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An analysis on the short-term sectoral competitiveness impact of carbon tax in China

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HIGHLIGHTS

CARBON TAX Market-based instruments offer a level of cost-effectiveness that has recently drawn the attention of the Chinese government. Particularly, carbon tax has been frequently debated at ministerial level. However, there is little research focusing on the short-term impact on sectoral competitiveness in China.

SECTORAL VIEW We divided China's economy into 36 sectors, based on its 2007 input-output table, in order to examine the ratio of carbon tax added costs to sector GDP. We then divided the sectoral trade impact into domestic competitiveness with regards to foreign imported products and international competitiveness external to the Chinese domestic market.

COMPETITIVENESS We examined which industries will potentially be affected, and to what extent, by the implementation of a carbon tax in China in order to determine the tax rate and to consider compensatory measures that may be required to address sectoral differences.

APPROPRIATE TAX RATES A high tax level (100 yuan/t CO_2) may necessitate compensatory measures to a few highly affected industries; a low tax rate (10 yuan/t CO_2) would generate few competitiveness problems for all industries and may therefore be considered as an appropriate starting point.

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Introduction

China is now encountering a period of both potential energy shortages and challenges related to climate change impacts. Its energy deficiency in terms of coal and natural gas could reach 25% of total domestic production, while its oil import dependency could attain 60% by 2020 (Mao and Chen, 2008). China is currently one of the world's biggest CO_2 emitters, with an annual energy-related CO_2 emissions growth rate projected at 2.8% during 2006-2030, compared to 0.1% for OECD European countries over the same period (EIA, 2009). It is not possible for China to replicate the development pathways of industrialized countries; its modernization trajectory must instead coordinate economic growth with greenhouse gas emission control (He et al., 2009). However, combating climate change is certainly in China's own interest (Zhang, 2000), a realization that has helped the development of a political willingness to tackle the problem. This desire to take action was strengthened by the setting of ambitious targets that aim to reduce carbon intensity per unit of GDP by 40%-45% and to increase the share of new and renewable energies to 15% of the total energy consumption by the end of 2020, compared to 2005 levels. Command-and-control policies, such as the closure of small and inefficient thermal power plants and energy-intensive factories, limiting the expansion and installation of new energy-intensive industries etc., have been massively implemented in China, and it is likely that their usage will continue in future (Wu, 2009). As a major policy tool, these regulatory instruments have successfully contributed to the energy efficiency improvement targets and market restructuring objectives of the 11^{th} Five Year Plan (2006-2010) (Chen et al., 2009; Zhang, 2009a). However, command-and-control policies are usually associated with high implementation costs and can be unfavorable in terms of social fairness (OECD, 2007; Ye and von Weizsacker, 2009). A first problem is that they generate deadweight loss by ignoring the interfirm differences in marginal abatement costs or the marginal damages of emissions (Muller and Mendelsohn, 2009); secondly, the lack of a clear price signal means that they do not stimulate substitution between clean energies and fossil fuels and do not correct consumption behavior. With an expected annual GDP growth rate of 9% for the coming decade (Hu et al., 2009; IEA, 2009) a significant increase in quality of life standards is anticipated in conjunction with a consistently increasing energy demand from domestic, transport and industry sectors. Command-and-control policies alone are unlikely to be sufficient to enable China to overcome this energy-climate bottleneck.

Market-based instruments offer a level of cost-effectiveness that has recently drawn the attention of the Chinese government. The December 2007 *Communist Party's Central Committee Conference* on economic issues clearly demanded a "speeding up in the implementation of fiscal, tax, pricing and financial policies to save energy and reduce CO_2 emission". However, thus far there are no systematic fiscal measures dedicated to energy saving and CO_2 emissions reduction in China. The taxes that exist cover only a part of China's energy mix and pollution. For example, restrictive fiscal measures on exports (export tax, export VAT refund rebate, etc.), which are revised annually, have only been imposed on certain energy-intensive products, accounting for just a small share of total Chinese exports and GDP (Wang and Voituriez, 2009). Fees (charges) are imposed on 113 pollutant types including waste-water, solids, noise pollution and radioactive materials, etc. accounting for 0.4% and 0.067% of China's 2007 total taxation revenue and GDP respectively (Ministry of Environmental Protection of China). However, no fees are collected on carbon emissions. Resource taxes have been levied on coal, oil and natural gas (Liu, 2007), the revenue from which reached 26.1 billion yuan in 2007, accounting for 0.6% of the total tax revenue in that year (Ministry of Finance of China). However, despite the fact that such taxes help to reduce CO_2 emissions indirectly, they do not explicitly reflect the external carbon costs of different fossil fuels. In such context, a carbon tax levied on fossil fuels based on their carbon contents could give clear price signals on carbon cost (Baumol and Oats, 1998; Stern, 2009) and cover most of the CO_2 emission sources. It could not only strengthen China's efforts to develop a low carbon economy, but also provide a unmistakable signal to the international community regarding China's efforts in the fight against climate change, compared to other actions that have received limited international recognition (Zhang, 2009b).

Several quantitative studies have focused on the impact of a carbon tax in terms of China's economy, the mid- and long-term incentive effects and CO_2 emissions, for example: Su (2009) and Fan et al. (2009) studied the general impact of a carbon tax on China's CO_2 emissions and GDP growth, but did not analyze impacts on a sectoral level; Liang et al. (2007) examined five major energy-intensive sectors and looked at the impact of a carbon tax on their output, prices and emissions, along with proposed exemption and subsidy measures to alleviate the negative impacts on these sectors; Jiang et al. (2009) also calculated the impact of a carbon tax on sectoral output, with projections until 2050; Brenner et al. (2007) examined the distributional effect of a carbon charge on fossil fuels in China by distinguishing China's rural and urban expenditure patterns, they concluded that a carbon charge with revenue recycling on an equal per capita basis could lessen the rate of increase in energy consumption and reduce income inequality; and Li (2003) adopted an econometric model projecting China's energy use under a carbon tax of 36.7 dollar/t CO_2 and concluded that it could contribute effectively to reducing energy consumption by 2030.

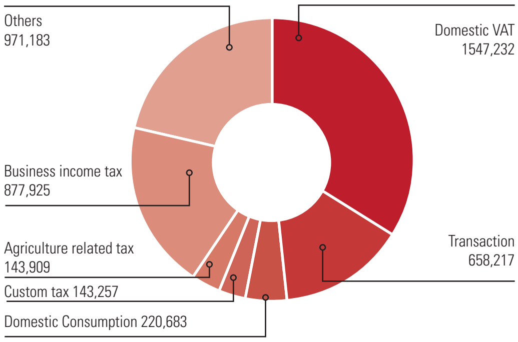
However, few studies focus on the short-term impacts of carbon tax when analyzed entirely at the sectoral level, particularly in relation to energy-intensive sectors. Carbon tax delivers a direct impact to energy-intensive industries by increasing their marginal production costs. This could potentially weaken the competitiveness of Chinese industries, on both international and domestic markets, and provoke fluctuations in related industries. It is therefore crucial, particularly for policy makers, to examine which industries will potentially be affected, and to what extent, by the implementation of a carbon tax in China in order to determine the tax rate and to consider compensatory measures that may be required to address sectoral differences. This paper is organized as follows: section 2 provides a brief introduction to China's fiscal regime; section 3 introduces a method for measuring the short-term impacts of carbon tax on competitiveness and related data; section 4 presents the results and examines the potential effects of carbon tax on different sectors by distinguishing various sectoral characteristics; and finally, we discuss our conclusions in section 5.

1. China's fiscal system

Since its economic transformation in 1978, China's taxation system has experienced several major reforms intended to make it better adapted to an emerging society characterized by fast economic growth (Lin, 2008; Liu, 2007; Toh and Lin, 2004). The Ministry of Finance generally implements fiscal policies under the authorization of the State Council or sometimes the People's Congress if legislatory procedures are required. The State Taxation Administration of China is responsible for tax collection, which it coordinates with local governments and local taxation administrations.

Under the current fiscal regime, there are more than twenty tax categories in existence, including: value-added tax, consumption tax, transaction tax, business income tax, personal income tax, resource tax, city and town land use tax, real estate tax, building tax, urban real estate tax, urban maintenance and construction tax, tax on occupation of cultivated land, land value-added tax, vehicle purchase tax, vehicle and vessel tax, stamp tax, contract tax, tobacco leaf tax, custom tax, tonnage dues, tax of adjustment for the orientation of fixed investment, etc (State Administration of Taxation of China). Value-added tax is the major source of tax revenue in China, accounting for 34% of the total tax revenue in 2007. Together with transaction tax and business income tax, they account for 68% of the total tax revenue (see Figure 1).

Figure 1. Tax revenue components in China 2007



Source: National Bureau of Statistics, China. Unit: billion Yuan.

2. Impact of a carbon tax on competitiveness in China

2.1 Method

In accordance with recent carbon tax implementation proposals in China, for our calculations we assumed that a carbon tax would be implemented and collected on fossil fuel production, based on its carbon content. We presumed that carbon content would be measured in terms of actual carbon emissions into the atmosphere during combustion, providing a true reflection of a fuel's contribution to global warming. The nature of tax collection allowed us to make two further assumptions. Firstly, we assumed that imported goods, except fossil fuels, would not be affected by this carbon tax. Secondly, we hypothesized that exported goods would not receive a carbon tax refund. In China, the prices of oil and natural gas are still regulated by government control; only the coal market is liberalized (Wang, 2007). As a consequence, predicting the price impact of carbon tax on fossil fuels other than coal becomes more difficult due to the influence of the government-controlled mechanism that may limit increases in the market price. However, for reasons of simplicity, we made the assumption that a carbon tax will engender immediate short-term impacts by increasing the market price of all fossil fuels and that the incremental price (cost) would be wholly passed on to downstream industries. This assumption seems reasonable since the government could authorize incremental carbon costs on fossil fuels to be passed through to downstream producers as part of a price control regime. As a result, carbon cost differentiation may greatly increase the production costs of industries that rely heavily on fossil fuels compared to industries with less intensive fossil fuel usage.

To calculate the carbon cost for each sector, we used a similar approach to Hourcade et al. (2007) and divided the incremental carbon cost into direct and indirect costs. The calculation of the direct cost caused by the carbon tax was based on the fossil fuels used in a sector's production procedures. Indirect cost is related to the increase in a sector's production costs due to the impact of the carbon tax on the price of electricity. We have assumed that this indirect electricity cost is totally absorbed by downstream producers, regardless of the fact that the price of electricity in China is subject to governmental control and capping. As above, this assumption appears logical, based on the possibility that there could be governmental authorization to allow the full rate of electricity carbon cost to be passed on. We applied the following procedure to study the impact of carbon tax on the competitiveness of different sectors: firstly, direct and indirect CO_2 emissions from industrial production processes were calculated. The direct emissions of a given sector i, which are expressed as DCO_{2i}, are caused by the use of fossil fuels in the production processes of that sector. DCO_{2i}, can be calculated using equation (1) where E_{ij} represents the jth energy consumption of sector i, C_j is the carbon content of jth energy and rb_j is its combustion rate.

$$DCO_{2i} = \sum_j E_{ij} \times C_j \times rb_j \qquad (1)$$

The indirect emissions ICO_{2i} of each sector are emissions related to electricity consumption during industrial production. These emissions can be calculated using equation (2), where Ele_i is the electricity consumption of sector i, and C is the units of carbon emissions from electricity in China.

$$ICO_{2i} = Ele_i \times C \quad (2)$$

Constrained by the unavailability of data on the exact amounts and specific usages of electricity for any given sector in China, we made the assumption that the electricity consumed by each sector has the same composition and thus represents an average value. The carbon emission intensity per unit of electricity C can be obtained by breaking down the general electricity production structure in China, according to equation (3):

$$C = \frac{\sum_k El_k \times EC_k \times Erb_k}{TEI} \quad (3)$$

where El_k represents the electricity generated by the consumption of the kth type of fossil fuel; and EC_k and Erb_k indicate respectively the carbon content of the kth fuel and its combustion rate. TEI is the total electricity (both thermal and non-thermal electricity) generated during a given year.

Direct (DC_i) and indirect (IC_i) costs that could result from a carbon tax for a given sector i are obtained by equations (4) and (5), where t denotes the carbon tax rates, DCO_{2i} is the sector's direct CO_2 emissions and ICO_{2i} is its indirect CO_2 emissions.

$$DC_i = t \times DCO_{2i} \quad (4)$$

$$IC_i = t \times ICO_{2i} \quad (5)$$

The potential short-term impacts of a carbon tax to a sector could then be measured using equations (6) and (7), where CtV_i represents the incremental carbon cost (which is a sum of direct cost DCO_{2i} and indirect cost ICO_{2i}) divided by a sector's value-added VA_i, and where $GDPS_i$ is equal to a sector's value-added divided by the total Chinese GDP. The higher the CtV, the larger the impact of the carbon tax on that sector; the higher the GDPS, the bigger the effect of a carbon tax on total GDP.

$$CtV_i = \frac{DC_i + IC_i}{VA_i} \quad (6)$$

$$GDPS_i = \frac{VAi}{GDP} \quad (7)$$

We examined sectoral trade intensity in an open economy based on the commonly used method [30,31] (EU Commission, 2009; Hourcade et al., 2007). Generally, the rate of trade intensity provides a first indication of a sector's level of exposure to the world economy. A higher rate indicates a higher level of a sector's involvement with the world exchange. For the Chinese situation, we have described the potential impacts of a carbon tax on both the exports and imports of a sector, through the use of the terms import intensity (IMI_i) and export intensity (EXI_i), which can be obtained by equations (8) and (9):

$$IMI_i = \frac{Im_i}{(Y_i - Ex_i + Im_i)} \quad (8)$$

$$EXIi = \frac{Ex_i}{(Y_i - Ex_i + Im_i)} \quad (9)$$

where Im_i indicates the ith sector's import, Ex_i the ith sector's export and Y_i the total output (turnover) of sector i.

Import intensity provides a measure of the domestic market share of foreign products. A high rate could be an indication of a high degree of market openness and a severe level of competition. The impact on the competitiveness of a carbon tax may be more significant on sectors with higher IMI than sectors with lower IMI. IMI level can also be used as a measure of a sector's dependency on foreign products, in the case where an industry has little domestic competition. In these instances, the effect of a carbon tax on competitiveness becomes almost neutral.

The export intensity provides a measure of the rate of exported goods to domestically supplied (consumed) goods in a given sector. This figure was used to examine sectoral distribution between domestic and international markets. The higher the rate, the higher the export dependency of that sector. A carbon tax could have a greater impact on sectors with higher EXI compared to those with lower EXI through its affect on international market performance. It should be noted that a sector's carbon intensity is at the core of the determination of its competitiveness. Through the separation of the impacts on domestic and international market competitiveness, it provides differentiation for further compensatory measures. For example, export refunding measures could be adopted for sectors that are negatively affected in terms of their export competitiveness, while other measures could be implemented for sectors that compete mainly at the domestic level.

Finally, it should be stated that we used total output instead of GDP when measuring IMI and EXI in order to maintain the gross value. However, gross value may not be the ideal proxy for measuring competition since domestic value may be embedded in imports, while exports may include foreign value. A better measurement could be the use of value-added in domestic and foreign industries to reflect their competitiveness and how a carbon tax may affect it. Koopman et al. (2008) provide a method to extract the value-added from Chinese exports by distinguishing processing trade and normal trade, however it remains difficult to calculate the value-added for goods imported to China since this would require each imported product to be distinguished according to its country of origin.

2.2 Data

We used 2007 data for our calculations, a decision that was not made arbitrarily. This data was not only the most up-to-date available but in our view provides the most representative picture of the Chinese economy, compared to subsequent data that reflects the impact of the world economic crisis, and data from previous years where China's economic structure was very different from the situation today.

In China, sectors are currently classified according to the GB/T4754-2002[1] standard. Similar to the NACE system, sectors are designated by a higher case letter, indicating the section name, followed by three numbers: there are 20 sections (from A to T), the first number, which ranges from 1 to 98, indicates the division, the next number represents the group, while the final number further divides the groups into classes. Under GB/T4754-2002, the 2007 Chinese Economy Input-Output Table divides into 135 sectors. To facilitate our analysis and for clarity, we consolidated these 135 sectors into 36 representative groups, as shown in Table 1. The sectors shown are defined according to GB/T4754-2002 down to the group number level.

1. See National Bureau of Statistics of China for detailed information. http://www.stats.gov.cn/tjbz/

Table 1. Consolidated sectors, classifications according to GB/T4754-2002 (down to group number)

Sectors	sectors under GB/T4754-2002
Agriculture, Forestry, Animal Husbandry, Fishery and Water conservancy	A1-5
Coal mining and washing	B6
Oil and gas exploitation	B7
Ferrous metal mining	B8
Non-ferrous metal mining	B9
Other mining	B10-11
Food and tobacco	C13-16
Textile	C17
Clothing, leather and product	C18-19
Lumber and furniture	C20-21
Pulp & Paper	C22
Printings and media recording	C23
Education and sport product	C24
Petroleum refining, coking and nuclear materials production	C25
Basic chemicals	C26
Drugs	C27
Chemical fibre products	C28
Rubber products	C29
Plastic products	C30
Non-metallic mineral products	C31
Ferrous metal	C32
Non-ferrous metal	C33
Metal products	C34
Mechanic equipment	C35-36
Transportation equipment	C37
Electronic equipment and machinery	C39
Communication, computer and other machineries	C40
Apparatus, cultural and office equipment	C41
Other manufactures	C42-43
Electricity & Heat	D44
Gas production and supply	D45
Water production and supply	D46
Construction	E47-50
Transport and stock	F51-59
Trade, accommodation and restaurant	H63,65; I66-67
Other services	G60-62; J68-71; K72; L73-74; M75-78;N79-81;O82-83; P84; Q85-87; R88-92; S93-97; T98

Table 2 provides the outline of China's input-output table (Zhang and Zhao, 2009). It is given in its competitive form where imports are included in the intermediate and final uses. Since our study aimed to examine the impacts of carbon pricing on sectors, we needed to maintain the total value-added for each sector. It was therefore unnecessary to make further distinctions between domestic and foreign value-added for each sector and the competitive type input-output table was thus suitable for our purposes.

According to the 2007 Input-Output table of the Chinese economy, the sector value-added is obtained from the "total value-added" row, and the total Chinese GDP is given by the sum of the sectoral value-added. Sector turnover is obtained from the corresponding "gross output" column, and export and import values are obtained from the "exports" and "imports" columns for each sector. The value of imports is calculated according to CIF (Cost, Insurance and Freight) plus custom duty, and the exports are measured by the FOB (Free On Board) price. All values refer to 2007 producer prices, which includes value-added tax (which is different to the *System of National Accounts* (SNA) 1993).

The fossil fuel consumption per sector in 2007 was obtained from the China Energy Statistical Year Book 2008 (ESY). The ESY contains energy consumption data from 44 sectors which are also classified under the GB/T4754-2002 standard. This allowed us to regroup the 44 sectors into our 36 consolidated sectors for the purposes of our study, and to obtain the corresponding energy consumption data for each sector. The carbon contents and combustion rates of fossil fuels used in equation (1) were obtained respectively from IPCC (2006) and Ou et al. (2009) (see Table 3).

In 2007, 82.9% (2722.9 TWh) of electricity generated came from thermal power plants. Table 4 lists the specific amounts of fossil fuels used for thermal electricity generation in 2007 in China. We thus calculated China's average electricity carbon emissions *C* to be 776.56 g CO_2/kWh (equivalent to 215.71 g CO_2/MJ) according to equation (3).

To demonstrate the different impact levels of a carbon tax, we assumed three scenarios where a carbon tax would be implemented at high, medium and low rates from the outset, respectively 100 yuan/t CO_2 (named A1), 50 yuan/t CO_2 (A2) and 10 yuan/t CO_2 (A3) (approximately 10, 5 and 1 euro/t CO_2, respectively). Historically, carbon tax is almost always implemented progressively. The short-term competitiveness impacts of the medium and high tax rates allow us to examine two important areas: first, whether these rates would be unacceptably high as starting points, from the point of view of competitiveness; second, they can be considered as providing an example of

Table 2. China input-output table structure.

OUTPUT / INPUT		Intermediate Use				Final Use										Imports	Errors	Gross Output
						Final Consumption					Gross Capital Formation							
						Household Consumption												
		Agriculture	…	Public administration and other sectors	Total intermediate use	Rural	Urban	Sub-total	Government	Total Final Consumption	Gross fixed capital formation	Change in inventories	Sub-total	Exports	Total Final Use			
Intermediate Inputs	Agriculture	Intermediate transaction				Final demand												
	…																	
	Construction																	
	…																	
	Public administration and other sectors																	
	Total Intermediate Inputs																	
Value Added	Depreciation of fixed capital	Primary input																
	Compensation of employees																	
	Net taxes on production																	
	Operating surplus																	
	Total Value Added																	
Total Inputs																		

a sudden augmentation in the tax rate under a progressive tax regime, allowing us to study the different sector competitiveness impacts and to look at the respective compensatory measures that may be necessary.

Table 3. Unit carbon content and combustion rate of major fossil fuels in China

	Coal	Coke	Oil	Gasoline	Kerosene	Diesel	Fuel Oil	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 4. Fossil fuel inputs in thermal power generation in China and their carbon contents, 2007

	EI_k	EC_k
	10000tce	(tC/TJ)
Coal	89908.4	25.8
Coke Oven gas	488.6	12.1
Other Gas	376.3	12.1
Crude Oil	22.7	20.0
Gasoline	0.2	18.9
Diesel	337.2	20.2
Fuel Oil	808.0	21.1
Refinery gas	59.1	15.7
Other Petroleum product	43.7	20.0
Natural Gas	1073.0	15.3
Other Energy	416.6	0.0

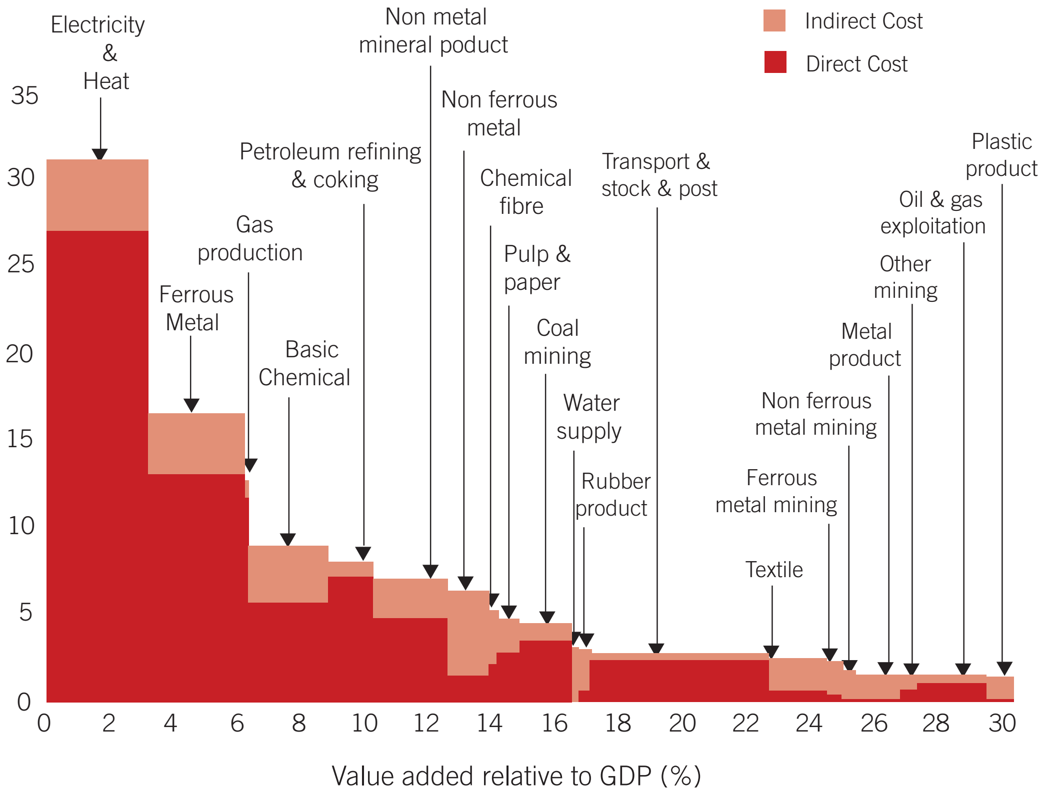
Source: *: Electricity Balance Sheet of China 2007, Energy Statistical Yearbook 2008;
**: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 Energy table 1.4;
Note: In thermal power generation, all energy inputs are considered to be used as fuels. Therefore, we have Erb_k=1 for all k in equation [3].

3 Results

3.1 Sector carbon costs per value-added and per GDP share

From our results we selected 20 sectors out of the total 36 that were the most affected by the carbon tax according to their ratios of incremental carbon costs to sector value-added (CtV). As shown in figure 2, with a carbon tax of 100 yuan/t CO_2, CtV levels across the different sectors can be approximately divided into three categories: high, medium and low. Electricity, heat production and supply, ferrous metal, gas production and supply sectors have the highest CtV. The medium category, which comprises eight sectors, all have CtV levels that are much lower than the high group, while the remaining sectors have low CtV levels. Similar results were obtained under scenarios A2 and A3. Results of A2 and A3 could be obtained by replacing the unit of vertical axis of A1 with 2.5, 5, 7.5, etc. and 0.5, 1, 1.5, etc., respectively.
The CtV value implicitly reflects the carbon GDP intensity of each sector. The value can be obtained by dividing CtV by the carbon tax unit rate. Further considerations regarding calculations of sector carbon intensity with related results can be found in the appendix.
Our results suggest that the electricity and heat supply sectors are likely to be the most affected industrial activities out of the 36 sectors, due to their high reliance on fossil fuels. The CtV for these activities was more than 30% in scenario A1 and 15% and 3% respectively for A2 and A3. However, as previously mentioned, we made the assumption that the CtV increase due to carbon tax for the electricity generation sector would be totally passed on to downstream producers, thus the incremental carbon cost would not be a burden to the sector itself. Furthermore, the electricity and heat markets in China can be considered as a state monopoly, with most of the electricity and heat being self-supplied with little foreign input (Ngan, 2010). Therefore, the competitiveness impact of a carbon tax in this sector would be slight. The same reasoning applies to the gas production and supply sector, for which the incremental carbon price should again be passed on wholly to downstream producers.
The next section of this article examines the cost impact of carbon tax on the remaining manufacturing sectors. However, the quantified results of the electricity, heat and gas production and supply sectors remain present in the figures below to demonstrate clearly the sectoral fossil fuel intensity.
Among all the manufacturing sectors,the ferrous metal production sector potentially becomes the most affected sector once carbon tax has been implemented. Its CtV is 16.7%, 8.3% and 1.7% respectively under scenarios A1, A2 and A3. This implies a high fossil fuel intensity, particularly the high coal dependency of China's ferrous metal production sector. The

Figure 2. Impact of carbon tax on value-added at 100 yuan/t CO_2



CtV level is significantly lower for the other sectors. Generally, this means that these sectors are implicitly much less carbon intensive than the ferrous metal sector. The CtV value of the basic chemical sector is almost half that of the ferrous metal sector with 9.1%, 4.5% and 0.9% respectively under A1, A2 and A3 scenarios. The CtV of the following manufacturing sectors escalates moderately from petrol refining and coking sector to coal mining sector under A1, A2 and As scenarios. The CtV of the rest of sectors remains relatively close to each other under all thress scenarios.

To define the scale effect of the impact on competitiveness in terms of GDP, we arbitrarily chose a CtV value at 1.5% above that which a carbon tax may be deemed to potentially affect a sector's competitiveness. Under scenario A1, 20 sectors are included, the sum of their sectoral value-added accounting for 27.1% of the total Chinese GDP (See Figure 2). Our calculations showed that three sectors had a sector value-added per total GDP (VtG) of more than 3% (including the electricity and heat sector); three sectors had a VtG of between 2 and 3%; and five sectors had a VtG of between 1 and 2%. VtG values for the remaining sectors were below 1%. Under scenario A2, 12 sectors with a total sector value-added accounting for 13.9% of the total GDP could potentially be affected by a carbon tax. Under scenario A3, only the ferrous metal sector, representing 3% of the total Chinese GDP, could be considered to be vulnerable.

3.2 Import intensity and domestic market competitiveness

To include the maximum number of sectors that a carbon tax could potentially affect, we studied the import intensities of sectors with a CtV above 1.5% under scenario A1 (see Figure 3). The further a sector is from the zero point in figure 3, the higher the potential that the sector's domestic competitiveness as regards foreign products is affected. In general, sectors with import intensities of greater than 10% that a carbon tax could potentially affect account for 6.9% of the total Chinese GDP under scenario A1.

We can replace the unit of horizontal axis of

Figure 3. Import intensities of potentially affected sectors under scenario A1.

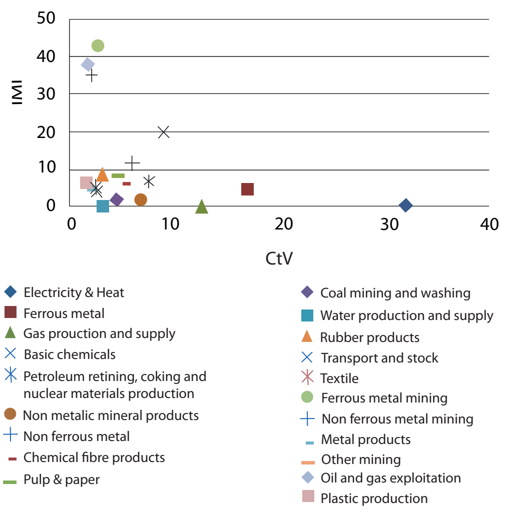


figure 3 by 5, 10, 15, etc. and 1, 2, 3, etc. in order to obtain A2 and A3, respectively. Under a CtV threshold of 1.5% and import intensities of greater than 10%, eight sectors (from transport and stock to plastic products in figure 2) would need to be removed from figure 3 under scenario A2, and only electricity and ferrous metal sectors would remain under scenario A3. Sectors with a CtV that is inferior to 1.5% would be unaffected by carbon tax, regardless of their import intensity.

It is necessary to differentiate between the characteristics of each sector in order to examine the import intensity effect. As shown in figure 3, the sectors with the highest import intensity rates are mainly composed of activities involving raw materials, including metal mining, oil and gas exploitation and basic chemicals. For the metal mining sectors (both ferrous metal mining and non-ferrous metal mining), some mining product imports (ores, for example) are conducted through contracts signed between Chinese domestic purchasers and foreign suppliers, of which the price and quantity provisions are predetermined for a given period that is usually longer than a year. The world supply capacity of such raw materials is limited and the short-term identification of new suppliers is difficult. In consequence, the possibility of an impact on short-term import intensity is low, even if the carbon cost effect is significant regarding the price difference between domestic and imported products. For oil and gas exploitation sectors, as the products are fossil fuels which could be directly affected by a carbon tax through the import process, there will be no carbon cost difference in price and thus no substitution effect between domestic and imported products. For the basic chemical sector, its high import intensity may potentially lead to a substitution effect between domestic and imported products. The higher the carbon tax rate, the stronger the effect. Therefore, the domestic sector per se may be affected by increasing imports in the short term. The same conclusions can be drawn regarding the non-ferrous metal sector. However, it is worth noting that some of the products from these two sectors are frequently used to produce other goods with much higher value-added. Further studies could focus on the ratio of incremental carbon cost to final product value-added. The lower the ratio, the higher the chance that the carbon cost difference between the domestic and imported materials of such sectors would be negligible to downstream producers in the short term. Therefore, the impact on domestic competitiveness could remain ambiguous even under a high carbon tax scenario.

3.3 Export intensity and international competitiveness

Similarly to section 4.2, we set a threshold of 1.5% CtV and an export intensity (EXI) of 10%, above which a sectors' international competitiveness was likely to be affected. Figure 4 presents the results under scenario A1, with the aim of including the maximum number of sectors that could be affected. As figure 4 shows, major energy-intensive sectors such as metal, chemical, pulp and paper, etc. have lower export intensities than other industries. This explains the domestic consumption-driven effect of energy-intensive products in China (Wang and Voituriez, 2009). In general, if we maintain the threshold levels of CtV and export intensity at 5% and 10% respectively, four sectors, which account for 10% of the total Chinese GDP, may require further examination regarding the impact of a carbon tax on their international competitiveness.

By replacing the unit of horizontal axis of 10, 20, 30, etc. in figure 4 by 5, 10, 15, etc. and 1, 2, 3, etc. respectively, we could obtain the

Figure 4. Export intensity of potentially affected sectors under scenario A1

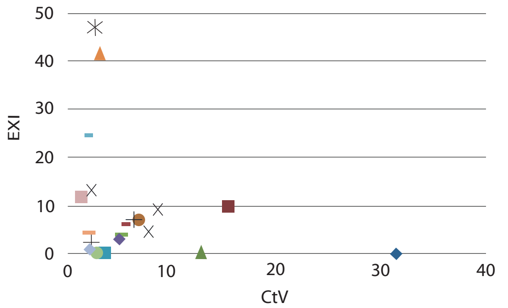
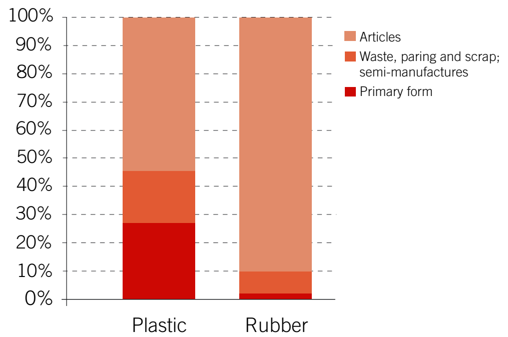


Figure 5. Share of exported products (in quantity) of plastic and rubber sectors at HS 4-digit in 2007.



Source: China Customs House.

Note: At HS-4 level, primary products of plastic include HS3901-3914, semi-manufactures include HS3915-3921 and final articles include HS3922-3926. Primary products of rubber include HS4001-4003, semi-manufactures include HS4004-4010 and final articles include HS4011-4017.

export intensity figures under scenario A2 and A3. Under the same 1.5% CtV and 10% EXI threshold for all three scenarios, eight sectors (from transport and stock to plastic products) can be removed from figure 4 under scenario A2, and only the electricity and ferrous metal sectors remain in scenario A3. The sectors with a CtV of less than 1.5% would be unaffected by a carbon tax, regardless of their export intensities.

The textile sector possesses the highest export intensity of all the energy-intensive sectors and, if we maintain the threshold level of export intensity at 10%, the next highest sectors are rubber, metal products, transport and stock, and plastic. Given the near homogeneity of the energy-intensity embedded into products in the textile and metal product sectors, in general their export competitiveness will potentially be affected by a carbon tax at the sector level. Assessing the impact on the transport and stock sector's export competitiveness depends on further data on its fossil fuel component.

We also focused on measuring the impact of the plastic and rubber sectors' export competitiveness by distinguishing different product types at export level. Figure 5 shows that the main type of exported goods are final products which usually have higher value-added and lower carbon intensities than primary products. The carbon incremental cost may account for a smaller proportion of the total value-added of final products in comparison to the primary or intermediary products of these sectors. Therefore, the export competitiveness impact on the final products could be less significant than on the primary products and the total sector competitiveness impact may be reduced.

Further studies on the price rigidity of certain products in these sectors should be made. Since China is a price maker for these exported products, the incremental carbon cost will therefore have little impact on the export competitiveness of such products.

3.4 Choice of threshold

The advantage of the threshold method applied here is that it allows an immediate assessment and rapid identification of sectors that would be vulnerable in the short term following the implementation of a carbon tax. However, our choice of the threshold levels (CtV, import and export intensity) to measure competitiveness impacts was arbitrary. Moreover, the threshold level does not necessarily have to be the same for all sectors. We have therefore provided related data in Table 5 of the appendix to assist those interested in further studies in this area.

To highlight one example of the changes that can be initiated by a different threshold, if the CtV threshold was increased to 5%, this would lead to nine sectors accounting for 11% of total Chinese GDP, and one sector accounting for 3%, that could be considered as being potentially vulnerable to a carbon tax under scenarios A1 and A2. Neither sector would be at stake under scenario A3. In the case of import intensity, if thresholds of 5% and 30% respectively were set for CtV and import intensity, above which a sector may be considered susceptible to carbon tax implementation in China, then only basic chemical and non-ferrous metal sectors, which account for 3.9% of the total Chinese GDP, would be affected under scenario A1. No sectors would be implicated under scenarios A2 and A3. A similar threshold combination applied to export intensity would not put the sector export competitiveness at risk in all three scenarios.

Conclusion

This paper has demonstrated that a carbon tax may cause turbulence to the short-term competitiveness of the Chinese economy in general with the potential impact differing among sectors. Within a sector, the competitiveness effect will also vary on domestic and export markets. The tax rate is a key determinant of the competitiveness impact. As we have demonstrated, if a carbon tax was implemented at the low rate used in this paper, no significant competitiveness impacts at the sector level would be generated. If a carbon tax was progressively augmented for environmental reasons following implementation, certain compensatory measures may be necessary, according to sector specificity, to keep the negative impacts to a minimum level. Further studies would be required at the sub-sector level, similar to the example described in section 4.3, in order to provide a more solid basis for decision-making on compensatory measures. In this study we did not provide examples of concrete compensatory measures or examine the possibility of a tax revenue redistribution system. These issues should also be the subject of further studies.

In this article we focused mainly on the domestic side of carbon tax. One issue that emerged from our analysis regarding competitiveness from an international aspect is the comparability of a carbon tax in China with other climate policies in developed countries, such as for example the European Union Emission Trading Scheme (EU ETS). Given the "common but differentiated responsibility", it becomes difficult to measure whether a certain carbon tax rate is equivalent to EU policies in terms of an absolute tax rate. If the criterion is that advanced developing countries are able to commit to reduce CO_2 emissions by 15 to 30% by 2020, based on the 1990 level compared to their business-as-usual (BAU) scenario (Council of the European Union, 2009), a low rate carbon tax itself cannot be considered as an equivalent measure to the EU ETS. However, if the criterion is the impact of climate policies on industrial competitiveness, then our study shows that a carbon tax in China could potentially affect industries representing a greater share of the GDP than the EU ETS[2] would, and thus on this basis it could be considered as an equivalent effort. ■

2. Several studies adopt a similar method to examine the impact of a carbon cap-and-trade system to EU and US industrial competitiveness. They demonstrate that within a threshold of 4% total carbon cost to sector value-added, a carbon trading system would influence around 1.1% and 1.5% of total British and German GDP respectively, with 20 euro/t CO_2 at full auctioning (Hourcade et al., 2007); and around 2% of US GDP, with 20 dollar/t CO_2 fully auctioned (Grubb et al., 2009).

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Appendix

Related results on sector carbon intensity

Sector carbon intensity CI_i can be obtained by equation (10) based on data provided in Table 5 where DC_i and IC_i denote respectively the sector's direct and indirect carbon cost to value-added in percentage form, t denotes the carbon tax rate (yuan/t CO_2).

$$CIi = \frac{DCi + ICi}{t \times 100} \quad (10)$$

Table 5. Results of related calculations

	DCi			ICi			GDPS	IMI	EXI
	A3	A2	A1	A3	A2	A1			
Electricity & Heat	2.715	13.576	27.153	0.408	2.044	4.088	3.311	0.057	0.207
Ferrous metal	1.318	6.591	13.183	0.356	1.781	3.562	3.044	4.318	9.54
Gas production and supply	1.182	5.914	11.829	0.159	0.796	1.592	0.083	0	0
Basic chemicals	0.579	2.897	5.795	0.327	1.639	3.279	2.509	19.869	9.188
Petroleum refining, coking and nuclear materials production	0.732	3.66	7.32	0.086	0.43	0.86	1.41	6.665	3.529
Non-metallic mineral products	0.49	2.453	4.906	0.233	1.167	2.334	2.354	1.738	6.837
Non-ferrous metal	0.156	0.783	1.566	0.493	2.466	4.933	1.439	12.259	6.796
Chemical fibre products	0.229	1.147	2.294	0.302	1.514	3.029	0.27	4.818	5.983
Pulp & Paper	0.301	1.509	3.018	0.188	0.944	1.889	0.682	7.193	3.632
Coal mining and washing	0.359	1.797	3.594	0.106	0.533	1.067	1.664	2.001	2.434
Water production and supply	0.012	0.061	0.122	0.316	1.584	3.168	0.206	0	0
Rubber products	0.081	0.408	0.816	0.235	1.175	2.351	0.331	8.386	41.922
Transport and stock	0.258	1.293	2.586	0.027	0.137	0.275	5.631	3.741	13.664
Textile	0.082	0.414	0.829	0.18	0.901	1.802	1.847	4.597	46.157
Ferrous metal mining	0.049	0.247	0.495	0.199	0.995	1.99	0.453	43.474	0.011
Non-ferrous metal mining	0.025	0.129	0.258	0.167	0.836	1.673	0.36	34.577	2.182
Metal products	0.026	0.132	0.265	0.144	0.723	1.446	1.385	3.968	24.155
Other mining	0.075	0.379	0.759	0.088	0.444	0.889	0.567	7.507	3.759
Oil and gas exploitation	0.12	0.601	1.203	0.042	0.214	0.429	2.141	38.125	1.147
Plastic products	0.026	0.131	0.263	0.133	0.665	1.331	0.847	5.847	12.383
Drugs	0.049	0.246	0.493	0.065	0.326	0.652	0.774	5.881	9.838
Food and tobacco	0.05	0.254	0.509	0.048	0.241	0.483	3.825	3.814	4.611
Mechanic equipment	0.04	0.2	0.401	0.058	0.292	0.584	3.426	17.266	14.063
Transportation equipment	0.031	0.156	0.312	0.051	0.256	0.512	2.414	9.184	10.037
Lumber and furniture	0.027	0.136	0.272	0.053	0.268	0.537	0.982	3.059	27.426
Education and sport products	0.015	0.078	0.156	0.058	0.291	0.583	0.233	10.252	136.063
Apparatus, cultural and office equipment	0.011	0.056	0.113	0.062	0.314	0.629	0.287	76.221	39.861
Electronic equipment and machinery	0.012	0.061	0.122	0.058	0.29	0.581	1.739	14.455	28.722
Communication, computer and other machinery	0.009	0.046	0.092	0.055	0.277	0.555	2.558	45.134	59.198
Agriculture, Forestry, Animal Husbandry, Fishery and Water conservancy	0.036	0.181	0.362	0.026	0.132	0.265	10.772	4.604	1.317
Printing and media recording	0.01	0.05	0.101	0.052	0.26	0.521	0.42	2.074	5.554
Other manufacture	0.014	0.074	0.149	0.044	0.221	0.443	2.007	16.584	23.015
Clothing, leather and related products	0.017	0.089	0.178	0.038	0.193	0.387	1.515	4.679	43.606
Trade, accommodation and restaurant	0.021	0.107	0.214	0.031	0.157	0.315	8.607	1.327	12.032
Construction	0.02	0.101	0.202	0.016	0.082	0.165	5.455	0.353	0.653
Other services	0.011	0.055	0.111	0.02	0.101	0.203	24.434	3.621	3.871

Note: all results in percentage form.

idées

pour le débat

An analysis on the short-term sectoral competitiveness impact of carbon tax in China

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