. Methods

2.1. Converting the unique carbon price into ad valorem sectoral ECT rate

This paper assumes that a unique carbon price is allocated to exports based on the direct CO_2 emissions generated by each sector's exports. The reason that only direct emissions are taxed is due to the nature of environmental taxation, which only taxes direct pollutant emissions. The direct CO_2 emissions for each sector i E_i is estimated by equation (3)

$$E_i = \sum_j E_{ij} \times C_j \times r_{bj} \qquad (3)$$

where E_{ij} is the jth type fossil fuel consumption of sector i, C_j is the carbon content of the jth fossil fuel and rb_j the combustion rate of the jth fossil fuel.

The direct CO_2 emissions E_i^{ex} due to export is estimated by equation (4)

$$E_i^{ex} = E_i \frac{\times VEX_i}{VTOT_i} \qquad (4)$$

where VEX_i is the gross value of the exported good i and $VTOT_i$ is the gross value (total output) of the same sector i.

The sector ad valorem ECT rates AVT_i were obtained by equation (5)

$$AVT_i = E_i^{ex} \times \frac{T}{VEX_i} \qquad (5)$$

where T is the unique export carbon tax rate. So far, the industrial process CO_2 emissions data are not publicly available in China. Export carbon tax base may need to include such emissions when available.

2.2. Integrating AVT into the model

According to equation (2), it can be written that

$$t_i^{ex} = \frac{\Delta T_i}{T_i} \times 100 \qquad (6)$$

where ΔT_i is the change of tax level in sector I, which in our case corresponds to the implementation of an ECT, T_i T_i is the power of the tax level of sector i. If $\Delta T_i = AVT_i$, then the export carbon tax can be inputted into the SICGE model.

3. Data and scenarios

Data from 2007 have been used in this analysis as at the time of the study these figures were the most up to date available.

3.1. Fossil fuel consumption by sector

The total sectoral consumption (physical quantity) of different fossil fuels is available from the 2008 China Energy Statistical Yearbook (ESY). Table 1 shows the conversion factors for translating physical units into the coal equivalent. The method for calculating final energy consumption in China differs slightly from the international standard in that final energy consumption includes the energy consumption and transformation loss of energy industries, as well as the non-energy use of fossil fuels, which are separated in the international standard (Wu, 2009). Consequently, sectoral CO_2 emissions are artificially overestimated, although such overestimation is minimal.

3.2. Carbon contents and combustion rates of fossil fuels

The carbon content and combustion rate of each fossil fuel are unique. Table 2 shows the related data.

3.3. Gross value of export and total output

The gross value of sectoral export and total output can be obtained from the 2007 input-output table of the Chinese economy. Its competitive form, which does not distinguish between domestic and imported inputs, is sufficient for this paper, given that direct CO_2 emissions from fossil fuel combustion for exports is generated by both imported and domestic inputs.

3.4. Sector division

China's Statistical Yearbook divides the Chinese economy into 44 sectors based on the National Industries Classification (GB/T 4754-2002) standard. This paper regrouped the 44 sectors into 36 sectors to facilitate analysis and clarity. Table A1 of Annex A provides details of the sector classification used in this paper.

3.5. Scenarios

3.5.1. Reference scenario

The baseline scenario (known as S0) is given for the period of 2007-2012 based on Mai (2006). The SICGE model is recalibrated using *China's External Trade Indices* for the period of 2003-2008 published by the General Administration of Customs of China. Major macroeconomic variables under S0 are given in Table 3. The export growth rates of major sectors are given in Table 4. The impact of the world economic crisis on the Chinese economy can be seen in the table for 2008 and 2009, with a recovery starting in 2010.

3.5.2. Policy Scenarios

An ECT with a comparable rate of 200 yuan/tCO_2 (roughly 30\$/tCO_2 or 22 euro/tCO_2) is assumed to be implemented on all export products based on their direct emissions (service and building sectors not included) given in the 2007 baseline scenario. This paper analyses three policy scenarios that are distinguished according to the way in which ECT revenue is redistributed:

Scenario S1: the revenue is not redistributed. This scenario could be considered as the most feasible option given that, for almost all existing taxes, China does not yet earmark tax revenues for specific uses.

Scenario S2: As shown below, investment is one of the most affected variables under S1. Under scenario S2, by keeping the fiscal neutrality, the tax revenue is redistributed to reduce the sales tax for investment goods in order to examine whether and how investment and related aspects are affected.

Scenario S3: Given that one of China's central objectives is to stimulate domestic consumption more than investment and export, the revenue is redistributed to reduce the sales tax to promote consumption by assuring fiscal neutrality.

A scenario involving the redistribution of tax revenue to exports is not analyzed in this paper. Such redistribution would improve the welfare effect by causing a lower reduction in

Table 1. Conversion factors for physical units into coal equivalent of fossil fuels (kgce/kg)

Raw coal	Coke	Crude oil	Fuel oil	Gasoline	Kerosene	Diesel	Natural Gas (kgce/cu.m)
0.7143	0.9714	1.4286	1.4286	1.4714	1.4714	1.4571	1.33

Source: China Energy Statistical Yearbook 2008.

Table 2. Unit carbon content and combustion rate of major fossil fuels in China

	Coal	Coke	Oil	Gasoline	Kerosene	Diesel	Fuel Oil	Natural gas
Carbon content (tC/TJ)*	25.8	29.2	20	18.9	19.6	20.2	21.1	15.3
Combustion rate**	0.9	0.9	0.98	0.98	0.98	0.98	0.98	0.99

Source: *: IPCC Guidelines for National Greenhouse Gas Inventories, 2006, Volume 2 Energy: table 1.4. **: Ou et al., 2009.

Table 3. Major macroeconomic variables under the baseline scenario (%)

	2007	2008	2009	2010	2011	2012
GDP growth (1)	14.2	9.5	8.7	9.4	9.0	9.0
Consumption growth	10.6	8.8	10.1	10.1	9.4	9.2
Capital formation growth	13.9	10.6	17.1	10.8	9.9	9.4
Export growth	19.9	8.4	-11.3	9.1	8.4	7.5
Import growth	15.8	7.7	-9.2	13.9	8.5	7.0
CPI growth	4.4	5.1	2.8	2.9	2.9	2.2
Employment growth	0.8	0.6	0.6	0.6	0.6	0.6
Share of labour in initial allocation (2)	46.5	46.9	46.9	46.9	47.8	48.5

Note: (1) Growth rate is given under comparable price

(2) Share of labour in initial allocation = total revenue of labour force/sum of the return of labour, capital and land

Table 4. Growth rate of the export of major sectors under the baseline scenario (%)

	2007	2008	2009	2010	2011	2012
Basic chemicals	23.0	-1.0	-23.4	11.5	7.0	3.4
Textile and clothing	12.0	6.2	-9.0	6.0	5.8	5.3
Rubber and products	26.6	-2.3	-12.5	5.8	6.0	5.2
Plastic and products	7.3	-0.2	-15.3	10.3	10.0	8.4
Non-ferrous metal	-4.7	-5.3	-25.5	7.7	4.7	0.5
Glass	25.4	12.0	-15.5	9.8	8.6	7.0
Manufacture of toys	19.7	-2.3	-7.4	5.6	5.8	5.9
Manufacture of electrical equipments	20.1	14.9	-2.8	14.6	12.9	11.7
Machinery	34.0	12.0	-18.5	13.6	11.3	9.0

exports, relative to S1, from energy-intensive sectors. However, it would also result in a lower reduction of direct CO_2 emissions from exports, compared to the other scenarios. Such a scenario would therefore work against China's central objective, which is to reduce the export of energy-intensive sectors. Moreover, the current fiscal regime makes it difficult to determine whether the tax revenue should be redistributed to producers or to exporters.

4. Results

4.1. Equivalent sector AVT and sectoral CO_2 emissions

Table 5 shows the sector AVT and direct sectoral CO_2 emissions in 2007, based on 2007 trade data and equation (5).

4.2. Impact of ECT under S1

This section provides a detailed analysis of the S1 scenario results, rather than all

Table 5. Sectoral export direct CO_2 emissions under the baseline scenario and AVT (major sectors)

Sectors	Sector AVT (%)	Eiex (Mn tons)
Agriculture	1.4	0.425
Mining and washing of coal	3.9	3.301
Extraction of petroleum and natural gas	1.2	1.438
Mining and processing of ferrous metal ores	0.0	0.330
Mining and processing of non-ferrous metal ores	0.1	0.196
Mining of other ores	0.4	0.596
Manufacture of foods, beverages and tobacco	2.4	0.248
Manufacture of textile	13.3	0.324
Manufacture of wearing and leather	2.3	0.080
Lumber and furniture	1.6	0.130
Manufacture of paper and paper products	2.1	1.313
Printing, reproduction of recording media	0.1	0.062
Manufacture of articles for culture, education and sport activity	0.6	0.067
Processing of petroleum, coking, processing of nuclear fuel	10.0	2.607
Manufacture of raw chemical materials and chemical products	39.8	2.281
Manufacture of medicines	1.0	0.286
Manufacture of chemical fibers	1.0	0.767
Manufacture of rubber	2.3	0.322
Manufacture of plastics	0.7	0.098
Manufacture of non-metallic mineral products	20.0	2.695
Smelting and pressing of ferrous metals	96.8	5.254
Smelting and pressing of non-ferrous metals	4.3	0.587
Manufacture of metal products	2.0	0.111
Manufacture of machinery	5.3	0.186
Manufacture of transport equipment	2.0	0.122
Manufacture of electrical machinery and equipment	1.4	0.042
Manufacture of communication equipment, computers and other electronic equipment	3.3	0.031
Manufacture of measuring instruments and machinery for cultural activity and office work	0.9	0.057
Other manufacturing	0.9	0.129

three scenarios, given that similar analytical methods were applied in each case. Unless specifically indicated, the reference scenario used throughout this section is S0. Detailed examination of the reliability of the results, based on the quantitative analysis framework of the Back of the Envelope Model (Dixon and Rimmer, 2002), is given in Annex B.

4.2.1. Macroeconomic impact

According to the model, implementing ECT at 200yuan/tCO_2 is equal to an average ad valorem export tax rate impact of 0.44%, generating 41.6 billion Yuan as tax revenue. Related results are given in Figure 1. A part of the impact of an export carbon tax is absorbed by the increase of the export FOB price, which will increase by 0.07% relative to S0. Another part of the impact will be absorbed by decreasing the production price of domestic products. However, under the general equilibrium theoretical mechanism, the producer price of different demands (such as export, household & government consumption, investment and intermediate input, etc.) for the same commodity will be identical. Therefore, under scenario S1 the GDP deflator and the average consumer price decreased respectively by 0.18% and 0.22%. The export demand decreased by 0.185% following an increase of the export FOB price of commodities. This would create unemployment (-0.05%) in the short term due to the presence of unskilled rural-urban migrant workers and labour market segmentation. Total GDP decreased slightly by 0.043% as a net effect of the unemployment, the decrease in welfare due to ECT implementation and the short term rigidity of technology and capital stocks. As components of GDP expenditure, household & government consumption, capital formation and imports experienced changes of 0.006%, -0.03% and -0.16% respectively.

4.2.2. Export structural effect

The structural effect on export is shown in Figure 2. For energy-intensive sectors, due to the method used in this paper for taxing the direct CO_2 emissions of exports, fossil fuel-intensive sectors showed a significant decrease in exports (iron and steel, chemical, coal mining product and glass sectors) while the impact on exports from some electricity intensive sectors was relatively slight (non-ferrous metal sector). Exports increased from labour-intensive sectors and those with higher value-added and technology contents (plastic, mechanism and electric & communication equipment sectors). This is due to the depreciation of the real exchange rate (-0.18%) which compensated for the volume effect of the export carbon tax on these products (-0.06%) and reduced their purchaser price on the international market.

4.2.3. CO_2 emissions

A decrease in the export of major energy-intensive sectors is the major source of the reduction of CO_2 emissions (see Table 6). As a result, the ECT reduced around 3.6% of direct CO_2 emissions due to exports.

4.2.4. Long-term impact

Figure 3 shows the long-term impact of an ECT on major economic indicators. The technology improvement is exogenous in this study. Employment is shown to be negatively affected due to the assumption of a rigid real wage in the short term. However, in the long term, the higher supply relative to demand would engender a reduction of real wages and therefore the demand for labour would recover toward its initial level. In precise terms, employment was shown to reduce by 0.05% in 2007 and by 0.02% in 2012. Investment decreased in the long term and the capital stock decreased by 0.01% in 2012. This led to a readjustment of the real rate of return of capital. The cumulative impact of primary production factors, labour and capital, lead to an impact of ECT on GDP that remains stable from 2009 at -0.07%, and because the export tax rate is fixed, the negative impact on export will remain at -0.20%.

Figure 4 illustrates the impact of an ECT on long-term CO_2 emissions reduction from export. As shown, total direct CO_2 emissions from export decreased continuously following ECT implementation. The upward trend in total direct CO_2 emissions reduction from export in 2009 is principally due to the impact of the economic crisis. Similarly to the findings of the short-term analysis, iron and steel, chemical, non-ferrous metal and glass sectors were the major contributors to the long-term reduction in CO_2 emissions from Chinese export.

4.3. Comparison of the different policy scenarios

4.3.1. Macroeconomic impact comparison

Table 7 shows the macroeconomic impacts of an ECT for all three scenarios. Under S2, the investment goods price decreased by 0.31%, just 0.05% lower than the same price decrease under S1. The decrease in the nominal rate of return of capital differs only slightly between S1 and S2. As a result, there was a smaller decrease in the real rate of return of capital in S2 than in S1, relative to S0, leading to a less negative impact on investment (-0.023%). The impacts on GDP for S1 (-0.043%) and S2 (-0.041%) are also similar while the impact on final consumption has changed from positive to negative. This could be due to GDP expenditure identity; however, a more likely explanation may be related to the relative changes in the general nominal prices of investment goods, final consumption and the GDP deflator. For instance, in S2, the general nominal price of investment goods decreased by a larger amount than in S1, relative to the price of consumption, which could be due to a more attractive investment demand in S2 among the items of GDP expenditure identity. Therefore, more national revenue is distributed to capital formation than to final consumption. However, this effect would run counter to China's willingness to stimulate consumption in the coming years.

Under S3, the consumption price decreased by 0.28%, a greater decrease than in S1. This stimulated an increase in household consumption (0.052%) that was higher than in S1 and S2. The negative impact of ECT on the nominal rental of capital is also less than in S1 and S2. This led to a lesser decrease, compared to S1, of both the real rate of return of capital and the investment demand. Finally, compared to S1 and S2, S3 had a smaller decrease in GDP, which resulted from a greater increase of consumption and a lesser decrease in investment.

Figure 1. Macroeconomic impact of ECT in China

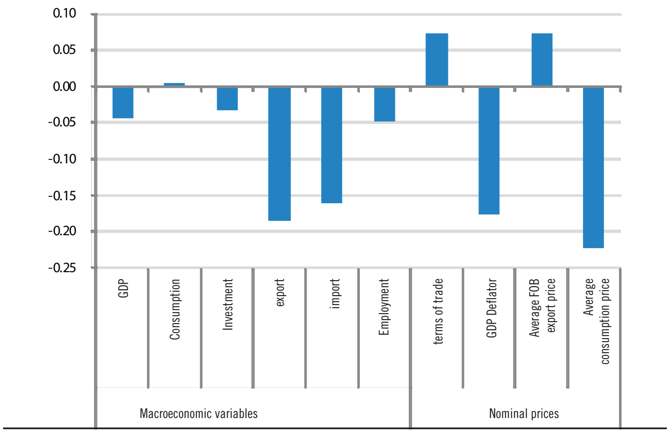


Figure 2. Structural effect of export carbon tax on China's export

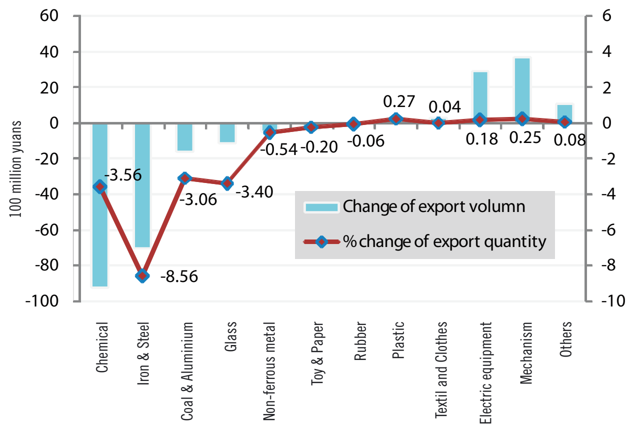


Figure 3. Long-term impact on major economic indicators

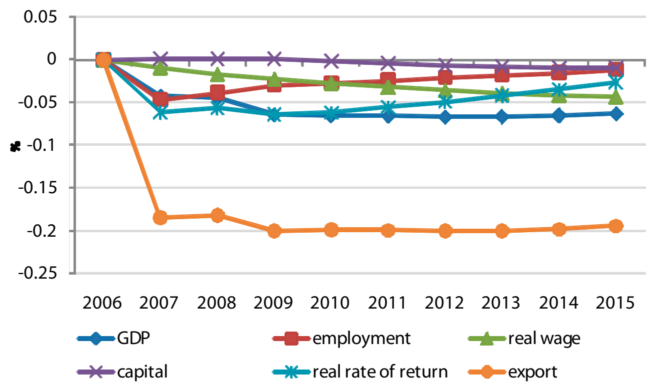
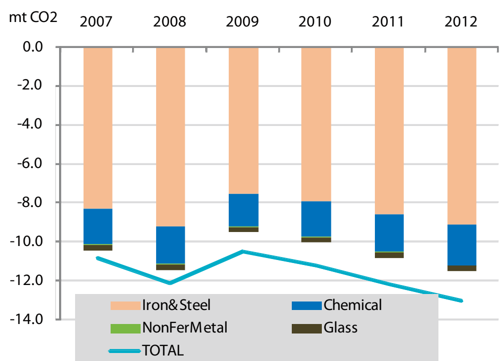


Figure 4. Long-term export CO_2 emissions reduction



4.3.2. Comparison of export structure changes between different scenarios

While ECT impact on exports was identical in all three scenarios, the tax revenue was not directly redistributed to the exporting sectors and thus the impact on the export structure change remained slightly different under the three policy scenarios (see Table 8).

4.3.3. Comparison of scenarios according to CO_2 emission reductions from exports

Directly determined by sectoral export, the sectoral export emissions reductions also differ only slightly across each scenario (see Table 9).

4.4. Sensitivity test

To test sensitivity, the ECT rate was doubled from 200 Yuan/t CO_2 to 400 Yuan/t CO_2. Following the same framework as Table 7, Table 10 compares the macroeconomic variables of the three scenarios. As shown, at this higher carbon price S3 demonstrated significant advantages and could therefore be confirmed as the optimal policy scenario of the three studied in this paper.

5. WTO compatibility with carbon export tax

Compared to other trade instruments, the export tax is less frequently discussed at the WTO and the necessary legislation is incomplete (Karapinar, 2010). The use of export tax can generally be considered as positive according to GATT Art XI para. 1, as long as the tax is non-discriminatory. Also, Art XIII para.1 of GATT clearly states that "[n]o

Table 6. CO_2 emissions reduction from export

	Baseline scenario emissions ($MtCO_2$)	CO_2 emissions reduction ($MtCO_2$)	CO_2 emissions reduction/ baseline emissions (%)
Chemical	49.8	-1.77	-3.60
Iron&Steel	96.8	-8.29	-9.38
Coal&OthMin	5.6	-0.17	-3.25
Glass	3.08	-0.10	-3.59
NonFerMetal	4.3	-0.02	-0.55
CultToy&Paper	4.3	-0.01	-0.12
Rubber	2.3	0.00	-0.04
Plastic	0.7	0.00	0.35
Textile&Cloth	15.6	0.01	0.07
Elec&CommuEquip	4.2	0.01	0.21
Mechanism	10.7	0.03	0.29
Others	84.9	0.07	-0.12
Total	282.3	-10.26	-3.6

Table 7. Scenario comparison of ECT impact on macroeconomic variables (%)

	S1	S2	S3
GDP	-0.043	-0.041	-0.021
Consumption	0.006	-0.006	0.052
Investment	-0.031	-0.008	-0.009
Export	-0.185	-0.186	-0.192
Import	-0.160	-0.154	-0.139
Employment	-0.047	-0.043	0.000
Price of household consumption	-0.223	-0.228	-0.276
Nominal rate of return of capital	-0.323	-0.317	-0.265
Price of investment goods	-0.262	-0.309	-0.254
GDP deflator	-0.176	-0.196	-0.188
Terms of trade	0.073	0.073	0.076
Real rate of return of capital	-0.061	-0.008	-0.012

Table 8. Scenario comparison of sectoral export changes (%)

	S1	S2	S3
Chemical	-3.56	-3.56	-3.58
Iron&Steel	-8.56	-8.57	-8.57
Coal&OthMin	-3.06	-3.07	-3.07
Glass	-3.40	-3.41	-3.41
NonFerMetal	-0.54	-0.54	-0.55
CultToy&Paper	-0.20	-0.20	-0.21
Rubber	-0.06	-0.06	-0.05
Plastic	0.27	0.27	0.26
Textile&Cloth	0.04	0.04	0.04
Elec&CommuEquip	0.18	0.18	0.17
Mechanism	0.25	0.24	0.24
Others	0.08	0.09	0.07

Table 9. Scenario comparison of CO_2 emissions from exports (MtCO2)

	S1	S2	S3
Chemical	-1.81	-1.81	-1.82
Iron&Steel	-8.29	-8.30	-8.30
Coal&OthMin	-0.26	-0.26	-0.26
NonFerMetal	-0.02	-0.02	-0.02
Textile&Cloth	-0.01	-0.01	-0.01
Glass	-0.29	-0.29	-0.29
Rubber	0.00	0.00	0.00
CultToy&Paper	0.00	0.00	0.00
Plastic	0.00	0.00	0.00
Mechanism	0.02	0.02	0.02
Elec&CommuEquip	0.01	0.01	0.01
Others	-0.18	-0.18	-0.20
Total	-10.84	-10.85	-10.87

Table 10. Scenario comparison of macroeconomic variables at an ECT of 400 Yuan/ton CO_2 (%)

	S1	S2	S3
GDP	-0.09	-0.08	-0.04
Consumption	0.02	-0.01	0.11
Investment	-0.06	-0.01	-0.01
Export	-0.36	-0.37	-0.38
Import	-0.32	-0.31	-0.28
Employment	-0.09	-0.08	0.00
Price of household consumption	-0.44	-0.45	-0.54
Nominal rate of return of capital	-0.63	-0.61	-0.51
Price of investment goods	-0.52	-0.61	-0.50
GDP deflator	-0.34	-0.38	-0.36
Terms of trade	0.14	0.15	0.15
Real rate of return of capital	-0.11	0.00	-0.01

prohibition or restriction shall be applied by any contracting party...on the exportation of any product destined for the territory of any other contracting party, unless...the exportation of the like product to all third countries is similarly prohibited or restricted".

It is, however, the elimination of export taxes that is commonly combined into the "WTO-plus" obligations for new entrant country members on accession to the WTO (for example, China, Mongolia, Saudi Arabia, Ukraine and Vietnam). In the Protocol of Accession of China (WT/L/432), it is clearly stated in Art. 11, para. 3, that "China shall eliminate all taxes and charges applied to exports unless specifically provided for in Annex 6 of this Protocol or applied in conformity with the provisions of Article VIII of the GATT 1994." Annex 6 includes 84 products (HS 8-digit), mainly steel and other non-ferrous metal products and related goods. Meanwhile, the note at the end of Annex 6 leaves flexibility for further export tax implementation: "China confirmed that the tariff levels included in this Annex are maximum levels which will not be exceeded. China confirmed furthermore that it would not increase the presently applied rates, except under exceptional circumstances. If such circumstances occurred, China would consult with affected members prior to increasing applied tariffs with a view to finding a mutually acceptable solution." Export taxes with the intention of addressing climate change, if properly designed and involving consultations with China's major trading partners, should therefore qualify as WTO compatible.

Conclusion

This paper showed that the implementation of a 200 Yuan/ton CO_2 ECT would contribute to China's own demand for development while also lessening carbon leakage concerns. An ECT generates very little decrease in GDP and reduces exports from major energy intensive sectors. The redistribution of ECT revenue towards the stimulation of consumption (S3) is the best choice among the scenarios studied in this paper. However, China's tax revenue redistribution function is still under reform and has not yet been adopted for existing taxes. Taking the slight welfare differences among scenarios into account, the non revenue redistribution (S1) scenario could also be considered as a politically feasible option. ■

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Appendix

Annex A

Table A1. Sector division

36 sectors (this paper)	44 sectors (2009 China Statistical Yearbook)
Agriculture	Farming, forestry, animal husbandry and water conservancy
Mining and washing of coal	Mining and washing of coal
Extraction of petroleum and natural gas	Extraction of petroleum and natural gas
Mining and processing of ferrous metal ores	Mining and processing of ferrous metal ores
Mining and processing of non-ferrous metal ores	Mining and processing of non-ferrous metal ores
Mining of other ores	Mining and processing of nonmetal ores
	Mining of other ores
Manufacture of foods, beverages and tobacco	Processing of food from agricultural products
	Manufacture of foods
	Manufacture of beverage
	Manufacture of tobacco
Manufacture of textile	Manufacture of textile
Manufacture of wearing and leather	Manufacture of textile wearing apparel, footware and caps
	Manufacture of leather, fur, feather and related products
Lumber and furniture	Processing of timber, manufacture of wood, bamboo, rattan, palm and straw products
	Manufacture of furniture
Manufacture of paper and paper products	Manufacture of paper and paper products
Printing, reproduction of recording media	Printing, reproduction of recording media
Manufacture of articles for culture, education and sport activity	Manufacture of articles for culture, education and sport activity
Processing of petroleum, coking, processing of nuclear fuel	Processing of petroleum, coking, processing of nuclear fuel
Manufacture of raw chemical materials and chemical products	Manufacture of raw chemical materials and chemical products
Manufacture of medicines	Manufacture of medicines
Manufacture of chemical fibers	Manufacture of chemical fibers
Manufacture of rubber	Manufacture of rubber
Manufacture of plastics	Manufacture of plastics
Manufacture of non-metallic mineral products	Manufacture of non-metallic mineral products
Smelting and pressing of ferrous metals	Smelting and pressing of ferrous metals
Smelting and pressing of non-ferrous metals	Smelting and pressing of non-ferrous metals
Manufacture of metal products	Manufacture of metal products
Manufacture of machinery	Manufacture of general purpose machinery
	Manufacture of special purpose machinery
Manufacture of transport equipment	Manufacture of transport equipment
Manufacture of electrical machinery and equipment	Manufacture of electrical machinery and equipment
Manufacture of communication equipment, computers and other electronic equipment	Manufacture of communication equipment, computers and other electronic equipment
Manufacture of measuring instruments and machinery for cultural activity and office work	Manufacture of measuring instruments and machinery for cultural activity and office work
Other manufacturing	Manufacture of artwork and other manufacturing
	Recycling and disposal of waste
Production and distribution of electric power and heat power	Production and distribution of electric power and heat power
Production and distribution of gas	Production and distribution of gas
Production and distribution of water	Production and distribution of water
Construction	Construction
Transport, storage and post	Transport, storage and post
Wholesale, retail trade and hotel, restaurants	Wholesale, retail trade and hotel, restaurants
Others	Others

Annex B: Use of a simplified framework to explain the model's results

Non-modelers and policy makers tend to view most CGE models as "black boxes" that produce results that are not always easily comprehended. This Annex follows the work of Dixon and Rimmer (2002) and builds a simplified framework to illustrate and justify the results obtained using the SICGE model. For simplicity, the macroeconomic results for S1 are used as a reference.

B.1 Impact on nominal price variables

B.1.1 Impact on nominal price of export

For simplicity, the following illustration assumes that a country produces just one good for domestic use and export. It also assumes that only one good is imported for intermediate input, investment and consumption usage, but it is not exported. Equations B1-B3 illustrate the framework by which domestic industries readjust their export prices after the implementation of an ECT in order to maintain international competitiveness,

$$d_{ex} = -\varepsilon \times p_{FOB} \quad (B1)$$

$$s_{ex} = \in' \times p_{pret} \quad (B2)$$

$$p_{FOB} = p_{pret} + p^{4t} \quad (B3)$$

where d_{ex} is the percentage change in the exported good's international demand (For example, the percentage change of a variable D is given by a lower case d, where

$d = \frac{\Delta D}{D} \times 100$), ε >0 denotes the absolute value of price elasticity of export demand and p_{FOB} the percentage change of export FOB price. It is assumed that the international demand would be directly affected by the FOB price of export, which would therefore substitute the consumer price of the exported good on the international market. The reason for this assumption is that the ECT would have little effect on the margins of international trade, so the change in FOB price of the export good would be totally passed through to the consumer price of the export good on the international market. Finally, s_{ex} is the percentage change of export supply, $\in'$ is its price elasticity, p_{pret} is the factory gate price of the export good and p4t, given in the percentage form of power, is the export tax change after ECT implementation. In this way, the domestic margin between the factory gate price and the FOB price is omitted for simplicity.

By equalizing the export supply and demand, it can be stated that

$$p_{pret} = -\varepsilon \times p4t / (\in' + \varepsilon) \quad (B4)$$

which illustrates the impact of an ECT on a domestic product's factory gate price. In the real world, a large number of export goods belong to a buyer's market and therefore have relatively higher supply price elasticity. In addition, an important share of China's export is composed of pocessing trade and therefore has a relatively lower supply price elasticity. In general, the percentage decrease of the factory gate price of the export good could be considered as lower than p4t.

According to the SICGE model, the implementation of an ECT could generate 41.6 billion yuan in tax revenue, which equals 0.44% as an average export tax rate, which leads to an export FOB price increase of 0.07% compared to S0. Taking the average price elasticity on Chinese exports (ε) which is 2.5 in the SICGE model, based on equation (B1), the export demand decreased by 0.175%, which is similar to the model's result (-0.185%).

B.1.2 Impact on other nominal price variables

Using the SICGE model, given the assumptions that only one product is produced in one sector and that it has a unitary producer price whether it is for domestic use or export, the export price before tax and the factory gate price of the good for a given sector are therefore identical. The implementation of an ECT would reduce the price of a domestic product for domestic demands as well as the price before tax of export products. As the SICGE model showed, the GDP deflator decreased by 0.176% relative to S0. This also indicates that the real exchange rate depreciates at 0.176%, given that the price of import is not affected by export tax.

B.2 Impact on real economic variables

B.2.1 Impact on profit loss of primary factors

Given the price distortion and labour market segmentation in China, an analytical framework was constructed to interpret the SICGE model results. Based on the GDP expenditure accounting approach, equation (B5) provides the determinant of the GDP deflator,

$$P_{GDF} = S_C \times P_C + S_I \times P_I + S_G \times P_G + S_{Ex} \times (P_{Ex} - P_{Im}) + (S_{Ex} - S_{Im}) \times P_{Im} \quad (B5)$$

where P_{GDP}, P_C, P_I, P_{Ex} and P_{Im} denote respectively the percentage change of GDP deflator, average price of consumption, average price of investment, average price of government consumption, average price of export and import. S_C, S_I, S_G, S_{Ex} and S_{IM} denote respectively the share to GDP of consumption, investment, government consumption and export and import.

Based on the definition of the marginal product of labour and capital, equations B6 and B7 can be obtained (in percentage form for lower case letters),

$$rw = P_{GDP} - P_C + mpl\,(K, L) - t \quad (B6)$$

$$q = P_{GDP} - P_I + mpk\,(K, L) - t \quad (B7)$$

where rw is the real wage, q is the real rate of return of capital, P_{GDP} is the GDP deflator, P_C is the consumption price, P_I is the investment average price, mpl and mpk are respectively the marginal product of labour and capital, which are a function of labour L and capital K, and t is the increase of export carbon tax above the general tax level.

Furthermore, in this analysis framework it is assumed that the policy has no impact on the progress of technology in the short term. The percentage change in GDP (lower case letters denote percentage forms) is determined as follows (by omitting the change of tax revenue):

$$gdp = S_L \times l + S_K \times K \quad (B8)$$

where gdp, l and k are respectively GDP, labour and capital changes; and S_L and S_k are respectively the share of labour and capital to GDP.

Equations B5-B8 therefore provide the results analysis framework for the short-term impact of an ECT on real economic variables. ECT increases the general taxation charge and therefore t>0. Real wage can be considered as rigid in the short term, thus rw=0. Since the import price remains unchanged and the export FOB price increases after the ECT implementation, it can be written that $P_{Ex} - P_{Im} > O$. Note that the impact mechanism on the price of consumption and investment is similar, their price change in percentage forms could also be said to be identical. According to (B5), the GDP deflator decreases by a smaller amount than the consumption and investment prices, thus $P_{GDP} - P_C > O$ and $P_{GDP} - P_I > O$. However, as an induced effect, these changes should be inferior to the tax change, so $P_{GDP} - P_C - t < O$ and $P_{GDP} - P_I - t < O$.

According to (B6), mpl(K, L)>0 means that the marginal product of labour increases after the implementation of an ECT. This would lead to a decrease in employment, which the SICGE model gives as -0.05%. The relative reduction of employment would cause a reduction in the marginal product of capital and, according to (B7), it can be stated that q<0. The SICGE model finds the real rate of return of capital to be -0.061%. Capital remains unchanged in the short term, therefore, according to (B8), GDP reduction correlates to the labour changes. The simplified system obtained a GDP reduction of 0.023%, which differs to the SICGE model's result of 0.043%. This could be explained by the absence of the the tax impact (see equation (B8)) in the simplified analysis framework.

B.2.2 Estimation of GDP when taking tax revenue into account

According to **B.2.1**, the GDP decrease not only includes the loss of profit of primary factor, but also the loss of net welfare. This tax effect can be illustrated in the following simple partial equilibrium framework. In Figure B1, it is assumed that export tax was not implemented at first where the export level is Ex' and related export price is p'. Following the implementation of an export carbon tax, the export was reduced to Ex'' with an export price increasing to p''. The net welfare lost Δ WelfLost therefore can be written as

$$\Delta \text{ WelfLost} = 0.5 \times (EX' - EX'') \times (P'' - P') \quad \text{B9)}$$

Its contribution to GDP decrease, referred to as CONTax, can be obtained by

$$\text{CONTax} = \times \frac{\Delta \text{ WelfLost}}{\text{GDP}} \times 100$$

$$= 0.5 \times \frac{EX'}{GDP} \times ex \times \Delta C\ axRate \quad (B10)$$

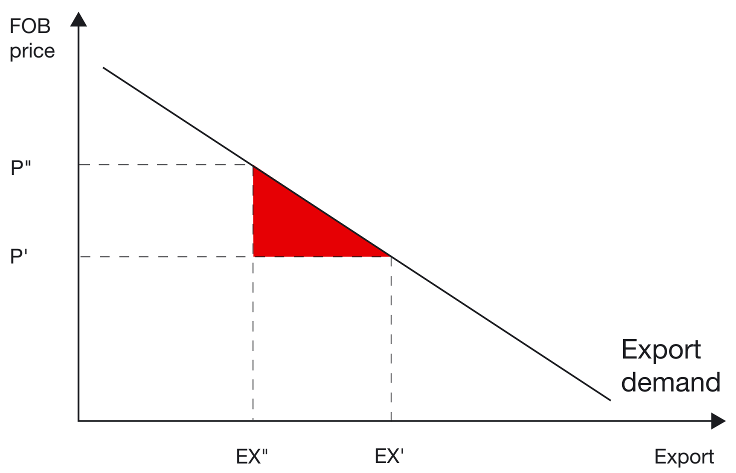
where Ex' and GDP are, respectively, the export amount and the GDP prior to ECT implementation, in 2007 the ratio of $\frac{EX'}{GDP}$ was 0.36. The percentage change of export ex is 0.185. ΔC axRate is the average tax burden of a carbon export tax on total export, which is 0.44%. By putting this data into (B10), the contribution of the GDP to the decrease in net welfare is found to be 0.015%. If this decrease is combined with the negative growth in GDP obtained in equation B8 (-0.023%), then a figure of -0.038% is obtained as the total GDP decrease following ECT implementation, based on this simplified analysis framework. This figure is close to the actual SICGE result (-0.043%).

B.2.3 Impact on GDP expenditure items

The impact of an ECT on household consumption is determined by the consumption price and GDP deflator. According to equation (B5), the household consumption price decreased to a greater extent than the GDP deflator after the implementation of an export carbon tax, which means that consumer goods would become relatively cheaper and therefore that the export carbon tax would trigger a positive effect on household consumption. The SICGE model gives a slight increase of 0.006%, compared to the baseline scenario, for household consumption .

In the SICGE model, the investment of year t is determined by the anticipated rate of return of capital in the future, which is obtained based on the real rate of return of capital of year t. According to the model and equation (B7), the real rate of return of capital decreased by 0.061% which results in a reduction of investment compared to the baseline scenario. Despite this, the investment price also decreased according to equation (B5), compensating in part for the investment reduction, for which the final value is -0.031% according to SICGE results. As the import price remained unchanged and the domestic price decreased, import demand decreased by 0.16% compared to the baseline scenario. ■

Figure B1. Welfare effect of export tax



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Is it in China's interest to implement an export carbon tax?

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