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The Contribution of Chinese Exports to Climate Change

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Abstract

Within 5 years, China's CO_2 emissions have nearly doubled, and China may already be the world's largest emitter of CO_2. Considerable anecdotal evidence implies that exports could be a main cause of this rise in Chinese CO_2 emissions; however, no systematic study has analyzed this issue, especially over time. We find that recently, around one third of Chinese emissions (1700 Mt CO_2 in 2005) were in the production of exports, and this proportion has risen from 12% (230 Mt) in 1987 and only 21% (760 Mt) as recently as 2002. It is likely that consumption in the developed world is driving this trend. Climate policies which would make the developed world responsible for China's export emissions have both benefits and costs, and must be carefully designed to achieve political consensus and equity. Whoever is responsible for these emissions, China's rapidly expanding infrastructure and inefficient coal-powered electricity system need urgent attention.

Keywords: China, CO_2 emissions, exports, climate change

1. Introduction

Within a very short period of time, from 2002 to 2007, China's CO_2 emissions have almost doubled and it is now believed that China is the world's biggest emitter of CO_2 (MNP, 2007). China faces increasing international pressure to curb its CO_2 emissions, but argues that "[t]he ramifications of limiting the development of developing countries would be even more serious than those from climate change." (Wu, 2007). China has several arguments for why it should not be required to limit its CO_2 emissions in the short term(National Development and Reform Commission, 2007). First, limits on China's CO_2 emissions would hamper economic development. Second, China has low per capita emissions, ranked 72nd in 2004, although this ranking is both higher than most developed countries and growing quickly (WRI, 2007). Third, historically China argues that it only contributes a small amount to cumulative emissions, ranking 91st in cumulative emissions since 1900 (WRI, 2007). Finally, despite capital investments and household consumption dominating China's increasing CO_2 emissions (Peters et al., 2007), China has currently focused arguments towards the role of exports, claiming it should not be responsible for emissions attributable to the production of exports(McGregor, 2007). In 2005 exports accounted for a relatively large amount: 33% of China's GDP, increasing from 12% in 1987.

Despite several references to this issue (Ahmad et al., 2003; Peters et al., 2008; Peters et al., 2007; Wang et al., 2007), there have been no systematic studies on the contribution of exports to China's CO_2 emissions, and particularly how this has changed over time. Several studies have estimated the emissions embodied in China's exports (and imports), but few studies have focused on this as the primary issue. Ahmad and Wyckoff (Ahmad & Wyckoff, 2003) using a related method to ours, found that in 1997, 15% of China's emissions were embodied in exports and 3% of China's domestic emissions were imported. In the Supporting Information, Peters *et al*. (Peters et al., 2007) found that in 1997 25% of China's emissions were exported and 24% imported and in 2002 32% and 34%. However, Peters *et al*. did not adjust for imports in the production of exports, and thus their method differs slightly from what is used here. Wang and Watson (Wang & Watson, 2007) estimated the emissions embodied in

China's exports in 2004 as 24%, though they used a relatively simple method which fails to capture supply-chain effects. The most comprehensive study to date, Peters and Hertwich (Peters & Hertwich, 2008) considered the emissions embodied in trade for 87 countries and regions and found that in 2001 China exported 24% of its CO_2 emissions and imported 7% of China's domestic emissions. This study is the most similar methodologically to the analysis presented here and will be used to supplement the results.

We apply environmental input-output analysis (Leontief et al., 1972) to estimate the CO_2 emissions emitted in the production of exports in China from 1987 to 2005, the most recent year available in data. This method considers all the upstream supply-chain inputs necessary for the production of exports. The following section describes methods and data sources, followed by the results and a discussion of their relevance.

2. Methods and Data

2.1 Environmental Input-Output Analysis (EIOA)

The calculations are based on environmental input-output analysis (EIOA) with some adjustments, (Miller et al., 1985; United Nations, 1999). A summary of the method is shown here, but more detailed treatments are available elsewhere (Miller and Blair, 1985, United Nations, 1999). We begin with the familiar Leontief economic balance (Leontief, 1986), where the total output of an economy, **x**, can be expressed as the sum of intermediate consumption, **Ax**, and final consumption, **y**:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{y} \tag{1}$$

where **A** is the economy's direct requirements matrix and **y** is the demand for which the supply chain output, **x**, is to be derived. The matrix **A** describes the relationship between all sectors of the economy. In this study we used four separate final demands, **y**, from each year's input-output table: household consumption, fixed capital investment, exports, and governmental consumption. When solved for total output, this equation yields:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y} \tag{2}$$

When coupled with an environmental matrix, **F**, which shows the environmental emissions caused by each sector in the model, normalized by the sector's economic output, $\mathbf{x} = (x_1\ x_2\ \dots\ x_m)^T$, the total amount of emissions can be calculated as:

$$\boldsymbol{f} = \boldsymbol{F}(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y} \quad \textbf{(3)}$$

with **f** representing the sector-wise total supply chain emissions to meet the final demand **y**.

This is the standard method for environmental IOA. However, this method is not sufficient for studies of trade as the direct requirements matrix **A** usually does not distinguish between domestically produced and imported products (United Nations, 1993). Thus, it is common (where import flow matrices are unavailable) to derive new requirements matrices and final demand vectors in which only domestic goods are included, $\mathbf{A_d}$ and $\mathbf{y_d}$:

$$\begin{aligned} \boldsymbol{A}_m &= \boldsymbol{diag}\left(\frac{\boldsymbol{m}}{\boldsymbol{x}+\boldsymbol{m}-\boldsymbol{x}}\right) * \boldsymbol{A} \\ \boldsymbol{y}_d &= \boldsymbol{diag}\left(\frac{\boldsymbol{m}}{\boldsymbol{x}+\boldsymbol{m}-\boldsymbol{x}}\right) * \boldsymbol{y} \end{aligned} \quad \textbf{(4)}$$

This method removes imported goods from the direct requirements table and from components of GDP other than exports, ***i*** (household consumption, capital investment, and government consumption). This method inherently assumes that the same share of imports are present in each sector's demand and in each final demand category; for example, it assumes that businesses, government, and households, who all consume software, each consume the same share of domestically produced and imported software.

For each year, then, the emissions embodied in exports (or other GDP components) are calculated as:

$$\boldsymbol{f}_d = \boldsymbol{F}(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y}_d \quad \textbf{(5)}$$

where $\mathbf{f_d}$ is total domestic emissions embodied in demand $\mathbf{y_d}$.

In addition to this standard method, IOA usually require some degree of country-specific manipulations depending on data availability.

2.2 Treatment of Others

The Chinese input-output tables (IOTs) follow most standard formats except for a final demand column called “Others”. This column appears in all years, except 1995. The GDP derived by summing the value added matches the GDP derived by summing final demand only if “Others” is included. The error in aggregated GDP by not including Others is small (<1%). However, on a sector-by-sector basis Others can represent up to 8% of output or even totally dominate final demand. This suggests considerable caution is needed if using “Others” as a final demand. Since “Others” plays a dominant role in some sectors, there is no obvious treatment of it to avoid spurious results.

According to NBS (National Bureau of Statistics, 1999) the Others column primarily represents different reported data, particularly related to trade. Thus, we interpret “Others” as an estimate of an error term representing different data sources. We do not include the error in our calculation of output, thus output, $\mathbf{x}_{\mathbf{total}}$, is given as the sum of the intermediate flows and the final demand not including “Others”. This output, not the output listed in the IOTs, is used to normalize the IOTs and emissions data.

2.3 Normalization

We follow standard procedures for normalization of the IOT and the energy and emissions data,

$$\mathbf{A} = \mathbf{Z}\,\hat{\mathbf{x}}_{\mathbf{total}}^{\mathbf{-1}} \qquad \textbf{(6)}$$

where **A** is the inter-industry requirements matrix which represents the technology of the Chinese economy. Because the energy data is more aggregated than the IOTs, it is necessary to map between the IO sectors and the energy sectors for each year. To normalize the total energy and emissions data, **T,** we first aggregate the output to the sector classification used in the energy and emissions data and then normalize,

$$\mathbf{F} = \mathbf{T}\left(\mathbf{P}\mathbf{x}_{\mathbf{total}}\right)^{-1}\mathbf{P} \qquad \textbf{(7)}$$

where **P** represents the mapping between IO sectors and energy sector, constructed from the sector descriptions of the IOT and energy data. This procedure assumes that all IO sectors that map to the one energy sector have the same emission intensity. Since the IOT and energy intensities now have the same industry classification, we can perform the calculation for each year, as shown above in equation 5.

2.4 Approximation of Regional Responsibility

Since IOTs do not include information about the country of destination for exports, additional data was needed to determine the destination of China's export emissions. This analysis was based on a previous study by one of the authors (GP) using multiregional model of international trade using the GTAP database (Peters & Hertwich, 2008). The methodology is similar as described in this paper, except that it covers 87 countries and regions at a 57 sector resolution for s aingle year, 2001. The calculation done here is extended by including the bilateral time series from 1980-2002 from the GTAP database. Since the trade data is in current prices, we only consider trade shares, which basically assumes that inflationary effects are constant between different countries. In terms of the CO_2 emissions, it assumes that each sector and region has roughly equal efficiency improvements. Due to the GTAP model's data availability, this method could only be used up to and including 2002.

For 2005 the destination of the emissions embodied in China's exports was approximated based on Chinese export data (total exports by country of destination) from the China Statistical Yearbook 2007(National Bureau of Statistics, 2007b). Data for years 2000, 2001, and 2002 were averaged to obtain approximate carbon intensities of total exports to each region; i.e., CO_2/yuan, which were then used for linear interpolation of embodied carbon in exports for 2003-2005 using total exports. For example, from 2000-2002, exports to the US were seen as relatively more carbon intensive than exports to the rest of the world, Table 1. These relative factors were then used in combination with total exports to each region (see Table 2) to approximate embodied CO_2 exported to each region in 2003-2005.

2.5 Input-Output Data

We employed China's input-output tables (IOT) from Li and Xue (Li et al., 1998) for 1987, 1990 and 1995 with 30 sectors in constant 1990 prices. We obtained the input-output tables from the Chinese National Bureau of Statistics (NBS) for 1992 with 118 sectors (National Bureau of Statistics, 1996), 1997 with 124 sectors (National Bureau of Statistics, 1999), 2002 with 122 sectors (National Bureau of Statistics, 2006), and 2005 with 42 sectors (National Bureau of Statistics, 2007a), all at current prices. All the tables have the same final demand categories: household consumption, government expenditures, capitals investments, exports, imports, and "others" (see above).

2.6 Energy and Emissions Data

The CO_2 by industry sector for 1992, 1997, and 2002 were constructed in previous work by two of the authors (GP and CW) , and data for all other years were calculated using the same method (see (Peters et al., 2006) for details). The emissions include both the combustion of fuels and industrial processes and were constructed using official Chinese energy statistics and the IPCC reference approach (IPCC, 1996). The energy and emissions data have 36 industry sectors.

It should be noted that several authors have questioned the legitimacy of the official Chinese energy statistics for certain years, especially from around 1996 to 2004(Sinton, 2001; Streets et al., 2001; Wu, 2007). During this period, Chinese coal consumption first declined and then rose precipitously, creating substantial variation in the energy intensity of the economy. There is still significant controversy over whether the 1996-2000 decline in energy intensity was real or a factor of under-reporting to data collection agencies (Peters et al., 2007), though recent satellite data seems to suggest some level of under-reporting(Akimoto et al., 2006). We utilize the raw data from the Chinese statistical agencies despite these issues, though we note that this may cause an underestimation of China's export emissions in 2000 and 2002.

3. Results

Figure 1 shows a breakdown of China's CO_2 emissions from 1987 to 2005 into the four driving forces of GDP: household consumption, capital investment, government expenditure, and exports. Since imports have already been subtracted from production functions (equation 4), the sum of these four components equals total domestic CO_2 emissions, as opposed to total CO_2 emissions embodied in consumption.

We find that in 2005, 33% (1,700 Mt) of China's domestic CO_2 emissions were in the production of exports and this has steadily increased from 12% (230 Mt) in 1987. Interestingly, these figures mirror very closely the rise of exports as a percentage of GDP, meaning that exports are on average no more or less carbon-intensive than domestic consumption and investment. To put this figure into perspective, China's export emissions in 2005 (1,700 Mt) were similar to the combined emissions of Germany, France, and the UK (1850 Mt) (EIA, 2007).

A dramatic rise in exported CO_2, from only 21% (759 Mt) of domestic emissions, has occurred since 2002, mirroring both the overall steep increase in China's CO_2 emissions (keeping in mind potential undercounting in 2002) and the large increase in exports over this period, from 22% of GDP in 2002 to 33% in 2005. In most years the growth rate of the emissions from the production of exports is greater than the growth rate of total emissions, showing the particular importance of exports to China's growth in CO_2 emissions.

It is useful to analyze the breakdown of Chinese export emissions by commodity. Figure 2 shows a breakdown of the growth in these emissions by major commodity group that China exports. Recently (in 2005), substantial fractions of total emissions are due to exports of electronics (22% of total), metal products (13%), textiles (11%), and chemical products (10%). It is clear that the large recent growth in export emissions is due more to advanced products than previously, as the 1995 breakdown of export emissions was substantially different: 19% textiles, 13% electronics, 12% machinery, and 10% chemicals, and 7% metal products. Emissions embodied in primary product exports (defined here as all mining, raw timber, raw chemicals, and basic metals) have decreased from around 20-24% in the early years of the analysis (1987-1992) to only 13% in 2002-2005.

Of course, China also is a large importer, and it avoids domestic emissions by importing raw materials as well as final goods and services. The method utilized here (singleregion EIOA) can be used to estimate the CO_2 emissions which would have occurred in China had all Chinese imports been made domestically (typically called “emissions avoided by imports”, EAI). However, the actual emissions embodied in imports are impossible to calculate without a global model with global trade data, since every country which China imports from must be modeled (see (Peters & Hertwich, 2008)). Table 4 shows such results, in million tonnes of CO_2 (Tg CO_2), for total Chinese emissions (total), emissions embodied in exports (EEE) and emissions in China avoided by importing (EAI) for all years.

Clearly, China avoids large amounts of emissions through its imports; in every year the avoided emissions are higher than the exported emissions. However, as previously explained EAI is a biased measure for China, since China’s carbon intensity is significantly higher than most(Peters & Hertwich, 2008; Peters et al., 2007). Previous work which has accounted for this difference has estimated that in 2001 carbon emissions embodied in China’s imports were four times lower than in its exports(Peters & Hertwich, 2008).

The current focus on China mirrors the importance of trade in the environmental profile of many other countries. For example, in 2001, 22% of global CO_2 emissions were in the production of exports(Peters & Hertwich, 2008). Countries vary widely in their relative shares of CO_2 in trade; most European countries have a high share of their domestic emissions in the production of exports (20-50%), the USA had 8%, Japan 15%, India 13%, South Korea 28%, and South Africa 45%(Peters & Hertwich, 2008). A key explanatory variable for the share of emissions in the production of exports is size – in general, small countries have larger shares while large, and thus relatively self-sufficient, countries have lower shares. China does not fall into this categorization as it is a large country with a large share of exports. China’s exports thus play an important role in its environmental profile compared to other countries.

A key question is whether the rapid growth of exports in China – or any other country – is at the expense of production in developed countries, loosely termed by many as “carbon leakage” (Metz et al., 2007) or the “pollution haven hypothesis (PHH)” (Rothman, 1998). The IPCC has placed low importance on carbon leakage since its definition of leakage only considers marginal emission changes in non-Annex I countries resulting *explicitly from climate policy* within Annex I countries. It is unlikely that China's increased export emissions are due to current climate policy in Annex I countries; they are simply a byproduct of China's other advantages for production such as lower environmental standards and lower labor costs. Using the IPCC definition one would expect to find low levels of carbon leakage, and thus, the problem has been defined away. But the issue does remain: increased consumption in Annex I countries is met by expanded production in non-Annex I countries(Peters & Hertwich, 2008; Rothman, 1998; Weber et al., 2007). A stronger definition of carbon leakage considers increases in emissions in non-Annex I countries that might occur for reasons other than climate policy in Annex I countries. It is this latter type of "carbon leakage" that lies at the core of China's increased export emissions.

Indeed, large portions of recent Chinese export emissions go to the developed world, with approximately 27% to the US, 19% to the EU-27, and 14% to the remaining Annex B countries, mainly Japan, Australia, and New Zealand (Figure 3). While approximately 40% of China's export emissions go to the non-Annex B developing world, these flows are still important because Chinese exports to developing countries may displace either domestic production there or production from another trading partner which would have released less CO_2 for the same amount of products.

This is because relative to production in most other countries, Chinese production is more polluting, due both to inefficient production systems and a coal-dominated electricity supply(Peters & Hertwich, 2008; Weber & Matthews, 2007). The low-cost of Chinese production does benefit most consumers, but this benefit comes at the detriment of both the local Chinese environment (Streets et al., 2006) and the global environment due to the effects of climate change. Cheap production in China could be globally beneficial in terns of the environment as well, though, particularly in driving down the costs of environmental products like energy-efficient lighting or wind turbines. Any increased emissions from production of these products in China would likely be outweighed by the positive impacts of their use. Unfortunately, this potential benefit of cheap Chinese production has not yet materialized.

Recently, China reacted to both the increasing pollution caused by the production of exports and fears of resource security by raising export taxes on certain products

(Ministry of Finance People's Republic of China, 2007). These export taxes were placed mostly on primary products such as raw metals and chemicals. However, as previously shown above, these products represent a small fraction of the emissions from China's exports—approximately 13% in 2005, even if all chemicals are included in this category (see fig. 2).

A more effective approach would use monetary or tax policy to discourage large-volume export commodities such as machinery (19% of exported CO_2 in 2005), electronics (22%), metal products (13%), and textiles (11%). However, since these higher value-added products contribute more to China's economic growth than primary products, this approach would lead to higher costs to the Chinese economy through loss in competitiveness, as well as costs to consuming countries through increasing inflation.

4. Discussion: Who is Responsible for China's Emissions?

It is clear Chinese exports are currently responsible for large amounts of greenhouse gas emissions; our estimate for 2005 (1700 Mt CO_2) represents 6% of global CO_2 emissions from fossil fuels(EIA, 2007). This staggering statistic begs the question of who should be responsible for the emissions resulting from the production of China's exports (Munksgaard et al., 2001). There are, of course, many arguments from both sides of the issue.

On the one hand, while China's economic development benefits from export growth, so do the consumers in developed countries, and it can be argued that they should be held at least somewhat responsible for emissions occurring because of their demand for low-priced goods. If these consumers were to become partially responsible for China's export emissions (Peters, 2008), perhaps China would be more willing to play an active role in post-Kyoto climate commitments. In general, recognizing the role the international trade plays in greenhouse gas emissions may open new opportunities, and are possibly a precondition, for political agreement(Peters & Hertwich, 2008).

However, there are also many arguments against countries taking responsible for emissions from Chinese imports. China itself imports many products, including many components of the final products it exports, and it avoids greenhouse gas emissions by doing so. As shown above, in all years analyzed, the emissions in China avoided by importing were actually higher than exported emissions, though in reality, since most countries are less carbon-intensive than China, the actual emissions embodied in China's imports are lower than the emissions avoided in China.

Further, although one-third of China's CO_2 emissions result from the production of exports, it is important to keep track of the remaining two-thirds of emissions. Capital expenditure necessary for building up infrastructure and production capacities has been responsible for between 32-37% of China's CO_2 emissions since 1987(see above Fig. 1). Of course, at least part of these emissions could be indirectly attributed to exports because much of the infrastructure improvements occurring are for export production. Interestingly, household consumption is responsible for a decreasing portion of emissions, from 45% in 1987 down to 28% in 2005, further showing the importance of exports and capital goods. Nevertheless, household consumption is widely seen as the future driver of China's economy, and thus its future CO_2 emissions (IEA, 2007).

Whoever is responsible for emissions to produce Chinese exports, inefficient and coal-dominated electricity production is at the core of China's CO_2 emissions, accounting for 44% of China's total emissions in 2005. It is clear that urgent improvements are needed in this sector. Increasing efficiencies, installing more renewable power, and overcoming the financial and technological hurdles involved with carbon capture and sequestration (CCS) should be the first priority of China and its export partners alike. Allowing Kyoto parties to count the incremental cost of CCS within the framework of the Clean Development Mechanism could be a crucial first step(de Coninck, 2008). However, the monumental size of the challenge ensures that all available options will be needed.

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References

Ahmad, N., & Wyckoff, A. (2003). **A. Carbon dioxide emissions embodied in international trade of goods Organisation for Economic Co-operation and Development**. Paris: OECD.

Akimoto, H., Ohara, T., Kurokawa, J.-i., & Horii, N. (2006) Verification of Energy Consumption in China during 1996-2003 by Using Satellite Observational Data. **Atmospheric Environment**, 40, pp. 7663-7667.
de Coninck, H. (2008) Trojan Horse or Horn of Plenty? Reflections on Allowing CCS in the CDM. **Energy Policy**, 36, pp. 929-993.
EIA. (2007). **International Energy Annual 2005**: Energy Information Administration.
IEA. (2007). **World Energy Outlook 2007**. Paris: International Energy Agency.
IPCC. (1996). **Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (3 volumes)**: Intergovernmental Panel on Climate Change.
Leontief, W. (1986). **Input-Output Economics** (Second Edition ed.). New York: Oxford University Press.
Leontief, W., & Ford, D. (1972). Air pollution and the economic structure: empirical results of input-output computations. In A. Brody & A. P. Carter (Eds.), **Input-Output Techniques** (pp. 9-30). Amsterdam: North Holland.
Li, Q., & Xue, T. (1998). **Sectoral analysis of China's economic development: comparable input-output tables**. Beijing: China Statistics Press.
McGregor, R. (2007). China takes stand on climate. *Financial Times*.
Metz, B., Davidson, O., Bosch, P., Dave, R., & Meyer, L. (Eds.). (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
Miller, R. E., & Blair, P. D. (1985). **Input-Output Analysis: Foundations and Extensions**. Englewood Cliffs, New Jersey: Prentice-Hall.
Ministry of Finance People's Republic of China. (2007). **Announcement of further adjustment on custom tariff from January, 1st 2008**. Beijing.
MNP. (2007). *China now no. 1 in CO_2 emissions; USA in second position*: Netherlands Environmental Assessment Agency.
Munksgaard, J., & Pedersen, K. A. (2001) CO_2 accounts for open economies: Producer or consumer responsibility? **Energy Policy**, 29, pp. 327-334.
National Bureau of Statistics. (1996). **1992 Input-Output Table of China** Beijing: China Statistics Press.
National Bureau of Statistics. (1999). **1997 Input-Output Table of China** Beijing: China Statistics Press.
National Bureau of Statistics. (2006). **2002 Input-Output Table of China** Beijing: China Statistics Press.
National Bureau of Statistics. (2007a). **2005 Input-Output Table of China** Beijing: China Statistics Press.
National Bureau of Statistics. (2007b). **China Statistical Yearbook 2007**. Beijing: China Statistical Press.
National Development and Reform Commission. (2007). *China's National Climate Change Programme*: National Development and Reform Commission People's Republic of China.
Peters, G. P. (2008) From production-based to consumption-based national emission inventories. **Ecological Economics**, In Press, Corrected Proof, pp.
Peters, G. P., & Hertwich, E. G. (2008) CO_2 Embodied in International Trade with Implications for Global Climate Policy. **Environmental Science and Technology**, 42, pp. 1401-1407.

Peters, G. P., Weber, C., & Liu, J. (2006). **Construction of Chinese Energy and Emissions Inventory**. Trondheim: Norwegian University of Science and Technology.

Peters, G. P., Weber, C. L., Guan, D., & Hubacek, K. (2007) China's growing CO_2 emissions - a race between increasing consumption and efficiency gains. **Environmental Science and Technology**, 41, pp. 5939-5944.

Rothman, D. S. (1998) Environmental Kuznets Curves-real progress or passing the buck? A case for consumption-based approaches. **Ecological Economics**, 25, pp. 177-194.

Sinton, J. E. (2001) Accuracy and Reliability of China's Energy Statistics. **China Economic Review**, 12, pp. 372-383.

Streets, D., Yu, C., Bergin, M., Wang, X., & Carmichael, G. (2006) Modeling Study of Air Pollution Due to the Manufacture of Export Goods in China's Pearl River Delta **Environmental Science and Technology**, 40, pp. 2099-2107.

Streets, D. G., Jiang, K., Hu, X., Sinton, J. E., Zhang, X.-Q., Xu, D., et al. (2001) Recent Reductions in China's Greenhouse Gas Emissions. **Science**, 294, pp. 1835-1837.

United Nations. (1993). **Handbook of National Accounting: Integrated Environmental and Economic Accounting. Studies in Methods**. New York: United Nations.

United Nations. (1999). **Handbook of input-output table compilation and analysis. Studies in Methods Series F, No 74. Handbook of National Accounting**. New York: United Nations.

Wang, T., & Watson, J. (2007). *Who owns China's carbon emissions?* : Tyndal Centre for Climate Change Research.

Weber, C., & Matthews, H. S. (2007) Embodied Environmental Emissions in U.S. International Trade 1997-2004. **Environmental Science and Technology**, 41, pp. 4875-4881.

WRI. (2007). *Climate Analysis Indicators Tool (CAIT) Version 5.0*

Wu, C. (2007). Action plan aims to cut gas emissions. *China Daily*.

Tables:

Table 1

Region	CO_2/yuan
US	1.28
EU27	1.02
EIT	0.86
Rest of B	0.90
Non-B	0.91

Relative carbon intensity of exports to each region, 2000-2002, as % of embodied emissions/% value of trade

Table 2

	2003	2004	2005
US	0.21	0.21	0.21
EU27	0.18	0.18	0.19
EIT	0.02	0.02	0.02
Rest of B	0.17	0.16	0.15
Non-B	0.42	0.43	0.43

Total export share to each region from 2003-2005 (see Figure 3 for country definitions)

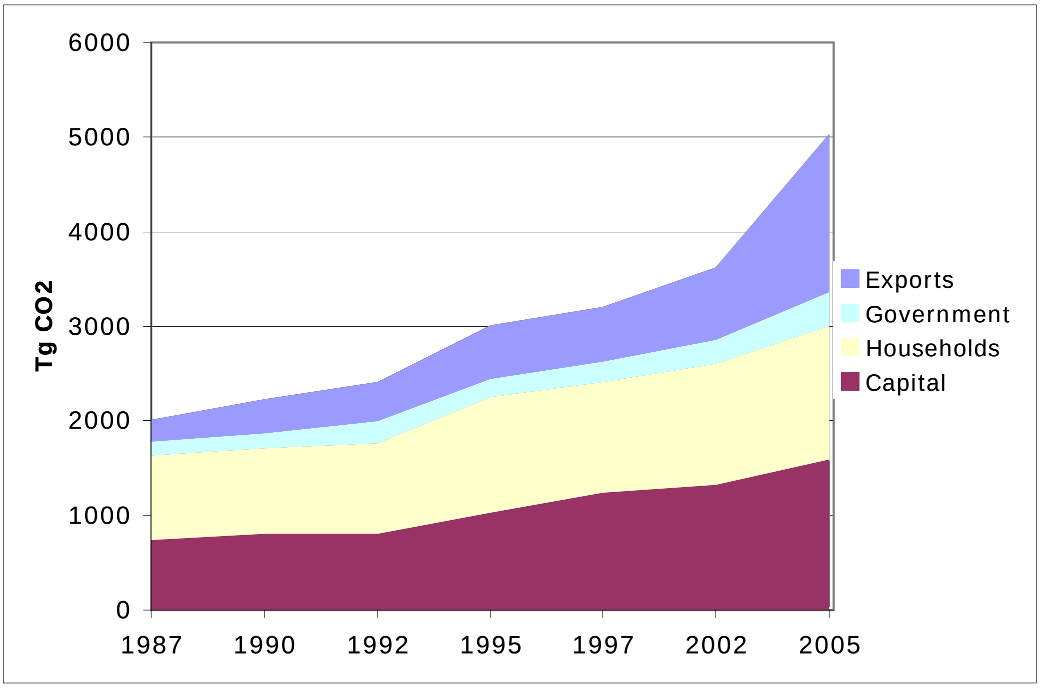
Table 3

	1987	1990	1992	1995	1997	2002	2005
Total	2010	2230	2410	3010	3210	3620	5030
EEE	230	360	420	570	580	760	1670
EAI	390	420	560	710	700	1170	2200

Total CO_2 emissions, emissions embodied in exports (EEE) missions avoided by imports (EAI), Tg CO_2

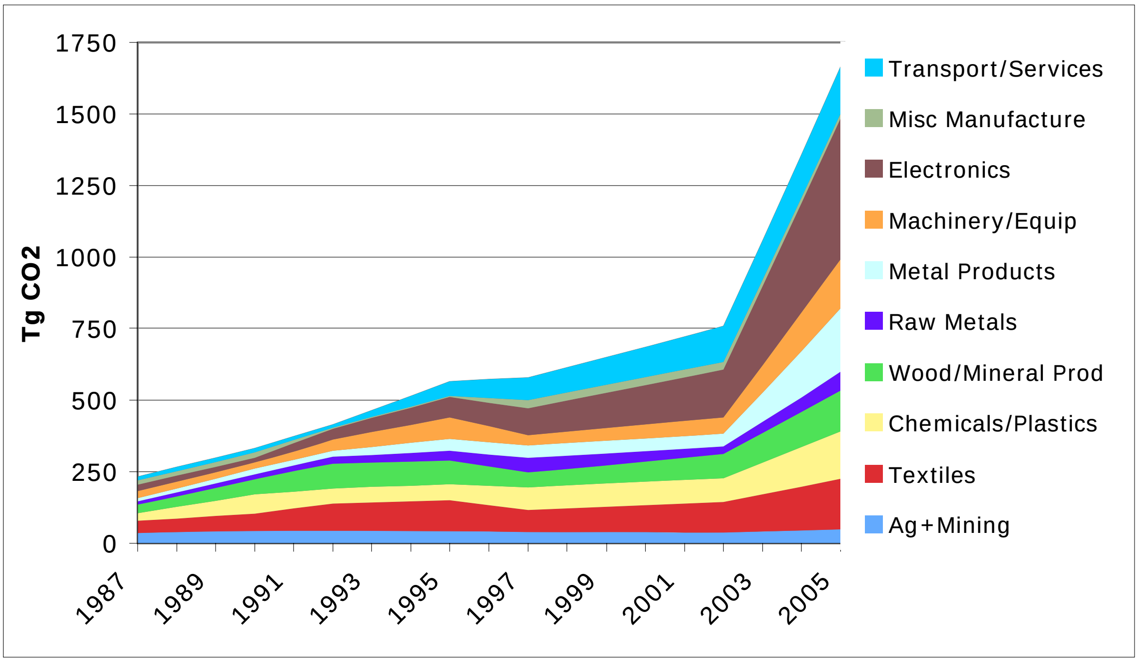
Figures:

Figure 1



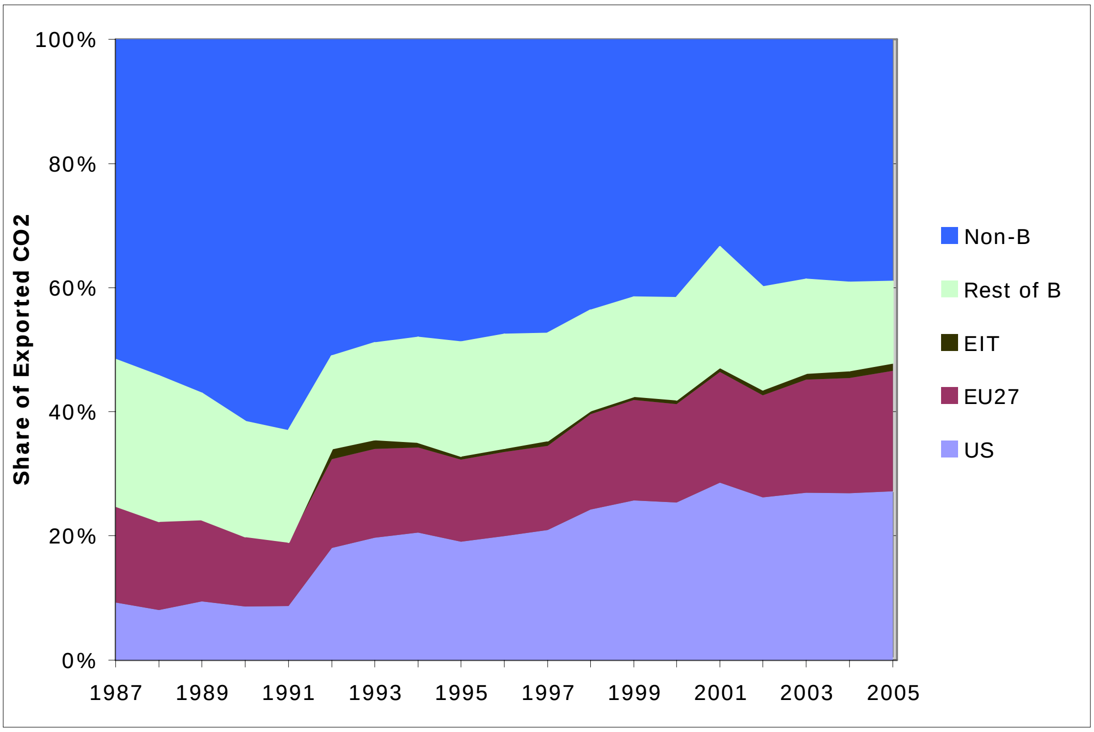
China's total domestic CO_2 emissions, divided by driving demand: exports, governmental consumption, household consumption, and capital investment

Figure 2



Chinese export emissions by major commodity group (Tg CO_2)

Figure 3



Region of destination for Chinese CO_2 emissions embodied in exports by year. EU27 does not include any economies in transition (EIT), and "Rest of B" represents all remaining Annex B countries which do not fall into another group.