CO_2 EMISSIONS EMBODIED IN CHINA'S TRADE AND REDUCTION POLICY ASSESSMENT

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Abstract

China is the world's largest emitter of carbon dioxide (CO_2) and is one of the world's largest exporters. In 2007, CO_2 emissions embodied in China's net exports totaled 1176 million metric tons (mmt), accounting for 22% of China's CO_2 emissions. We calculate CO_2 emissions embodied in China's net exports using the latest release of a multi-regional input-output database developed by the Global Trade Analysis Project (GTAP 8). We find that the majority of China's export-embodied CO_2 is associated with production of machinery and equipment rather than products traditionally classified as energy intensive, such as steel and aluminum. The largest net recipients of embodied CO_2 emissions from China include the EU (360 mmt), the US (337 mmt) and Japan (109 mmt). We also develop a global general equilibrium model with energy and CO_2 emissions detail. We use the model to analyze the impact of a sectoral shift from energy-intensive industry to services and a tax on energy-intensive exports, which reflect policy objectives in China's Twelfth Five-Year Plan (2011-2015) on CO_2 emissions embodied in China's net exports and on global CO_2 emissions. We find that while both policies reduce China's export-embodied CO_2 emissions, global there is only a small change in global CO_2 emissions.

Key words: embodied CO_2 emissions, multi-regional input-output analysis, computable general equilibrium (CGE) analysis

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1. Introduction

China's rapid growth over the last thirty years has brought great benefits but has come at a cost of massive increases in energy use and heavy environmental damage. With the rapid growth of its economy and international trade linkages, China has become the world's largest exporter, the second largest importer and the second largest national economy in the world (World Bank 2012). In 2010, China was responsible for 20% percent of global energy demand (BP, 2011) and surpassed the US to become the largest energy consumer and CO_2 emitter in the world (International Energy Agency, 2011). A large portion of the CO_2 emissions in China is embodied in goods produced for export and consumed by other countries. In 2007, China's net exports of embodied CO_2 emissions totaled 1176 million metric tons (mmt), accounting for 22% of its total domestic emissions.

How to account for emissions embodied in trade is an important issue in discussions of how to allocate responsibility for greenhouse gas emissions reductions between developed countries and developing countries. Comparative advantage has resulted in the relocation of many labor-intensive industries, such as manufacturing, from developed countries to developing countries. Given that developing countries generally have less advanced production technologies and fewer environmental restrictions, the shift of manufacturing is often considered tantamount to a transfer of environmental impacts from developed countries to developing countries (Copeland & Taylor, 1994, 1995; Muradian et al., 2002). Quantitative evaluations of the environmental cost embodied in trade have been conducted by numerous studies at the global level (Chen & Chen, 2011; Davis & Caldeira, 2010; Peters & Hertwich, 2008; Skelton et al., 2011). and at the regional level, including for the US (Weber & Matthews, 2007), Austria, (Munoz & Steininger, 2010), The Netherlands (Edens et al., 2011), India (Goldar et al., 2011), China (Liu & Ma, 2011) and Estonia (Gavrilova & Vilu, 2012).

Large total and exported quantities of embodied CO_2 emissions in China cause damage to the environment and also make China a target of carbon tariff policies implemented overseas. Developed countries with strict climate policies have discussed imposing tariffs based on the carbon content embodied in trade to avoid carbon leakage and shore up the competitiveness of domestic producers. As carbon tariffs imposed in OECD (Organization for Economic Cooperation and Development) countries penalize carbon intensive exporters, non-OECD countries including China could potentially suffer substantial welfare losses. One analysis has suggested that China in particular would suffer a GDP loss of 4% as a result of imposing such tariffs (Böhringer et al., 2011). China has grown aware of the vulnerabilities associated with the high energy and emissions intensity of its exports. As a result, China has implemented policies to reduce export-embodied emissions.

Several researchers have quantified carbon emissions embodied in China's trade. Shui and Harriss (2006) estimate that about 7% to 14% of China's CO_2 emissions were a result of producing exports for US consumers. They found that global emissions increased by 720 mmt due to the transfer of production from 1997 to 2003, with emissions increases largely driven by the use of less efficient manufacturing technologies and coal-intensive electricity and heavy industry production in developing countries. Peters et al. (2007) found that trends in net trade flows have had a small effect on total emissions as emissions reduced by relying on imports have been offset by growth in emissions from the production of exports. Yan and Yang (2010) have estimated the amount of CO_2 emissions embodied in China's foreign trade during 1997-2007 and find that 10.03% to 26.54% of China's annual CO_2 emissions are generated from the production of exported goods destined for foreign consumers. Xu et al. (2011) examined the CO_2 emissions embodied in China's exports from 2002 to 2008 and found that the change in composition of exports was the largest driver of export-embodied emissions. Guo et al. (2012) analyzed China's embodied CO_2 emissions in international and inter-provincial trade with a Multi-Regional Input-Output Model. They find that the eastern area accounts for a large proportion of China's trade-related embodied CO_2 emissions. Since emissions from developed countries have been reduced through the relocation of domestic emissions-intensive production to developing countries, many argue that China should not be held responsible for addressing carbon emissions embodied in trade, and that developed countries should cover some, if not all, of the cost of abating trade-embodied carbon (Zhang, 2011).

Much of the research discussed above adopts the environmental Input-Output analysis within a single-region framework, which does not distinguish technology differences between imported and domestic production within the same sector (Shui & Harriss, 2006; Peters et al., 2007; Yan & Yang, 2010; Xu et al., 2011). A Multi-region input-output MRIO model can address this challenge with a global economic dataset in which countries are distinguished, bilateral trade flows are recognized, and imported and domestically produced intermediate inputs are tracked separately (Wiedmann, 2009). In recent decades, MRIO models have been developed and adopted in many research to estimate the embodied environment impacts of international trade (see Wiedmann et al., 2007, 2009 for a review of this literature). Based on the existing research, we develop and employ a MRIO model to compare the carbon content in production across countries. For this work we use the Global Trade Analysis Project 2007 data set (GTAP 8), which was released in the spring of 2012. Following the MRIO analysis, we also employ a multi-region, multi-sector computable general equilibrium (CGE) model to assess the impact of two representative CO_2 control policies that represent policies included in China’s Twelfth Five-Year Plan (FYP) (2011-2015). The two policies we simulate are focused on 1) increasing the service sector share of China’s economic output, with and without a decrease in China’s trade surplus, and 2) increasing the export tariff on energy intensive sectors in China. By comparing the two scenarios with the reference case, we are able to evaluate the impact of the two policies on carbon emissions embodied in China’s trade as well as on global CO_2 emissions.

This paper is organized as follows: **Section 2** briefly introduces the background related to two representative policies intended to reduce the emissions intensity of China’s industrial production and exports. **Section 3** includes a detailed discussion of the methodologies and data adopted in our analysis. **Section 4** presents the results of China’s embodied carbon emissions in 2007 and an assessment of the two policies. **Section 5** summarizes and discusses the findings.

2. Policy Background

China implemented a number of administrative and financial policies for the energy conservation and emissions reduction in the Eleventh FYP (2006-2010). These policies set short and medium term intensity targets for energy use, CO_2 emissions and other pollutants. Decision makers claim that policy approaches are intended to incentivize both technical progress and what is commonly termed "structural change" or "economic rebalancing".[1] It is estimated that over 70% of China's energy savings reflect technical approaches in the Eleventh FYP (Xie, 2012). China has prioritized economic rebalancing in its Twelfth FYP (2011-2015) and set a target for the service industry to reach a 47% value share of GDP in 2015 from a level of 43% in 2010 (State Council of China, 2011). A series of subsidies and government investment initiatives are about to be introduced to boost the services industry. The reduction in industrial production will have a large impact on China's trade pattern and scale, and also have an effect on the carbon emissions embodied in traded goods.

In part to address the issue of trade-embodied carbon, China has taken steps to control the export of "energy-intensive, pollution-intensive and resources-consuming" goods. Reductions in tax rebates and increases in export tariffs on energy intensive products have been implemented gradually since 2004. In 2004, for the first time, China cancelled the export tax rebate on coke to limit exports of this commodity. In 2005 and 2006, China reduced the tax rebate on exports of energy consuming sectors such as coal, iron, and chemical goods, and in 2007 China cut tax rebates on around one third of its total traded goods, including many types of energy-intensive products. Due to the impact of the global economic crisis, China reinstated the tax rebate on some energy-intensive sectors in 2009, but cancelled them

[1] The term "economic rebalancing" is used in China to refer to two policy adjustments. The first is increasing the contribution of domestic consumption at the expense of overseas investment. In this connection, the Chinese government has announced a focus on increasing domestic demand as its primary task in the 12th FYP (China Daily 2012). Second, it is used to refer to shifting the industrial structure within China from predominantly heavy-industry led to knowledge-intensive, high value added industries such as services, which mostly have a lower energy footprint.

again in 2010. Aside from the tax rebate, China has also used export tariffs to limit the export of energy-intensive production, which are included as a complementary measure in the Comprehensive Energy-saving Reduction Program Work Notice of China in China's Twelfth FYP (The State Council of China, 2011). On separate occasions in 2008, China increased the export tariff on steel and nonferrous metals (from 5% to 10% and then from 10% to 15%)

3. Method and Data

3.1 MRIO Calculations of Embodied Carbon

MRIO models have been widely applied to study the environmental impacts embodied in international trade. With the advantage of combining domestic input-output matrices with import matrices from multiple regions into one comprehensive matrix, the MRIO model tracks the contribution of different points in a sector's supply chain and encompasses all trading partners involved (Wiedmann, 2009).

Following Böhringer et al. (2011), we adopt a MRIO model to calculate the life-cycle carbon content embodied in production. Both the direct carbon emissions from the combustion of fossil fuel and indirect carbon emissions associated with demand for intermediate non-fossil inputs are captured. We calculate the lifecycle carbon content associated with production of good *i* in region *r* as the product of the carbon content per dollar of production, $Ay_{i,r}$, multiplied by the value of production, $y_{i,r}$. This product is equal to the sum of direct emissions from the burning of fossil fuel inputs in the production process, $Ed_{i,r}$, and indirect emissions associated with intermediate non-fossil inputs from domestic sources, $Eid_{i,r}$, and imported sources, $Eim_{i,r}$, as described by equation (1).

$$Ay_{i,r} \times y_{i,r} = Ed_{i,r} + Eid_{i,r} + Eim_{i,r} \qquad (1)$$

Direct emissions associated with energy consumption in sectoral production can be easily extracted from the MRIO database. To calculate indirect emissions, we exploit the input-output coefficients in the database. Indirect emissions from domestic intermediate inputs are calculated as:

$$Eid_{i,r} = \sum_{j} Ay_{j,r} \times y_{j,i,r} \tag{2}$$

where j indexes goods used as intermediate inputs in the production of good i.

Indirect emissions from imported intermediate inputs are the sum of emissions associated with the production of those intermediates and emissions from international transportation:

$$Eim_{i,r} = \sum_{j,s} (Ay_{j,s} \times y_{j,i,s,r} + At_{j,r} \times y_{j,i,s,r}) \tag{3}$$

where $y_{j,i,s,r}$ is the quantity of imported input j used in the production of good j imported from region s in region r, $At_{j,r}$ is the per-dollar carbon content of transportation services required to deliver good j to region r, which is calculated as:

$$At_{j,r} = (\sum_{t,s} vtwr_{t,j,s,r} \times ATr_{t}) / \sum_{t,s} vtwr_{t,j,s,r} \tag{4}$$

$$ATr_{t} = (\sum_{r} vst_{t,r} \times Ay_{t,r}) / \sum_{r} vst_{t,r} \tag{5}$$

In Equation (4), $vtwr_{t,j,s,r}$ is the value of good j transported from region s to region r by service t (t includes air transport, water transport and land transport), ATr_t is the average carbon content of transport service t. In Equation (5), $vst_{t,r}$ and $Ay_{t,r}$ are respectively the quantity of transportation service t and the per dollar carbon content of transport service t supplied by region r.

Equations (1)-(5) represent a system of simultaneous equations, where the lifecycle per-dollar carbon content of each good ($Ay_{i,r}$) are endogenous variables and other variables are exogenous. Values for exogenous variables are sourced from a MRIO database and the simultaneous equation model is solved iteratively, after assigning intial values for $Ay_{i,r}$.

Table 1. Sectoral and regional aggregation

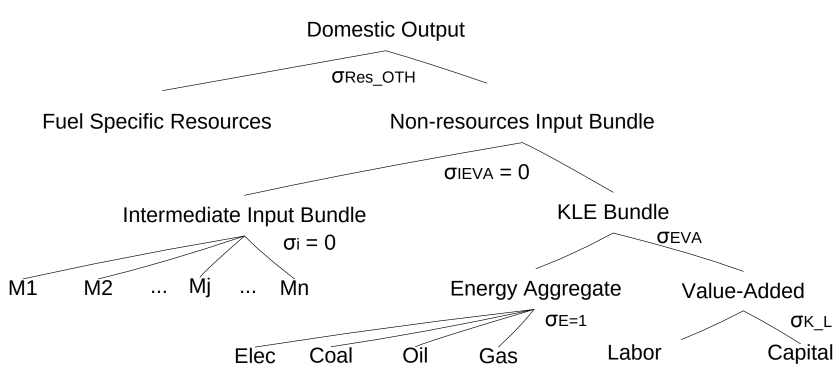
Sector	**Abbreviation**	**Region**
Agriculture	agr	China
Coal	coal	Japan
Oil	oil	Korea
Gas	gas	Taiwan
Refined oil	roil	India
Electricity	elec	United States
Paper & paper products	ppp	Russia
Chemical rubber & plastic products	crp	Australia - New Zealand
Non-Metallic minerals	nmm	Europe
Iron & Steel	i_s	Rest of Europe
Fabricated Metal Products	fmp	Africa
Non-Ferrous Metals	nfm	Middle East
Food production	food	Latin America
Metal ores	omn	Rest of East Asia
Textiles	tex	South Asia
Wearing apparel	wap	Canada and Mexico
Leather product	lea	
Wood products	lum	
Electronic equipment	ele	
Machinery and Equipment nec*	ome	
Manufactures nec*	omf	
Transport equipment	tre	
Transport service	trs	
Services	serv	

Note: *The abbreviation nec stands for not elsewhere classified.

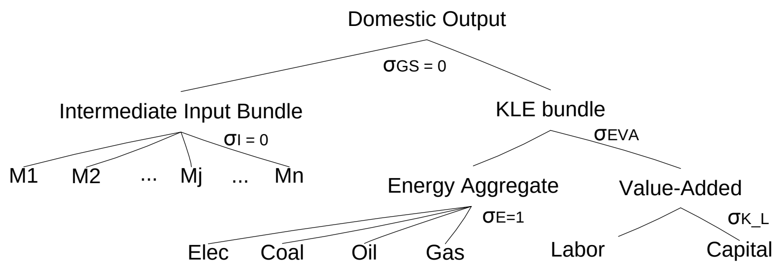
Our MRIO model is based on the latest release of GTAP 8 database. The database is a global economic and energy dataset that includes value flows for 57 sectors and 129 regions in 2007 (Narayanan et al., 2012). The dataset combines individual national energy and economic accounts together with data on bilateral trade flows and CO_2 emissions. For our purposes, we aggregate the database to 23 sectors and 27 regions, by aggregating sectors and regions which account for a small proportion of China's total trade. To focus on embodied emissions, our aggregation identifies three primary energy sectors (Coal, Crude oil, and Gas), Electricity, six energy-intensive sectors (Paper and paper products; Chemical, rubber and plastic products; Non-metallic minerals; Iron and steel; Fabricated metal products; and Non-ferrous metals). Detailed sectoral and regional aggregation is listed in Table 1.

3.2 The CGE Model for Policy Assessment

To assess the impact of current policies on the reduction of trade-embodied carbon emissions in China, we employ a multi-sector, multi-region static CGE model of the global economy. In the model, there are three types of production processes: extraction of primary fuels (crude oil, coal and gas), production of electricity, and other production activities including refined oil, manufacturing and services. Each of the production technologies is captured by a nested constant elasticity of substitution (CES) cost function. Detailed nesting structures for the three production activities are portrayed in Figure 1, where σ is used to denote elasticities of substitution. An important feature of the nesting structure is the ability for firms to substitute among fossil fuels and between aggregate energy and value added. Firms are assumed to compete in perfectly competitive markets.



(a)



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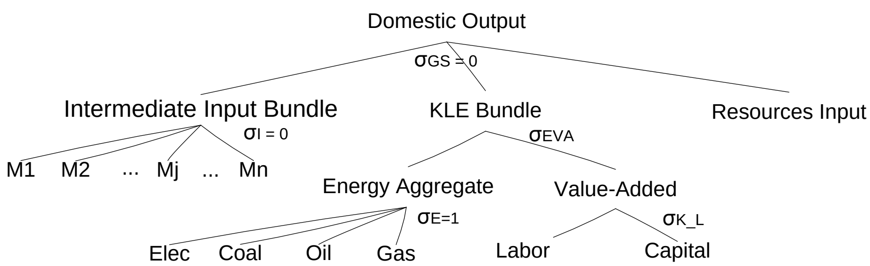

(c)

Figure 1. The nesting structure of production sectors is shown for (a) primary fuels (coal, crude oil and gas), (b) electricity, (c) refined oil and other production.

Final demand by consumers in each region is determined by a series of nested CES functions. The nesting structure splits consumption into an energy composite and other goods and services. Investment is fixed and government consumption is exogenous. Consumers chose their demand profile to maximize their welfare subject to the budget constraint and receive income from payments to capital, labor, and fuel resources (factor income) and tax revenue.

Bilateral trade is specified using the Armington assumption that domestic and imported goods are imperfect substitutes and are distinguished by region of origin (Armington, 1969). The CES structure is applied to describe production from domestic and foreign sources, as shown in equation (6).

$$A_{i,r} = \left[\alpha D_{i,r}^{\rho_i} + (1-\alpha) M_{i,r}^{\rho_i} \right]^{1/\rho_i} \tag{6}$$

where $A_{i,r}$ is the Armington composite of good i in region r, $D_{i,r}$ is the domestic variety, and $M_{i,r}$ is the imported variety, which is a further CES aggregation of imports from different regions. The α are CES share coefficients. The Armington substitution elasticity, δ_i, between domestic and the imported goods is given by:

$$\delta_i = 1/(1-\rho_i) \tag{7}$$

The CGE model is calibrated using the MRIO database (GTAP 8) used to analyze embodied carbon emissions. The model is formulated as a mixed complementarity problem (MCP) using the mathematical programming system (MPSGE) language, which is a subsystem of the General Algebraic Modeling System (GAMS), and solved with the PATH solver to derive the vector of prices that clears the market and the associated demands across all sectors (Mathiesen, 1985; Rutherford, 1995; Rutherford, 1999).

4. Scenarios and Results

In this section, we discuss our scenario design and simulation results. We first present our analysis of China's trade-embodied carbon emissions in 2007 using the MRIO model. We then use the CGE model to simulate two policy shocks based on measures outlined in China's FYP and evaluate the impact on the economy, total emissions, and China's trade-embodied CO_2 emissions.

4.1 MRIO calculation of carbon emissions embodied in China's 2007 trade

To derive trade-embodied carbon emissions, we multiple carbon intensities by sector and region ($Ay_{i,r}$) by China's export and import values. Europe, the United States and Japan are China's largest trade partners, and combined account for more than half of China's total trade by value. The calculations also reveal that sectoral carbon intensities are much higher than those in Europe, Japan and the US, and also higher than the global average.[2] The results also show that domestic intermediate input emissions, which are mainly due to direct and indirect use of electricity, are the largest contributor to lifecycle embodied emissions, rather than direct emissions (Figure 2).

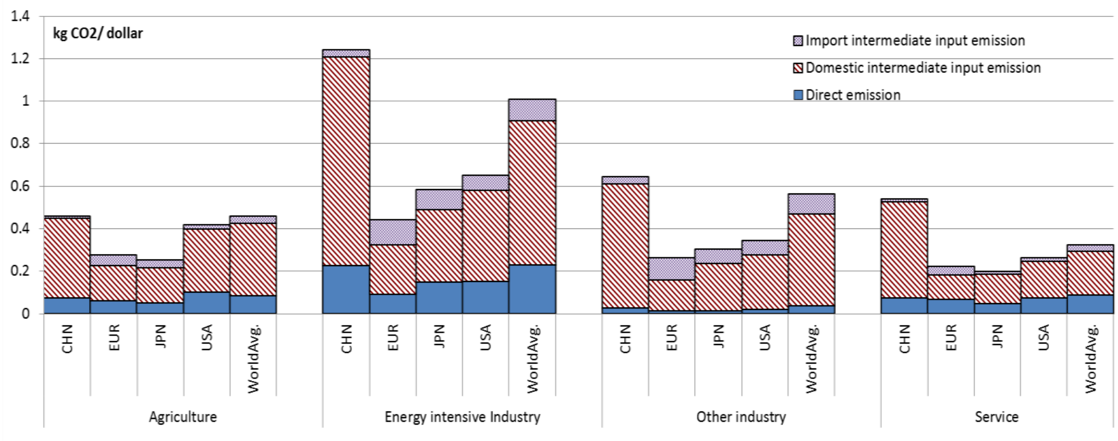

Figure 2. Carbon intensity by sector and by source comparison in 2007

Figure 3 plots China's scetoral export value shares against sectoral lifecycle carbon intensities. We find that some of the least emissions-intensive sectors have a high value share, while some of the most emissions-intensive sectors barely show up in China's trade composition. As shown in Figure 3, Electricity (elec) and Gas (gas) production are the two most carbon intensive sectors in China but have very limited trade flows with other regions. Energy intensive sectors, such as Non-metallic minerals (nmm) Fabricated metal products (fmp), and Iron and steel (i_s), have relatively higher carbon intensities but their trade volumes are generally small, together accounting for only 20% of total trade value. Electronic equipment (ele) and Machinery and equipment (ome) account for 22% and 18% of total trade, respectively. However, the carbon intensities of these sectors are relatively low.

[2] We convert among currencies using market exchange rates. If purchasing power parity exchange rates are used, carbon intensities in China are closer to the world average level but remain above those in the US, Europe, and Japan.

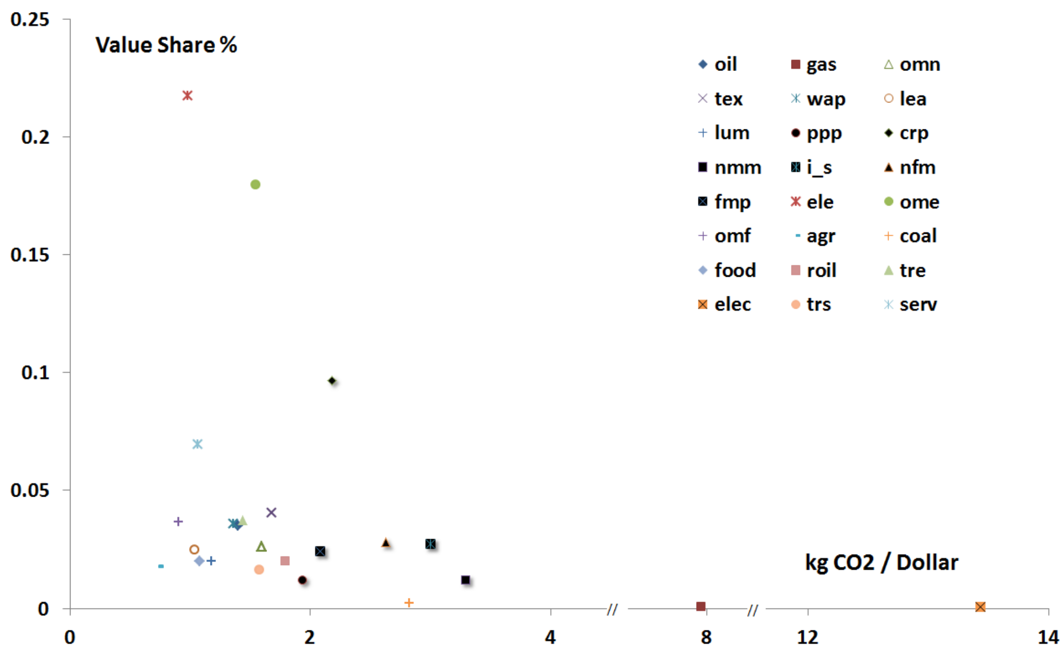

Figure 3. China's sector carbon intensity and trade value in 2007

A comparison of carbon emissions embodied in China's trade by sector in 2007 is shown in Figure 4. We found exports of Machinery and equipment and Electronic equipment together account for 34% of China's exports of embodied carbon, while the energy-intensive sectors combined account for a total of 30%. Textiles and apparel are also significant sources of embodied emissions. These findings reveal that energy intensive sectors are not the primary source of China's embodied carbon exports, despite the fact that most policies in China target energy-intensive sectors. Meanwhile, exports of mechanical and electronic equipment are encouraged in order to spur development of so-called "high tech" sectors. Overall, the CO_2 emissions embodied in China's net exports in 2007 totaled 1176 million metric tons (mmt), accounting for 22% of China's CO_2 emissions.

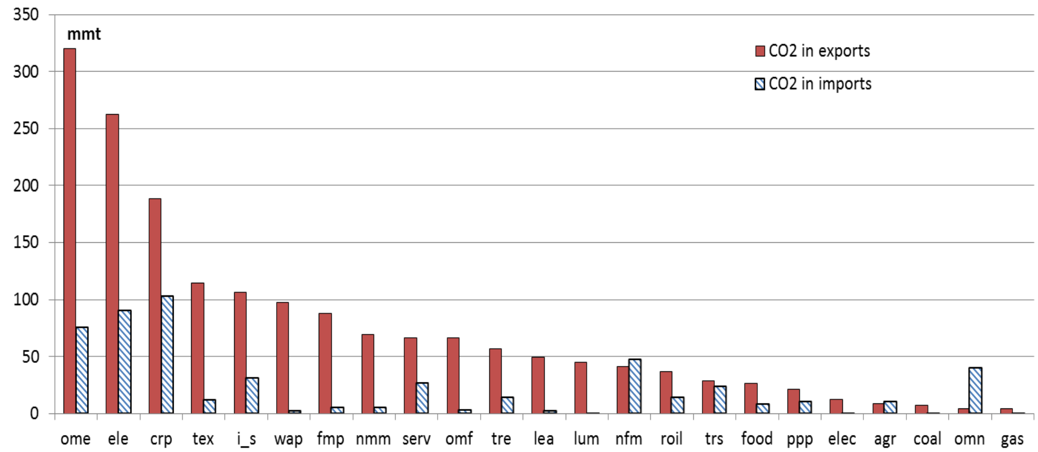

Figure 4. CO_2 emissions embodied in China's exports and imports by sector in 2007

4.2 Policy Scenarios and Simulation Results

Using the MRIO analysis of China's trade embodied CO_2 emissions in 2007 as the reference scenario, we use a static CGE model to simulate two representative policy scenarios: 1) an economic rebalancing policy (ER) scenario and 2) a scenario in which additional export tariffs are imposed on energy-intensive industries (ET), simulating the effect of reduced incentives to export. The objective is to evaluate the impact of the two policies on China's trade and CO_2 emissions.

Scenario 1: Economic Rebalancing Policy (ER)

Under the Twelfth FYP, China's policymakers aim to encourage adjustment in the country's economic structure to reduce reliance on heavy industry and increase the contribution of services and less energy intensive industries, while simultaneously encouraging domestic consumption. As part of our simulation of an economic rebalancing policy, we develop two variants of our first scenario to simulate the impact of a policy aimed at rebalancing the economy (ER1) and the effect of combining it with a domestic demand expansion policy (ER2). Detailed assumptions for each variant of Scenario 1 are listed in Table 2.

Table 2. Scenario description – economic rebalancing with and without domestic demand expansion.

		Reference Scenario (RF)	Scenario 1 (ER)	
			Economy Rebalancing Scenario (ER1)	Economy Rebalancing & Domestic Demand Expansion (ER2)
Sectoral share of GDP	Agriculture	12%	8%	8%
	Industry	48%	45%	45%
	Service	40%	47%	47%
Trade surplus (billon US dollars)		270	270	135

The reference case reflects China's economic situation in 2007 as described by the GTAP 8 database. China's rebalancing target in 2015 is reflected in the targets for sectoral share of GDP for each scenario, and is based on the targets in China's Twelfth FYP (State Council of China, 2011) and in the report of the Development Research Center of the State Council (Xinhua, 2010). In ER1, we only consider the economic rebalancing policy and we assume that China's trade surplus remains unchanged from the reference scenario. However, in ER2, we decrease the trade surplus by half, capturing the situation in which China would spend more money on domestic consumption, rather than investing abroad. The implementation of the economic rebalancing targets is achieved by imposing endogenous taxes or subsidies on all sectors within each sectoral group to achieve the GDP shares in Table 2. In practice, a fiscal policy approach would be a (potentially more) important approach to stimulate domestic consumption. However, in our analysis, we are not focused on specific policy comparisons, but are interested in providing insight into the impact of a generic rebalancing policy. We are further interested in quantifying the effects of the policy on carbon emissions embodied in China's trade. The change in China's trade surplus is simulated as an exogenous shock to the capital account balance.

When we implement endogenous tax instruments to achieve the targets in Table 1, we find that the price of industry output rises by 20% and that for services falls by 25% compared to the reference case in order to achieve the targets. As shown in Figure 5, the increase in the industry price leads to significant decreases in the net exports of both energy-intensive products and also goods produced by other industries. However, the drop in the price of services stimulates exports of this sector significantly. Our simulation suggests that under the rebalancing policy China's trade patterns have been fundamentally altered from manufacturing-oriented to service-oriented, which is considered a desirable goal by many policymakers in China.

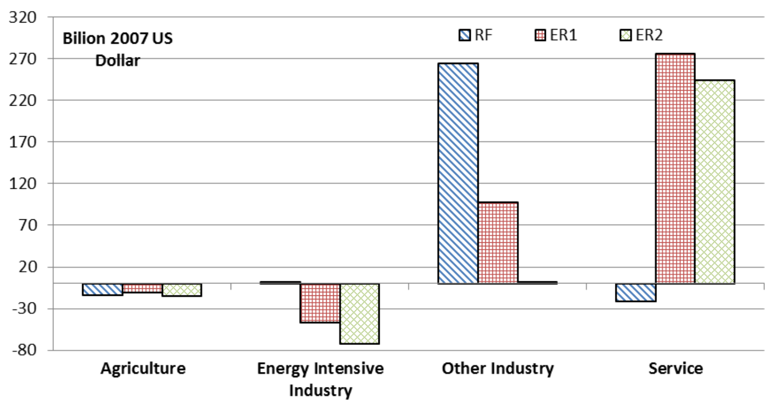

Figure 5. Net exports values by sectors in China's trade in RF and ER scenarios

A comparison of ER1 and ER2 suggests that the expansion of domestic demand helps to reduce net exports in all the sectors, as expected. The net exports of energy intensive products and other industry goods decrease as the economy becomes more service oriented as a whole.

A change in the relative prices across China's domestic products would change the input-output structure in production and affect the carbon intensities of all sectors. Therefore we recalculate the embodied carbon with the MRIO model based on the economic and environmental variables as forecasted in the CGE analysis. Changes in emissions due to economic rebalancing are outlined in Table 3.

Table 3. The forecasted impact of economic rebalancing measures on export-embodied CO_2.

Units: mmt CO_2	RF	Scenario 1	
		ER1	ER2
Net exports of emissions	1177	1127	917
Agriculture	-2	0	-3
Industry	1139	802	630
Services	40	325	290
China domestic emissions	5268	4986	5011
ROW emissions	21255	21316	21285
Global emissions	26523	26302	26296

By comparing results for the reference scenario with those for the ER1 scenario, we focus on the impact of domestic economic rebalancing measures alone. We find evidence that in response to policy, industry largely reduces the net CO_2 exports embodied in China's trade. However, the emissions from the services sector increases significantly in part due to the rapid growth of services exports. Emissions embodied in the services sector also includes inputs that required electricity to produce, and thus the contribution of these electricity-related emissions is included in the total. On balance a reduction in the manufacturing (secondary) industry's export-embodied emissions is offset by an increase in embodied emissions in the service sector. Net exports of China's trade-embodied CO_2 emissions do not change significantly.

By results for the ER1 and ER2 scenarios, we find that the expansion of domestic demand will reduce total trade-embodied CO_2 emissions. By importing more and exporting less of energy intensive production and other industry goods, CO_2 emissions are displaced as production moves offshore from China to countries where production methods may be more or less carbon intensive. The trend in the services industry is qualitatively similar—the CO_2 emissions embodied in China's exports are reduced more significantly in ER2 than in ER1.

By examining global CO_2 emissions and emissions in individual countries, we find that the economy rebalancing strategy in China affects energy use and emissions through bilateral trade linkages. By promoting services at the expense of manufacturing, China's domestic emissions decrease by about 5%. With the reduction of manufacturing exports from China, other regions must expand production to meet global demand and thus total emissions in these regions increase. Europe, Japan and Korea experience the greatest emissions growth as a result of international trade rebalancing—these countries account for 11%, 9% and 9%, respectively, of total global emissions growth. There is also growth in trade between emerging Asian economies and developed countries. The value of exports from the Rest of Asia (ROA) region (which includes Vietnam, Cambodia, and Laos) to Europe, Japan and the US increases by around 8%. China sees a decrease in the supply of industrial products it provides to the developed countries in part because these advanced economies begin to undertake production themselves and in part because this capacity is being transferred to other emerging economies. The net effect is only a slight reduction in CO_2 emissions due to the benefits of cleaner technology in advanced countries and a lower overall emissions intensity in developing countries that replace production in China (e.g., Rest of Asia (ROA) has an emissions intensity of 1.27 kilograms of CO_2 per dollar compared to China's 1.77, with the discrepancy largely due to the lower reliance on coal in electricity production in ROA).

Scenario 2: Impose export tariffs on the Energy Intensive sectors

China has acted to control the export of energy intensive products by reducing the tax rebate on exports and increasing export tariffs on production activities in these sectors. These two policies are also listed in the Comprehensive Energy-saving Reduction Program Work Notice of China section of China's Twelfth FYP (The State Council of China, 2011). This policy program aims to limit the export of energy-intensive commodities. Reducing tax rebates on exports and imposing an export tariff operate through essentially the same mechanism with the goal of increasing the costs of exporting industries that the government wants to discourage. In our model, we use an export tariff policy to simulate the effect of both policies on carbon emissions embodied in China's trade and its broader global implications.

In our model, as noted in Section 3, the "energy-intensive sectors" include Paper and paper products (ppp), Chemical, rubber and plastic products (crp), Nonmetallic mineral products (nmm), Iron & steel production (i_s), Non-ferrous metals (nfm), and Fabricated metal products (fmp). Current export tariffs on these products range from 4% to 6%. As targeted export tariffs on these sectors are not set in China's work plan and could be flexible in practice, we make a simple assumption in our scenario that the tariff rate is double the 2007 tax rate.[3]

We first consider how trade patterns are affected by the export tariff policy. As shown in Figure 6, an export tariff is forecast to decrease the net exports of energy-intensive products in China. The impact is not only limited to the energy-intensive sectors, but also affects the exports of all industries. As observed in Figure 6, exports of non-target industries increase, with the exception of agriculture. This effect occurs because the export tariff on energy-intensive sectors decreases the output of these sectors, resulting in a reduction in energy demand and prices. These price decreases reduce the production cost for other sectors, which result in these becoming relatively more competitive in global markets.

[3] Defining a precise tax rate is not necessary here as we are focusing on providing a performance benchmark for a potential policy instrument rather than aiming to inform the choice of tax rate.

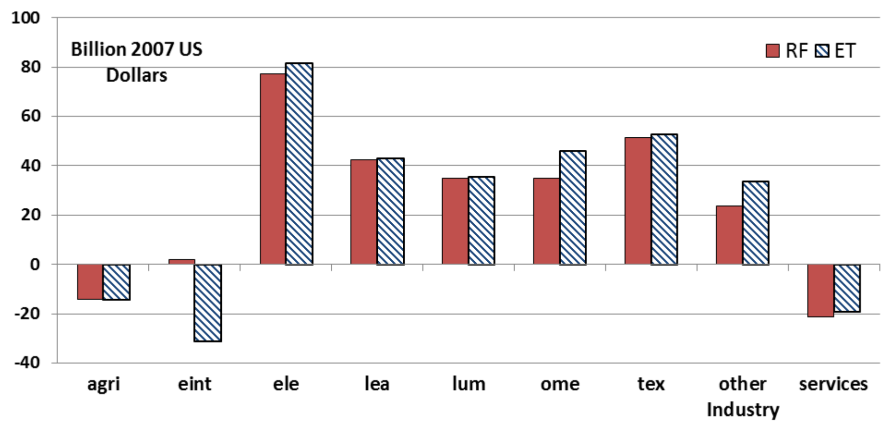

Figure 6. Net export values of China's trade in reference (RF) and export tariffs (ET) scenarios

Export tariffs also affect the price of domestic production in China and change sectoral carbon intensities. As for our previous simulations, following implementation of the policy shock, we recalculate embodied emissions for all sectors and regions based on production inputs estimated by our CGE analysis. Changes in trade embodied emissions and changes in emissions by aggregated regions are reported in Table 4.

The results indicate that the emissions embodied in the exports of energy-intensive production in China decrease as the magnitude of the trade flows shrink. However, the policy also incentivizes increases in exports from non-target industries, thereby increasing CO_2 emissions embodied in exports of these commodities, which partially offsets the reduction in the net exports of emissions from energy-intensive sectors. Overall, the tariff policy reduces CO_2 exports from energy-intensive sectors, but there is virtually no effect on total CO_2 emissions.

Table 4. Change in carbon emissions under the Export Tariff scenario.

Units: mmt CO_2	**Reference Scenario**	**Scenario 2 Export Tariff Policy**
Net exports of emissions	1177	1133
Agriculture	-2	-2
Energy intensive industries	312	226
Other industries	827	867
Services	40	42
China total emissions	5268	5239
ROW emissions	21255	21269
Global emissions	26523	26508

The export tariff policy imposed in China also influences the global economy and CO_2 emissions through its impact on bilateral trade patterns. A tax policy that targets a reduction in the contribution of the energy-intensive sectors indirectly stimulates the production of non-target industries, causing little net change in China's overall domestic CO_2 emissions. By reducing the supply of energy intensive products from China, other regions have to produce (or import) these "dirty" goods themselves, which increases emissions in other regions. The growth of emissions in Europe, the US and Japan is 11%, 11% and 8%, respectively. There is also an increase in imports of energy-intensive products to the US, Europe and Japan from regions other than China. As in the case of the rebalancing scenario, a reduction in the supply of Chinese-made energy-intensive goods to the developed countries is partially compensated by production in advanced economies, and is partially transferred to their other trade partners. Consequently, there is only a small change in global emissions, as in the rebalancing scenario.

5. Conclusions and Discussion

We have analyzed carbon emissions embodied in China's trade in 2007 by conducting a MRIO analysis using the Global Trade Analysis Project 2007 data set (GTAP 8). Insights from the MRIO analysis helped to guide our investigation of the impact of two representative CO_2 reduction policies using a multi-region, multi-sector static global general equilibrium model. As the world's largest exporting country, China's trade-embodied emissions are also the biggest in the world. Large exports of embodied CO_2 emissions in China both threaten the environment and also make it a major target for carbon tariff policies implemented overseas. China has become aware of its vulnerabilities, and has taken measures to address concerns surrounding energy and carbon emissions embodied in its trade through a range of policy approaches. This paper has provided insight into the factors influencing China's trade-embodied emissions. It has also attempted to evaluate the effect of two policies representative of measures in China's Twelfth FYP—one focused on economic rebalancing with and without an emphasis on stimulating domestic consumption and the other focused on reducing incentives for China to export energy-intensive products.

In the MRIO analysis, we find that the CO_2 emissions embodied in China's net exports are considerable, accounting for 22% of its total emissions. Mechanical and electronic equipment products are the major source (34%) rather than the energy intensive sectors (30%). Trade with Europe, Japan, and the US accounts for more than half of China's total trade volume. The carbon intensities of production in China were found to be much higher than that in Europe, Japan and the US.

Neither of the two policies we investigate has a significant impact on total global CO_2 emissions. The policy aimed at rebalancing China's economic structure altered China's trade patterns, from an industry-based to a service-based orientation, but did not significantly influence China's trade-embodied CO_2 emissions. Tariffs on energy intensive (EI) products are effective at reducing EI sector exports and its embodied emissions, but only reduce China's total export-embodied CO_2 emissions by a small amount, due to the offsetting effect caused by an increase in other production activities, including services. A policy that targets the expansion of domestic demand is observed to be more effective at reducing China's export-embodied CO_2 emissions, although it does not explicitly take into account shifts in consumption patterns that may occur as household incomes increase. In both scenarios, we find evidence that the policy-induced decrease in industrial products supplied from China to developed countries would be partially offset by relocation to the advanced economies where products are consumed, and increased production in other trade partners. As a result, climate policies implemented in China would indirectly lead to increases in emissions in other regions. Globally, CO_2 emissions would fall only slightly, as regions with less CO_2-intensive production produce energy-intensive products previously made in China. But this effect is very weak and hard to predict, as it is the combined result of global production redistribution and is influenced by estimates of technology costs and the economic structure characterizing each region.

Estimates of embodied carbon emissions are sensitive to trade values and patterns. Given the limited availability and long lead times that precede the release of global input-output dataset, we conduct our research based on 2007 data. However, with the impact of global economic slowdown starting in 2008, China's trade surplus has shrunk from 261.8 billion dollars in 2007 to 155.1 billion dollars in 2011 (National Bureau of Statistics of China, 2011; National Bureau of Statistics of China, 2012). Meanwhile, if the current expansion of China's domestic demand continues, it is predicted that China may rank as top global importer within a few years (Xinhua, 2012). If this occurs, the trade surplus of China would be further reduced relative to that in our database. Concerns around trade-embodied carbon emissions would be potentially mitigated or replaced by concerns about the energy and CO_2 intensity of consumption. Furthermore, the impact of the policies discussed in this paper on CO_2 emissions is limited, in part because these policies do not address the potential for displacing emissions from targeted industries to other sectors. A carbon tax or comprehensive nation-wide cap-and-trade regime may be more effective in this regard. China will start emissions trading systems in seven pilot provinces in 2013 and aims to extend the market to the entire country in 2015 (China Securities Journal, 2012). Implementation of a carbon tax is also being considered in China (Economic Information Daily, 2012). These policies present a more economically efficient way to constrain energy consumption and emissions from all sectors in a more cost-effective manner.

6. Reference

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