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On The Pollution Content of China's Trade: Clearing the Air?

By

Chris Milner and Fangya Xu

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The Authors

Chris Milner is a Research Fellow in GEP and Professor of International Economics in the School of Economics at the University of Nottingham; Fangya Xu is a Research Student in the School of Economics at the University of Nottingham.

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Abstract
This study compares alternative measures of the potential and actual pollution content of China's trade using an environmental I-O methodology. Using the conventional, potential measure adopted by other researchers, we find that China 'saves' on local environmental resources by exporting goods that on average embody less pollution content than imports would if they were produced locally in China. A less positive, assessment of the environmental impact of China's trade emerges, however, if the assumption of a common technology for producing exports and imports is dropped. Using an actual pollution content methodology for measuring the pollutants embodied in the production of both exports and imports, we find that China is actually a net exporter of embodied pollutants.

JEL classification: F18, Q56

Keywords: Trade, pollution content, China

Outline

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Non-Technical Summary

There has been considerable interest in the environmental implications of China's opening up and the associated expansion of its exports and imports. We can empirically explore the environmental impacts of China's international trade by measuring its pollution content in a similar fashion to that used by trade economists to measure the factor content of trade. This involves the measurement of the emission of pollutants associated with the production of imports and exports; the international exchange of these goods embodying therefore pollutant emissions and the use of environmental services.

Some recent evidence (Dean and Lovely, 2008) shows that Chinese exports are less water pollution-intensive, and generally less air pollution-intensive than Chinese imports. They interpret this as evidence that trade liberalisation has favoured China's environment, inducing more specialisation in cleaner, labour-intensive and processing activities in China. This effect might be viewed as a type of 'gain' from trade for China; with relatively scarce environmental resources being saved in China. But this favourable view of the effects of trade arises from the use of a potential pollution content measure of China's trade, which compares the pollution emissions induced by the production of China's exports with those of its imports as if these imports had been produced in China. However, when measuring the pollution content of trade it may be important to measure also the actual pollution content of trade, which involves comparing the pollution embodied in the production of exports with that actually embodied in the production of imports in the exporting countries. From evidence on the actual pollution content it is possible to comment on the actual environmental impact of China's trade.

We report in this paper on both the potential and actual pollution content of China's trade, using an I-O modelling framework that captures both the direct and indirect pollution effects of the production of exports and imports. The study focuses on air pollutants for various years over the period 1987 to 2002. For the case where we assume exports and imports are produced using the local (Chinese) technology (i.e. the potential pollution content measure) our findings are consistent with the existing research; China's exports are cleaner than its imports and China is therefore a net importer of embodied pollutants and environmental services. China has gained 'environmentally' from the opening up of the economy and expansion of trade, with it specialising more in the production of relatively cleaner exportables and reducing relatively the production of environmentally damaging importables goods.

By contrast, if one drops the common technology assumption and measures the actual pollution content of both exports and imports (i.e. using the technology for countries exporting to China), China is found to be a net exporter of embodied pollution. Trade has allowed China to save on local environmental resources given its own technology and environmental regulations, but China's trade results overall and on average in more pollution generation in China than in the rest of the world. There is therefore considerable scope for reducing the pollution content of China's trade through the adoption of more energy-efficient production methods in China.

1. Introduction

There has been considerable interest in the environmental implications of China's enormous trade expansion, both in terms of its global emissions implications and of the distribution of emissions across countries. The net effect in global economic activity associated with the expansion of China's exports and imports will have raised global emissions (*scale effect*), but there is concern also about whether there is a further tendency for global emissions to increase due to the relocation of economic activity from 'cleaner' locations towards China. This relocation effect will come about as a result of contracting output outside of China and expansion of production in China, associated with the changes in trade specialisation and increase of foreign direct investment in to China (*compositional effect*). What drives this compositional effect has in turn been of interest, because it might be driven by either differences in the stringency of environmental regulations or in endowments (labour, capital etc) in China and elsewhere or by both.

A number of research approaches have been used to investigate this issue empirically. One natural way is to measure the pollution content of China's trade, in a similar fashion to that used by trade economists to measure the factor content of countries' trade – going back to the pioneering work of Leontief (1953). A number of studies have measured the pollution content of different countries' trade, either using simple, direct measures of the emissions associated with the production of exports compared with imports - strictly import-substitutes (e.g. Grether et al., 2006) or more ambitious measures of the direct and indirect emissions using input – output (I-O) techniques (Leontief, 1970; Walter, 1973; Machado, Schaeffer and Worrell, 2001).

Recent evidence on the embodied pollution in China's trade shows that China's exports are cleaner than its imports. For instance, Dean and Lovely (2008), using a direct measurement approach for air and water pollution for Chinese industries in the period 1995 to 2004, conclude that Chinese exports are less water pollution-intensive, and generally less air pollution-intensive than Chinese imports. They interpret this as evidence of a compositional effect that has favoured China's environment, one induced by trade-induced specialisation in China towards cleaner, labour-intensive and processing activities and away from dirtier, capital-intensive production. (This is consistent with the finding Temurshoev (2006) for US – China trade.) This favourable compositional effect might be expressed as a further gain from trade for China and globally; a net saving of relatively scarce environmental resources in China and net usage of relatively more abundant environmental resources in the rest of the world. But is that necessarily so? Dean and Lovely (2008) are using a common technology approach to measure the (*hypothetical or potential*) pollution content of China's trade; *a measure which compares the pollution embodied in the production of China's exports with what would be embodied in the imports consumed by China from abroad if they had been produced by the corresponding import-competing industries in China.* This is a sensible comparison if you want to examine the environmental gains from trade from China's view point only, or if there is in fact a common or uniform technology across countries.

A common technology assumption across countries has traditionally been employed in empirical factor content studies of trade because the standard H-O model of international trade explains trade in terms of endowment differences across countries with assumed common technologies. This was also a convenient assumption because it allowed information on the technology of one country (often the USA) to be imposed on the production of exports in all locations. It is, however, now widely recognised as a very strong assumption (Dietzenbacher et al., 2005), and one that does not hold, especially across countries with marked development differences. It is, therefore, now common to allow for technological differences in the factor content testing of H-O trade models (Trefler and Zhu, 2000; Davis and Weinstein, 2001; Cabral, Falvey and Milner, 2009). When measuring the factor content of trade it may also be important to measure the actual, rather than a potential or hypothetical, factor content of trade (see, for example, Cabral, Falvey and Milner, 2006). We argue in this paper that it is the case also when measuring the pollution content of trade, where the actual pollution content *compares the pollution embodied in the production of China's exports with that actually embodied in the production of China's imports (outside of China).* From evidence on the actual pollution content it will be possible to comment on the actual environmental impact of China's trade.

We report in this paper, therefore, on both the potential and actual pollution content of China's trade, using an I-O modelling framework that captures both the direct and indirect pollution effects of the production of tradeables. The study focuses on air pollutants and various years over the period 1987 to 2002. The remainder of the paper is organized as follows. Section 2 provides a brief review of the literature on measuring the pollution content of international trade. The methodology employed by the study is set out in section 3. Section 4 describes the data used and provides some information on pollution-intensities of production in China, while section 5 provides the alternative estimates of the pollution content of China's trade. The summary conclusions of the study are given in section 6.

2. Literature Review

Trade can be either conceived as the overt exchange of goods or as the exchange of the services of production factors embodied in that exchange of goods. Vanek (1968) introduced the factor services version of the H-O model of trade, which we traditionally view in terms of factors of production such as capital and labour. If we extend this representation to involve environmental services or usage of environmental endowments, then we can represent international trade as involving of the exchange of the pollutants embodied in that exchange of goods.

Measurement of direct effects

Some studies measure only the direct pollution content of trade by multiplying industrial emission intensities with the levels of industrial production corresponding with these trade volumes. Due to data limitations, quite a few studies of industrial pollution rely heavily on US industrial pollution emissions data such as the Industrial Pollution Projection System (IIPS) database. Lucas et al. (2002) admit that the assumption of constant, U.S.-based, output intensities limits the usefulness of some of this analysis. The assumption of constant and common output pollution intensities embodies three questionable components: that similar technologies and enforcement standards exist across countries; that there is a similar mix of products within each industry across countries; and that emissions are related to output not value added.

Muradian et al. (2001) provide an overview of the pollution embodiment in trade for 18 industrialized countries for various years over the period from 1976 to 1994. Using the emissions intensities of five air pollutants from the Industrial Pollution Projection System (IIPS) database, the authors find that in the 1990s embodied emissions tended to be larger in imports than in exports for these industrial countries. Also using IPPS coefficients, Grether et al. (2005) measure the amount of pollution emitted per dollar of imports. The authors explore, in a gravity model framework, the determinants of pollution content in trade as well as the factor content of trade specialization for 16 different pollutants in more than 50 countries over the 1986-1996 periods. Using CO_2 emissions per dollar of GDP as the preferred proxy for environmental stringency, their results suggest an influence of both standard factor endowment and laxer environmental standards on patterns of international specialisation.

Using trade flows data with the country specific CO_2 emissions per unit of GDP from China's trading partners, Wang and Watson (2007) estimate that about a quarter of Chinese CO_2 emissions in 2004 can be attributed to the net exports of goods and services. However, they recognize this may be an over-estimate since they do not distinguish between CO_2 emissions intensities for different traded products.

With growing data availability in China, more studies on China's environment now apply Chinese-specific industrial datasets such as those reported by China's State Environmental Protection Agency (SEPA). One example is Chai (2002) which finds that freer trade has enabled China to specialise in labour- intensive, cleaner industries and that the aggregate pollution intensity of imports was much greater than that of its exports during the periods 1980-1982 and 1996-1998.

To account for pollution emission intensity differences across industries, Dean and Lovely (2008) apply annual Chinese pollution intensities across industries and annual trade data for the years 1995 to 2004. Their results suggest that Chinese exports appear to be much cleaner than Chinese imports. Of the four pollutants (COD, SO_2, smoke and dust) being examined, they find the first three are more intensive in Chinese exports than in imports (assuming that imports were produced using Chinese technologies). While both exports and imports are becoming cleaner over time, they also find that the difference in pollution intensity in exports and imports is also diminishing.

Measurement of indirect and direct effects

Input-output (I-O) techniques have a relatively long vintage in estimating pollution embodiment. Walter (1973) examines the product-profile of U.S. exports and imports and compares it with a pollution profile. Pollution content is defined as environmental control costs consisting of R&D, operating costs, capital cost and appreciation of equipments. For each product group, the direct environmental management cost is estimated and the 1966 U.S. input-output coefficients are applied to account for the indirect costs in intermediate inputs attributable to environmental management. Using 1968-1970 imports and exports data, the author finds that the average annual overall environmental cost loadings in exports as a ratio of exports was insignificant though slightly larger than that of imports using a common technology assumption.

In contrast with Walter (1973), most studies investigating pollution content measure the physical flows of emissions such as greenhouse gases. Wyckoff and Roop (1994), for instance, estimate the amount of carbon contained in imports of manufactured goods for six of the largest OECD countries in the mid-1980s: Canada, France, Germany, Japan, the UK and the USA. They use country specific input-output tables, origin specific imports[1], country and industry specific energy use data, and a carbon conversion ratio for each fuel type. The authors conclude that the embodiment of carbon in manufactured goods is significant in the mid-1980s with about 13% of the total carbon emissions of the six countries estimated to be embodied in manufactured imports (excluding imports of refined petroleum products).

Antweiler (1996) uses the notion of the pollution terms of trade index (PTTI) to eliminate the balance of trade effect in pollution embodiment calculations and assign weights to different pollutants to obtain a unique physical dimension. Using the US 1987 I-O table, identical technologies assumption (US industrial pollution data) and trade flows, the author calculated the index values for 164 countries in 1987. The results suggest that exports of the industrialized countries are less environmentally

[1] It is assumed that imports from any country other than the six OECD countries have been produced using the same technology as the importing country.

clean than their imports, while the opposite holds for the developing countries (including China).

Hayami et al. (1997) investigate the applications of I-O techniques in environmental management. The emission of global warming gases in Japan is simulated conditional on the production technology (e.g. choice of cement production approaches) and consumer preferences. The authors also compare SO_2 emission in Japan and China in 1987. Replacing certain characteristics of the Chinese economy by the Japanese counterparts, they find that China could have increased SO_2 emissions by adopting Japanese consumption patterns. By contrast a substantial reduction in emissions would have occurred had Japanese energy usage (patterns, energy efficiency and removal ratio of sulphur and SO_x) been adopted in China.

As international treaties such as the Kyoto protocol push the issue of global warming to a higher platform, a number of investigations explore whether producers' responsibility or consumers' responsibility should be accounted for in burden sharing of GHG emissions reduction. For example, Proops et al. (1993) distinguish "CO_2 emission" from "CO_2 responsibility" in a comparative input-output study of Germany and the UK. Assuming identical technologies in imports, Munksgaard and Pedersen (2001) use "consumer responsibility" and "producer responsibility" to examine the time series change in Danish CO_2 production and consumption. Using country specific I-O tables mostly produced/converted by the OECD Secretariat, Ahmad and Wyckoff (2003) compare "domestic consumption" and "domestic production" in 24 countries (responsible for 80% of global CO_2 emissions) in the mid-1990s. Increased data availability has enabled related studies to focus on the developing countries such as Brazil, Thailand, India and China. Machado et al. (2001) use the so-called hybrid input-output model (energy commodities in physical units and non-energy commodities in monetary units) and convert energy data to carbon figures using IPCC 1996 guidelines. They find that, in terms of energy and carbon embodiment in trade, Brazil is not only a net exporter in non-energy goods but also the embodiment in exports is substantially greater than that in imports in 1995.

Using Indian input-output tables for 1991/1992 and 1996/1997 and IPCC guidelines, the two related papers Mukhopadhyay and Chakraborty (2005) and Dietzenbacher and

Mukhopadhyay (2007) find that India gained environmentally from international trade in 1991/1992 and 1996/1997. Dietzenbacher and Mukhopadhyay (2007) refer to this phenomenon as Green Leontief Paradox. By contrast Mukhopadhyay (2006) concludes that Thailand moved from a net pollution importer in earlier years to a net pollution exporter in 2000.

3. Methodology

In this study, we focus on three air pollutants: carbon dioxide (CO_2), the single largest greenhouse gas in volume, as well sulphur dioxide (SO_2) and nitrous oxide (NO_x). It is estimated that the use of solid fuels (coal), liquid fuels (oil) and gaseous fuels (natural gas) contributes to over 90% of CO_2 emissions from fossil fuel combustion[2]. Since these primary energy commodities are built in I-O tables, we assume[3] that all the coal, oil and natural gas are combusted whenever they are used as an intermediate input generating greenhouse gases. Combustion processes and abatement technologies also affect the final release of emissions. We estimate the emissions generated from combustion process but not the removal of them in the abatement process. The combustion process is assumed to derive the maximum amount of energy per unit of fuel consumed, hence delivering the maximum amount of emissions.

Environmental Input-Output Analysis

We adopt the environmental I-O analysis developed in Miller and Blair (1985). This methodology has been used in number of subsequent studies, for example, Ahmad and Wyckoff (2003), Dietzenbacher and Mukhopadhyay (2007), Mukhopadhyay and Chakraborty (2005), and Temurshoev (2006). It combines I-O modelling and the emission factors suggested by IPCC guidelines[4]. The linear relationships of the

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2 Emissions can be generated from other sources such as biological metabolism, chemical reactions, and volcanic eruptions, burning wood etc. The magnitude of the emissions generated from these sources may not be negligible. However, they are not explicitly analyzed in this study.

3 See also in Mukhopadhyay and Chakraborty (2005), Dietzenbacher and Mukhopadhyay (2007), and Temurshoev (2006).

4 IPCC (1996) argue that the manufacture of secondary fuels should be ignored in the main calculation, as the carbon in these fuels has already been accounted for in the supply of primary fuels from which they are derived. Refined fuel products are for information only. In the case of fuel combustion, the emissions of non-CO_2 gases contain very small amounts of carbon compared to the CO_2 estimate and, at Tier 1; it is more accurate to base the CO_2 estimate on the total carbon in the fuel. This is because the

interlinked sectors in an I-O model enable us to investigate the impact of demand (final consumption deliveries) on production and hence on pollution. The model basics are as follows:

In a particular year **t,** for an individual country **c**, there are **N** commodities each serving as final deliveries as well as intermediate inputs for themselves and other commodities. All the energies are derived from **M** primary energy commodities: Raw Coal, Crude Oil and Natural Gas. Let a_{ij} represent the input coefficient, i.e. the number of units of commodity i needed to produce one unit of commodity j (i, j=1, 2…, N). An N * N matrix of input coefficients is represented by A= {aij}. X is an N * 1 vector denoting domestic output of commodities and Y is an N * 1 vector denoting the final demand. The equilibrium condition of supply equalling demand is captured by the following equation:

$$X=AX+Y \quad (1)$$

where Y can be further decomposed into final consumption of domestic goods (Y^D), final consumption of imported goods (Y^M) and goods that are exported (Y^X).

By matrix operational rules, we can solve X as:

$$X= (I-A)^{-1}Y \quad (2)$$

The N * N matrix $(I-A)^{-1}$ is often referred to as "the Leontief inverse", which represents the totality of the direct and indirect input requirements of domestic goods. This relationship implies that any change in the components of final demand will affect domestic production and in turn any change in domestic production will result in a change of pollution emissions and on the environment if we view pollution emissions as "consumption" of environmental resources.

The commodities coal, crude oil and natural gas are the basic fossil fuels. We denote the energy requirement matrix (extracted from matrix A) as B of order M * N. Hence

total carbon in the fuel depends on the fuel alone while the emissions of the non-CO_2 gases depend on many factors such as technologies, maintenance etc which, in general, are not well known. At higher tiers, the amount of carbon in these non-CO_2 gases can be accounted for.

b_{ij}[5] refers to the requirement in monetary units on energy commodity i per unit of the output of commodity j.

Chemical emission factors are the product of the net calorific values for each fuel and the chemical (CO_2, SO_2, NO_x) content in net calorific values as suggested in IPCC guidelines. Denote E as a 3*M emission matrix for the three emissions per SCE (Standard Coal Equivalent) of combustion for each fuel type.

Since the coefficients in B are in monetary units while the coefficients in the emission matrix E are in physical units, we have to reconcile the two before multiplication. Comparing the physical units and the monetary units in total fuel output, we can obtain an approximation for the ratio of SCE per unit of currency[6] for each energy type in producer's price. Denote the ratios in M*M diagonal matrix as R. Hence the pollution embodied (P) in a final delivery Y (could be output, imports, exports etc) can be calculated using the formula:

$$P = E.R.B\,(I-A)^{-1}Y \qquad (3)$$

We can also break down the pollution intensity into three elements: direct pollution intensity (DPI), induced pollution intensity (IPI) and overall pollution intensity (OPI). Thus:

$$DPI = E.R.B\,(A) \qquad (4)$$
$$IPI = E.\,R.\,B\,[(I-A)^{-1}-A] \qquad (5)$$
$$OPI = E.\,R.\,B\,(I-A)^{-1} \qquad (6)$$

Pollution content measures

We use two measures to describe the pollution embodiment in trade: the balance of emissions terms of trade and pollution terms of trade. The balance of emissions terms of trade (BETT) can be donated as the difference of pollution embodied in exports and pollution embodied in imports:

[5] As Chinese IO tables do not report imported intermediate inputs separately, this coefficient denotes fuel inputs both domestically produced and imported.
[6] SCE is an acronym of Standard Coal Equivalent which is applied in China and Renminbi (RMB) is in current prices.

BETT = $E_c R_c B_c (I - A_c)^{-1} Y^X - \sum_f E_f R_f B_f (I - A_f)^{-1} Y_f^M$ (7)

where c refers to China and f refers to a trading partner that has produced the relevant imports. BETT indicates the net pollution embodiment in China's trade. A positive BETT value suggests that China's exports embody more pollution content than its imports and vice versa. When using identical technologies for Chinese exports and imports, BETT represents the difference between pollution generated from exporting and pollution avoided from importing and can be simplified as:

BETT = $ERB(I - A)^{-1}(Y^X - Y^M)$ (8)

Similar to Antweiler (1996) but without assigning weights to pollutants, the pollution term of trade (PTOT) for a pollutant is constructed as the ratio of the overall pollution intensity in a unit of exports relative to that in a unit of imports:

PTOT = $\dfrac{F^X}{F^M} = \dfrac{ERB(I - A)^{-1} Y^X / j_I^{'} Y^X}{ERB(I - A)^{-1} Y^M / j_I^{'} Y^M}$ (9)

where j'_I= (1,.., 1) is a 1 by N vector.

PTOT indicates the rate of exchange of pollution embodiment in matched international trade. If the ratio for an emission is greater than unity, the country can be viewed as exporting goods on average that are relatively more pollution intensive than the goods it imports, and vice versa. (The use of the two measures allows the effect of the composition of trade to be separated from that of the overall balance of trade.)

Since this study focuses on the impact of trade on pollution emissions by taking into full account of the interdependences of industries, the distinction between domestic produced intermediates and imported intermediates is crucial. However, the available technology matrices in the Chinese I-O tables do not distinguish between domestic and imported intermediate inputs. If the supply-use matrix is applied directly, it is equal to assuming that imports are all final goods. This obviously ignores the role of China in international vertical specialization. Given that a substantial amount of China imports are of intermediate goods in bulk for processing and export[7], this omission from the analysis may imply a serious measurement error (Dietzenbacher et al., 2005; Lahr, 2001). For example, it is estimated by Ping (2006) that China's vertical specialization ratio rose from 14.2% in 1992 to around 22% in 2003. We make the assumption that imported goods are substitutes for domestic goods, and that imported goods are proportional in domestic use, be it final deliveries (which includes the possibility of re-exports) or intermediate use and imported goods are proportional as intermediate use for other sectors[8].

Hence, a_{ij} denotes the input requirement of combined (domestic produced and imported) good i to produced one unit of good j. One unit of good i imported is treated as final good as well as substitutive domestic input. Suppose p_i unit of it is used as intermediate goods while 1-p_i unit of it is used as final goods. p_i is calculated as $p_{i.} = \frac{IM_i}{\text{Gross Output}_i + IM_i}$ where IM_i is imports of good i and Gross Output is domestic production of good i.

We denote the diagonal matrices of the ratios as follows[9]:

$$\hat{D} = \begin{pmatrix} 1-p_1 & & 0 \\ & \ddots & \\ 0 & & 1-p_n \end{pmatrix}$$

The domestic Leontief inverse matrix becomes $(I - \hat{D}A)^{-1}$. This changes our formula in (8) to:

$$\text{BETT} = ERB(I - \hat{D}A)^{-1}(Y^X - Y^M) \qquad (8)'$$

Eq. 6 similarly becomes:

$$\text{PTOT} = \frac{F^X}{F^M} = \frac{ERB(I - \hat{D}A)^{-1}Y^X / j_I' Y^X}{ERB(I - \hat{D}A)^{-1}Y^M / j_I' Y^M} \qquad (9)'$$

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7 "Processing trade" accounts for almost half of China's total international trade since 1995.

8 It is also referred to as Import proportionality assumption which is used by OECD countries to help construct imported goods flow tables. See also Hummels et al. (2001) and Feenstra and Hanson (1999).

9 According to convention, a "hat" denotes that the off-diagonal elements are all zeros. By doing so, we calculate commodity specific pollution content in trade

4. Data and Evidence on Pollution Intensities

In China, basic I-O tables are published both at the national and provincial level every five years. Up to now, four basic national I-O tables have been published for the years 1987, 1992, 1997 and 2002. Based on the basic I-O tables, China also produces extended I-O tables every two or three years after a basic one is produced. Available extended I-O tables are for the years 1987, 1990, 1992, 1995, 1997, 2000 and 2002. The basic I-O tables are more detailed in commodity classifications (over 100 commodities) than extended I-O tables which are aggregated into only dozens of commodities. All the four basic I-O tables in China have been composed using different commodity classifications. The definitions of sectors in extended I-O tables are reported in Appendix B.

We use the basic I-O tables to calculate the pollution intensity and content of China's trade. The results obtained by employing extended I-O tables can serve as a sensitivity check for aggregation effects.

We first assume identical technologies across countries or in other words "if imports were made at home".[10] Later we will relax this assumption by using the technology of a reference country for import content measurement.

Accurate gas emissions from fuel combustion depend on knowledge of several interrelated factors such as fuel types, combustion technology as well as abatement efficiency. Yet, CO_2 emissions are primarily dependent on the carbon content of the fuel which enables calculation at a highly aggregated level (IPCC, 1996). However, for SO_2 and NOx, IPCC guidelines suggest that they are calculated on a detailed activity/technology level. Detailed discussion and calculation of the emission factors can be found in the appendix A. We adopt the emission factors reported in Table 1 to construct matrix E.

[10] Because of a lack of comprehensive data on technology matrix A, we assume identical technologies across countries, which is common practice in the study on pollution content of trade. See Trefler (1995), Antweiler (1996), Mukhopadyay and Chakraborty (2005).

Table 1: Average Emission Factors (Ton/SCE)

	Raw coal	Crude oil	Natural gas
CO_2	2.712	2.15	1.633
SO_2	0.0225	0.0070	0
NO_x	0.0088	0.0059	0.0044

Note: Since crude oil and natural gas are reported together in the 2002 basic I-O table and all the extended I-O tables, we recalculate the emission factors according to the mix of crude oil and natural gas using annual Chinese energy consumption data.

The adopted emission factors are consistent with scientific understanding that raw coal is more polluting than crude oil and natural gas. Note also that the carbon dioxide emission factor is much higher that those of sulfur dioxide and nitrous oxides for all three fuels. Usually classified as an "no direct local environmental impact" indicator, carbon dioxide has more global impact. Compared to other hazardous local environmental pollutants, governments have fewer incentives to unilaterally address global pollutants due to their widespread impact (Grossman and Krueger, 1994).

Data on energy outputs in monetary units are obtained from Chinese I-O tables and energy outputs in physical units are obtained from the Chinese Statistical Yearbooks. We construct the diagonal matrix R as follows:

Table 2: Average Emission Factors (thousand SCE/RMB)

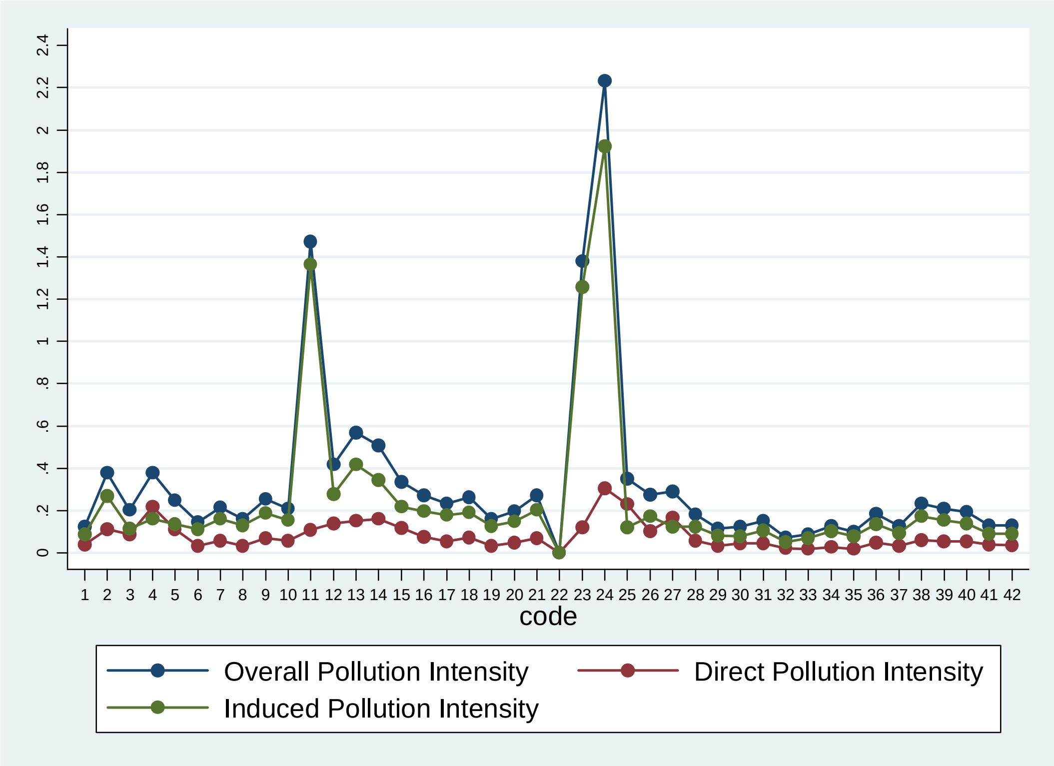
Year	Raw Coal	Crude Oil	Natural Gas
1987	24.27	7.72	10.77
1992	10.98	3.40	15.81
1997	4.40	1.50	2.56
2002	2.59	0.86*	

*In 2002 IO, we only have two primary energy sectors since crude oil and natural gas are reported in a combined manner. We treat the producer's prices of crude oil and natural gas as identical.

Pollution intensities

We first show the overall pollution intensity (OPI) at the sectoral level (2 digit), with the breakdown in to indirect (IPI) and direct pollution intensity (DPI). Taking the example of the extended 2002 IO table, the sectoral pollution intensities of carbon dioxide are plotted in Graph 1.

Graph 1: Sectoral Pollution Intensities of Carbon Dioxide



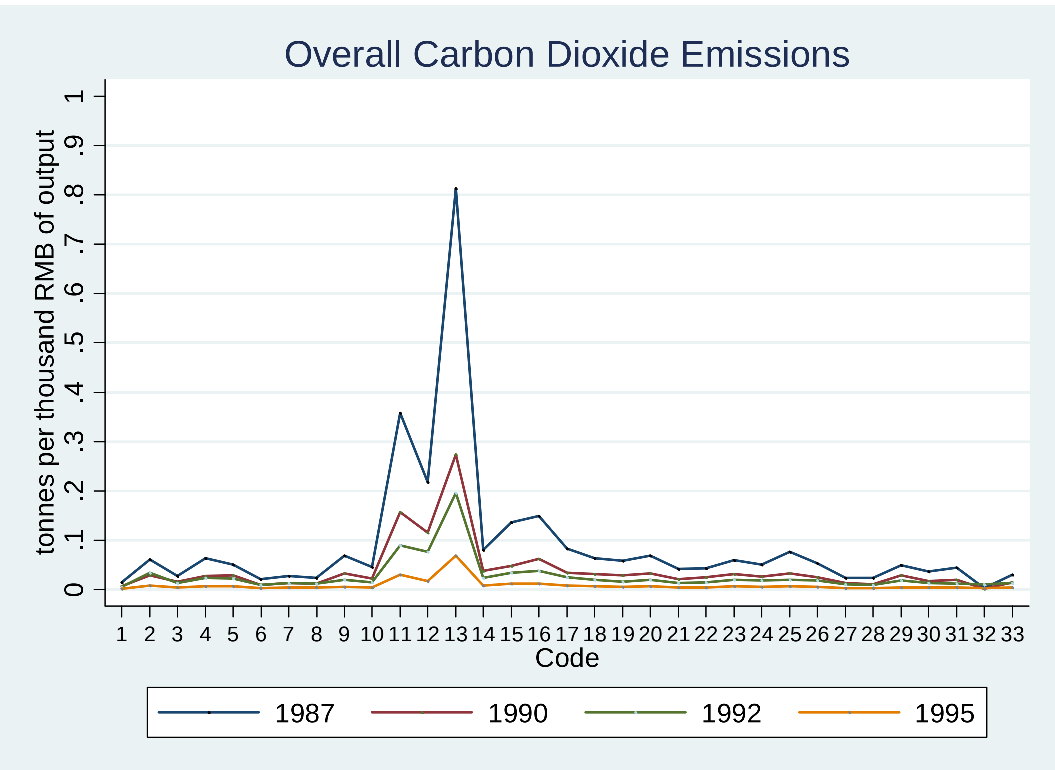
Though the sectoral variations in all the three pollution intensities are quite dramatic, the differences are more prominent in terms of IPI and OPI than DPI. This implies that the impact on the environment from some sectors is more influential than it first appears. Comparing indirect pollution intensity with direct pollution intensity, we find that IPI is greater than DPI for most sectors. The only exceptions are 4 (Metal mining), 25 (Waste) and 27 (Transportation and warehousing), which also have relatively low overall pollution intensities.

We also observe that heavily polluting industries usually have a higher DPI and a very large IPI (for example, sectors 12 Chemicals, 13 Non-metallic products, 14 Iron and steel, 23 Electricity and steam and 24 Coke and gas products). These sectors not only pollute directly and heavily, but they also induce substantial indirect pollution emitted in the production of their intermediate inputs. This finding is at odds with that of Chung (1998), who finds that major polluting sectors have higher direct pollution intensity than indirect pollution intensity. A closer inspection of sector 24 (Coke and gas products) is informative: it is the heaviest polluting sector in terms of CO_2

emissions in 2002. However, its direct pollution intensity is only 0.35*10^{-3} ton CO_2 per RMB output, while indirect pollution intensity is 1.96*10^{-3} tonnes CO_2 per RMB output.

Since the extended I-O tables for 1987, 1990, 1992 and 1995 are constructed using the same I-O definitions, we can investigate the evolution of overall pollution intensity of CO_2 at sectoral level. Graph 2 shows that over the years the emission intensities have been decreasing for almost all the sectors, with the most dramatic changes being for the heavily polluting sectors: 11 (Petroleum refineries), 12 (Chemicals), 13 (Non-metal mineral products), 15 (Metal products), and 16 (Machinery). The most noticeable decrease in overall pollution intensity lies in 13 (Non-metal mineral products, including cement, stone and clay products which are in many studies listed as notorious heavy polluters); the overall pollution intensity of this sector decreased from over 0.8 tonnes CO_2 per RMB of output to 0.27 tonnes CO_2 per RMB of output.

Graph 2: Evolution of CO_2 Intensity



Note: To enable compatibility, all prices are inflated to 2002 level; price indices are from China statistical yearbooks; 10^{-3} tonnes of CO_2 per RMB of output.

5. Pollution Content of China's Trade

Potential pollution content (common technology)

Trade data are from the Chinese I-O tables[11]. The results based on the basic I-O tables, and an assumption that exports and imports are produced using Chinese technology, are set out in Table 3.

Table 3: BETT and PTOT Measures of Pollution Content (Common technology)

Year	Pollutant	BETT 10^4 tonnes	PTOT
1997	CO_2	-1250	0.76
	SO_2	-14	0.79
	NO_x	-2	0.77
2002	CO_2	-12903	0.74
	SO_2	-86	0.74
	NO_x	-39	0.74

Given that the I-O tables of 1987 and 1992 do not report imports and exports of commodities separately, our proportionality assumption for decomposing intermediate inputs in to domestic and imported inputs could be only applied to the 1997 and 2002 I-O tables. The BETT values in the table 3 show that China has a 'pollution deficit', with imports embodying more pollutants than its exports. This is despite a substantial trade surplus in goods. The average per unit content of exports must be significantly lower than that of imports. This is confirmed by PTOT ratios less than unity, indicating that each unit of China's exports is less pollution intensive than China's imports on average. These results are consistent with other findings (discussed in the introduction) and with China having a comparative advantage in "cleaner" industries based on labour endowment advantages and with China 'gaining' environmentally from trade overall and from matched expansions of exports and imports .

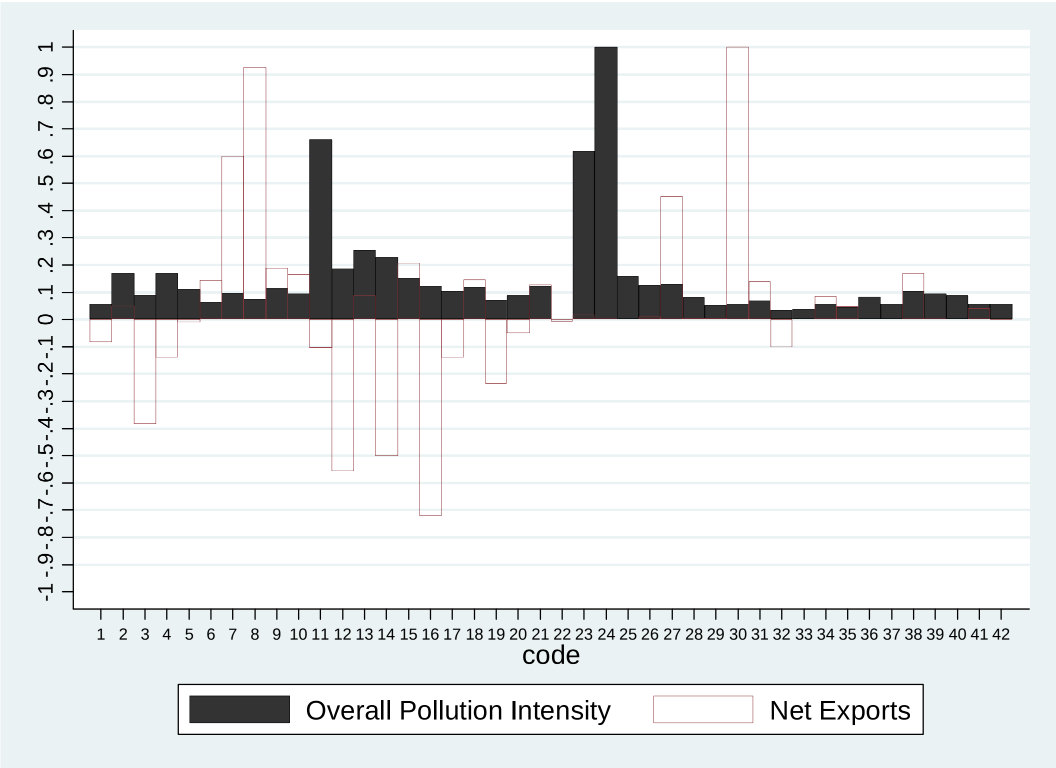
[11] There are some data quality issues concerning the trade data in Chinese IO tables; firstly, imports are recorded as CIF while exports are recorded as FOB. In other words, transportation and insurance costs lift the nominal value of imports. Secondly, imports also include custom duties. Ahmad and Wyckoff (2003) assume 10% of the import value reflects both transportation and insurance costs.

We also use the more aggregated extended I-O tables to carry out a sensitivity check. There are 33 sectors for the 1987,1990,1992,1995 extended I-O tables, 40 sectors for 1997, 17 sectors for 2000 and 42 sectors for 2002. Using the same methodology and assumption used to obtain the pollution content measures in table 3, we report in Table 4 alternative PTOT values based on the alternative industry aggregation. Although larger than the previous results, the PTOT values are consistently less than unity and continue to show a unit of China's exports to be less pollution intensive than its imports on average. In contrast to the alternative estimates, however, the PTOT values increase between 1997 and 2002 for all pollutants.

Table 4: PTOT Estimates for Industry Aggregation (Common Technology)

Year	Sectors	CO_2	SO_2	NO_x
1997	40	0.80	0.82	0.80
2002	42	0.84	0.85	0.84

Graph 3: Scaled Sectoral Pollution Intensities and Net Exports



To understand this overall result we explore the (normalised) relationship between net exports and overall pollution intensity at the sectoral level; net exports of each sector being expressed as ratio the largest sector net exports (30 Wholesale and Retail) and overall pollution intensity of each sector as a ratio of the most polluting sector (24 Coking). Graph 3 shows that China has relatively large trade surpluses in the relatively clean sectors such as (7 Textiles, 8 Wearing apparel, 27 Transportation and warehouse, 30 Wholesale and retail). In the dirty sectors, China either has a very small trade surplus (e.g. the sectors 13 Non-metal mineral products, 23 Electricity and heat and 24 Gas) or runs a trade deficit (sectors 11 Petroleum refineries, 12 Chemicals and 14 Metal smelting).

As a further robustness test we explore the recent compositional effects of post-WTO membership and liberalisation by applying the 2002 I-O technology (the latest year for which we have an I-O table) to China's import and export composition in the years 2003 to 2006. We are assuming that relative prices and technologies have not changed. Although this is unlikely in a precise sense, energy requirements per unit of GDP have been relatively stable in this period (after a period of rapid decline). Using trade data is in HS 2002 code from UNCOMTRADE database converted to Chinese I-O 2002 code, we produce (shown in Table 5) projections of our BETT and PTOT measures of pollution content.[12]

Both measures are consistent with earlier results. BETT values are negative for all years and pollutants, though they tend to decline in absolute terms. The PTOT values also remain less than unity for all years and pollutants. The recent, small increases in the PTOT ratio do not alter the general conclusion to be drawn about the pollution content of China's trade based on a common (Chinese) technology assumption; in the post-trade liberalisation period China has tended to specialise in the production and export of goods that are relatively clean in terms of Chinese technology.

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[12] The database only report data of commodity trade which can be grouped into 85 sectors (see attachment of the 85 sectors). We have therefore to exclude the service trade in the projection. The import values are on a CIF basis while export values are on FOB basis.

Table 5: Pollution Embodiment in Commodity Trade

Year	Pollutant	BETT 10^4 tonnes	PTOT
	CO2	-22625	0.76
2003	SO2	-143	0.78
	NOx	-69	0.77
	CO2	-27514	0.78
2004	SO2	-160	0.81
	NOx	-83	0.79
	CO2	-18089	0.79
2005	SO2	-98	0.81
	NOx	-54	0.79
	CO2	-9620	0.80
2006	SO2	-19	0.83
	NOx	-24	0.80

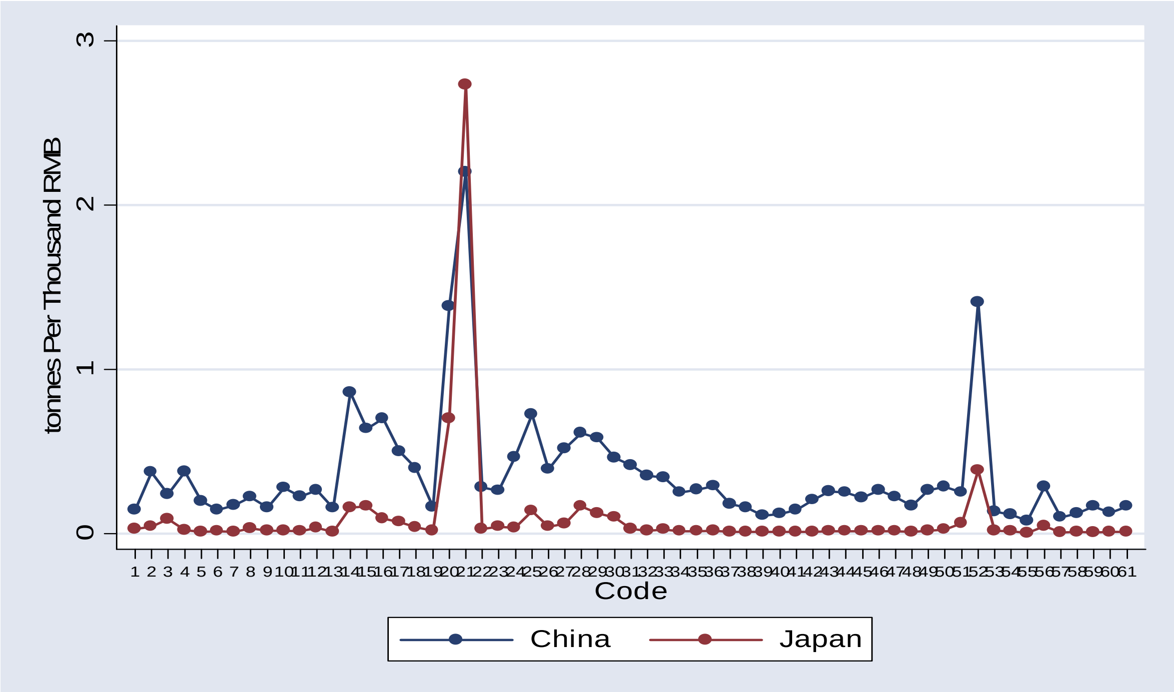
Actual pollution content (technology differences)

So far our calculations have been based on the implicit assumption that countries share the same production technologies. For a country like China that trades a lot with developed countries this assumption is likely to produce an overestimate of the actual pollution embodied in imports. China has a coal predominated energy structure which depends heavily on fossil fuels, while its trading partners especially OECD countries depend more on cleaner fuels (partly due to pollution limits constrained by international agreements and national regulations). There are also likely to be different inter- and intra-sectoral linkages across countries expressed in the differences in I-O matrices.

To explore the implications of technology differences we use Japan as a representative exporting country to China. Japan is one of the most important trading partners to China and adopts a similar structure of commodity classification in its I-O tables to that of China. This allows us to match the 71-commodity Japanese extended I-O table with the 122-commodity bench mark Chinese I-O table for the year 2002 to create a concordance based on 61 sectors. Trade data is derived from Chinese 2002 I-O table.

We initially compare the overall pollution intensities for China and Japan in 2002 in terms of carbon dioxide emissions. Graph 4 shows that Japan is generally more energy efficient than China. The only exception is sector 21 (Coking), which is the most polluting industry in both economies. Japan has less sectoral variation in pollution intensities compared to China. There are several sectors in China which significantly lag behind their Japanese counterparts. For example, the second heaviest polluting sector in both economies is 52 (Electricity, steam and hot water production), but the pollution intensity in sector 52 in China is about 3.6 times that in Japan.

Graph 4: Overall Pollution Intensities in China and Japan



Using the methodology outlined in the previous sections, we re-calculate actual and alternative, potential pollution content measures for China's international trade in 2002. The results are reported in Table 6. The first set of results replicates the calculations of pollution content based on a common Chinese (CN) technologies assumption for both exports and imports using the newly aggregated 61 sector Chinese I-O table. The results are qualitatively consistent with the previous analysis; the BETT measures are negative for all three pollutants and the PTOT measures are less than unity (though much closer to unity than previously). The second set of results is where differentiation of technologies in producing exports and imports is allowed for. The pollution content of exports is calculated by using the Chinese I-O table (CN technology), while the pollution content of imports is calculated by using

Japanese I-O table (JP technology). In this case the BETT measure is now positive and the PTOT measure is greater than unity (indeed well in excess of unity). The sign on actual pollution content of China's trade which allows for technology differences between China and its trading partners is reversed relative to the hypothetical pollution content based on the common technology measure. The actual measure shows that China actually exported more pollution content than it imported, in total and per unit. The BETT measure captures in part the influence of the trade surplus, but the results indicate that on average a unit of Chinese exports actually embody (i.e. induce emissions of) about 75% more air pollutants than embodied in a unit of imports (produced outside of China).[13] China's (matched) trade expansion would induce saving on China's environmental services or capacity (given its technology), but it has not actually been 'saving' given the actual technology available to the countries exporting to China.

Table 6: Potential and Actual Pollution Content of China's Trade (2002)

Technology	Pollutants	Exports	Imports 10^4 tonnes	BETT	PTOT
Common (CN for both X and M)	CO_2	70972	83505	-12533	0.98
	SO_2	485	565	-80	0.99
	NO_x	220	259	-38	0.98
Differentiated (CN for X and JP for M)	CO_2	70972	46974	23998	1.74
	SO_2	485	302	183	1.84
	NO_x	220	144	76	1.76
Alternative Common (JP for both X and M)	CO_2	35673	46974	-11300	0.87
	SO_2	225	302	-76	0.86
	NO_x	109	144	-35	0.87

a.CN refers to use of Chinese I-O table and JP to use of Japanese I-O table to measure pollution content of exports (X) or imports (M) or both.

[13] Although not explicitly reporting BETT values, Ahmad and Wyckoff (2003) and Shui and Harriss (2006) report results for China with differentiation of technology between trading partners which are consistent our finding on the actual content of China's trade. In our case the fact that PTOT is also greater than unity allows us to conclude that China's exports are actually more pollution-intensive than its imports having controlled for China's trade surplus.

China's trade in 2002 actually induced (overall and on average) more production – related pollution in China than in the rest of the world. It is important, therefore, to recognise when it is appropriate to apply potential or actual measures of pollution content. Potential measures are useful for commenting on the 'gains' for a country from trade, given its endowments and technology. When searching or testing for the factors driving trade, for example when investigating the relative importance of national differences in factor endowments and environmental regulations, one needs to allow for technological differences in measuring the actual factor or pollution content of trade. The present findings show that the use of a common or differentiated technology matters for the measurement of the pollution content of trade. Equally it matters the common technology that is adopted. In the final set of results in table 6 we move back to a common technology assumption, but this time use Japan's I-O table (JP technology) to measure the pollution content of both exports and imports (i.e. 'as if' China had the energy efficiency level of an advanced industrial country). Not surprising the pollution content of exports and imports (combined) is lower than either of the other two cases, but the results in terms of the net measures (BETT and PTOT) are similar to the first set of results where CN technology was assumed for both exports and imports. If China adopted an advanced country technology with regard to energy efficiency and the current composition of trade is held constant, China would be a net importer of environmental services. In that sense it would be able to continue to 'gain' from trade, while reducing overall emissions. Note, of course, is that the corollary of this is that the rest of the world would continue to 'lose' from world trade in terms of the international location of the production of tradable goods; with less polluting labour-intensive production being drawn towards China and more polluting, capital intensive production towards the rest of the world. The rest of the world has of course an interest in China reducing its emissions from export production!

6. Conclusions

This paper extends on the previous research on the pollution content of trade in China in a number of ways. Firstly, we use recent Chinese I-O tables, which allow the measurement of the pollution content to be up-dated to include the post-WTO period and also the use of tables that give finer sectoral breakdown. This also allows sensitivity checking on the effects of aggregation bias in measuring factor content. Secondly, we consider pollution intensity in terms of a number of important greenhouse gases and allow for direct and indirect effects by using an I-O modelling approach. Finally, and importantly, we measure the actual pollution content of China's trade as well as the potential pollution content. Other research typically assumes a common technology to produce a country's exports and the imports (it would have had to produce if it had not imported them). We also consider the more realistic case that the imports were actually produced using a different technology abroad to that used in China.

Under the common technology assumption (i.e. the potential or hypothetical pollution content measure) our findings are consistent with the existing research; China's exports are cleaner than its imports. Our time series analysis also shows that Chinese sectoral pollution intensities have been decreasing in recent years. In fact, we find that the composition effect has contributed positively to China's environment and has more than offset the trade surplus effect. China has gained 'environmentally' from the opening up of the economy and expansion of trade, with China specialising more in the production of relatively cleaner exportables and reducing relatively the production of environmentally damaging importables production.

The identification of 'environmental gains' for China from international trade is a natural and appropriate interpretation of the potential pollution content measures, which for 'what if' purposes assume there is a common technology across countries and that imports, as well as exports, are produced locally (i.e. in China). On this basis China is found to be a net importer of embodied pollutants and environmental services. However, if one drops the common technology assumption and measures the actual pollution content of both exports and imports (i.e. using the technology for countries exporting to China), China is found to be a net exporter of embodied pollution. We interpret the alternative pollution content measures as indicating, on the one hand, that trade allows China to save on local environmental resources given its own technology and environmental regulations, but on the other that China's trade results overall and on average in more pollution generation in China than in the rest of the world (though this could be reversed by the adoption of more energy-efficient production methods in China).

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Appendix A: Construction of Emission Factors

CO_2 emissions are primarily dependent on the carbon content of the fuel and hence we can calculate them from fuel combustion. SO_2 and NO_x, emissions estimation requires more detailed information. Accurate estimation of their emissions depends on knowledge of several interrelated factors, including combustion conditions, technology, and emission control policies, as well as fuel characteristics. IPCC guidelines suggest that they are calculated based on applied on a detailed activity/technology level.

Emission factors vary in fuel types as well as across industries and from different data sources. Peter et al. (2006) compare emission factors from Chinese Energy Statistics Yearbooks, CCCS and IPCC guidelines as well as other studies. We use these sources to construct emission factors for the three air pollutants.

Carbon Dioxide Emissions

According to IPCC guidelines, we can construct carbon dioxide emission factors by multiplying the carbon emission factor of the corresponding fuel by the fraction of carbon oxidized and the molecular weight ratio of carbon dioxide to carbon – see table A1.

Table A1: Carbon Emission Factors and Fraction of Carbon Oxidized

Fuel Type	**Coal**	Soft coke	**Natural gas**	LPG	Naphtha	Motor gasoline	**Fuel oil**
Emission factors (T C/TJ)	**25.8**	25.8	**15.3**	17.2	20.0	18.9	**20.2**
Oxidization factors[a]	**0.98**	0.98	**0.995**	0.995	0.99	0.99	**0.99**

Source: IPCC guidelines. a. Oxidization factor vary across industries ranging from 0.8 to 0.98. We use the default values which are overestimates for some industry.

We use the values in bold to construct our carbon dioxide emission factors. To make the values comparable to other studies and to suit the Chinese case, we also present the carbon emission factors in different units – see table A2.

Table A2: Carbon Emission Factors in Different Units

Fuel type	T C/TJ	T C/SCE[a]	T C/TOE[b]	T C/ T[c]
Raw Coal	25.8	0.75613608	1.0801944	0.5394264
Crude Oil	20.2	0.59201352	0.8457336	0.8446832
Natural gas	15.3	0.44840628	0.6405804	n/a

Note: a. SCE is an acronym of Standard Coal Equivalent which refers to the amount of energy released by burning one metric ton of coal. It is widely used in Chinese energy statistics.1 SCE=$29.3076*10^{-3}$TJ

b. TOE is an acronym of Ton Oil Equivalent which refers to the amount of energy released by burning one metric ton of oil. It is accepted by many nations to record their energy statistics. 1 TOE=$41.868*10^{-3}$ TJ. 1 SCE is about 0.7 TOE.

c. T denotes one metric ton. We use net calorific values for raw coal 0.020908 TJ per ton and for crude oil 0.041816 TJ. per ton. Natural gas is often measured in volume and thereby we don't report the carbon content in physical mass.

The value 3.66 is applied as the molecular weight ratio of carbon dioxide to carbon. The following (table A3) is carbon dioxide emission factors based on the methodology and data mentioned above.

Table A3: Carbon Dioxide Emission Factors

Fuel type	Raw Coal	Crude Oil	Natural Gas
CO_2 ton per SCE	2.712	2.145	1.633
CO_2 ton per TOE	3.874	3.064	2.333

Sulfur Dioxide Emission Factors

Sulfur dioxide emission factors are constructed by multiplying the sulfur content of the corresponding fuel by the fraction of sulfur oxidized and the molecular weight ratio of sulfur dioxide to sulfur – see Table A4.

Table A4: Sulfur Content in Different Fuels (%)

Fuel type	Raw Coal	Crude Oil	Natural Gas
IPCC low	0.5	1	n/a
IPCC medium	**1.5**	**3**	**0**
IPCC high	3	4	n/a
Jingru	1.1	0.5	n/a

Source: Peters et al. (2006)

Not all the sulfur content in fuels will be oxidized; there will be certain proportion of remains in ash. Sulfur content and retention in ash varies dramatically in fuel types. IPCC provides various values of sulfur content and retention in ash according to fuel types. Table A5 below shows a variation in estimation in different data sources.

Table A5: Sulfur Retention in Ash (%)

Fuel type	**Raw Coal**	**Crude Oil**	**Natural Gas**
IPCC, hard coal	5	n/a	n/a
IPCC, brown coal	30	n/a	n/a
Jingru	20	n/a	n/a
CCCS, P53	**27**	**n/a**	**n/a**

Source: Peters et al. (2006)

We use IPCC medium sulfur content values (in bold) and sulfur retention ratio in ash 27% according to CCCCS. Due to data limitation, we imply a strong assumption that sulfur removal technology is absent/ inefficient. We then use 2 as the molecular weight ratio of sulfur dioxide to sulfur – see Table A6.

Table A6: Sulfur Dioxide Emission Factors using Jingru Sulfur Content

Fuel	**t /SCE**	**t /TOE**	**t/ T**	**KT/PJ**
Raw coal	**0.0225**	0.0322	0.0161	0.768127
Crude oil	**0.0070**	0.0100	0.0100	0.2391429
Natural gas	**0**	0	n/a	0

Source: Peters et al. (2006)

Nitrous Oxides Emission Factors

We use IPCC default nitrous oxides emission factors numbers for industry/energy and construction as follows (Table A7).

Table A7: Nitrous Oxides Emission Factors

Fuel	t /SCE	t/TOE	t/T	kg/TJ
Raw Coal	**0.00879228**	0.0125604	0.0062724	300
Crude Oil	**0.00586152**	0.0083736	0.0083632	200
Natural gas	**0.00439614**	0.0062802	n/a	150

Note: Nitrogen emission factors are IPCC default numbers for the sectors Industry, Energy and Construction.

Emission factors

The final emission factors used are summarized in Table A8.

Table A8: Emission Factors (ton/SCE)

	CO_2	SO_2	NO_X
Raw coal	2.712	0.0225	0.0088
Crude oil	2.145	0.0070	0.0059
Natural gas	1.633	0	0.0044

For 2002, where crude oil and natural gas are referred to in the IO tables as one commodity, we recalculate the emission factors based on the mix of crude oil and natural gas in Chinese energy production/consumption.

Appendix B

Table B1: Definitions of Codes in Different Extended I-O Tables

Codes	1987/1990/1992/1995	1997	2002
1	Agriculture	Agriculture	Agriculture
2	Coal mining and washing	Coal mining and washing	Coal mining and washing
3	Crude petroleum and natural gas	Crude petroleum and natural gas	Crude petroleum and natural gas
4	Metal mining	Metal mining	Metal mining
5	Other mining	Other mining	Other mining
6	Food and tobacco	Food and tobacco	Food and tobacco
7	Textiles	Textiles	Textiles
8	Wearing apparel	Wearing apparel	Wearing apparel
9	Wood and furniture	Wood and furniture	Wood and furniture
0	Paper and educational products	Paper and educational products	Paper and educational products
11	Electricity, steam and hot water	Petroleum	Petroleum
12	Petroleum	Chemicals	Chemicals
13	Gas and coke products	Non-metallic products	Non-metallic products
14	Chemicals	Iron and steel	Iron and steel
15	Non-metallic products	Metal products	Metal products
16	Iron and steel	Machinery, non-electric	Machinery, non-electric
17	Metal products	Transport equipment	Transport equipment
18	Machinery, non-eletric	Machinery, eletric	Machinery, eletric
19	Transport equipment	Electronic and communication appratus	Electronic and communication appratus
20	Machinery, eletric	Professional and scientific equipment	Professional and scientific equipment
21	Electronic and communication appratus	Machinery repair	Other manufacturing
22	Professional and scientific equipment	Other manufacturing	Waste
23	Machinery repair	Waste	Electricity and steam
24	Other manufacturing	Electricity and steam	Gas
25	Construction	Gas	Waster
26	Transportation and postal services	Waster	Construction
27	Business	Construction	Transportation and warehouse
28	Restaurant	Transportation and warehouse	Postal services
29	Passenger transportation	Postal services	Information and software
30	Public and residential services	Business	Whole sale and retail
31	Cultural, Educational, sports and scientific research	Restaurant	Hotel and restaurant
32	Finance and insurance	Passenger transportation	Finance and insurance
33	Administration	Finance and insurance	Real estate
34		Real estate	Renting and business services
35		Social services	Travel
36		Health, sports and social welfare	Scientific research
37		Education, arts,cultural and recreational services	General technical services
38		Scientific research	Other social services
39		General technical services	Education
40		Public administration	Health and social welfare
41			Cultrual, sports and recreational
42			Public administration and public organizations

Table B2: 61 Sectors for China and Japan in 2002

Code	Description
1	Agriculture
2	Metal mining
3	Other mining
4	Coal
5	Crude oil and natural gas
6	Food and tobacco
7	Beverage
8	Textiles
9	Clothing and other fiber products
10	Wood products
11	Furniture
12	Paper and paper products
13	Printing and publishing
14	Chemical fertilizers
15	Basic chemicals
16	Plastic products
17	Chemical fibers
18	Chemical products
19	Medical and pharmaceutical products
20	Petroleum
21	Coking
22	Plastic products
23	Rubber products
24	Glass and glass products
25	Cement
26	Ceramic ware
27	Other non-metal mineral products
28	Pig Iron and crude steel
29	Steel pressing
30	Steel products
31	Nonferrous metal smelting
32	Nonferrous metal processing
33	Metal products
34	General industrial machinery
35	Special industrial machinery
36	Other general industrial equipment and parts
37	Office equipment
38	Household electronic and electrical apparatuses
39	Computers and accessories
40	Communication machines
41	Other electronic instruments
42	Electronic element and device
43	Generators
44	Other eletrical machinery
45	Car
46	Parts and accessories for cars
47	Other transport equipment
48	Instruments
49	Other manufacturing products
50	Construction
51	Public projects
52	Electricity, steam and hot wather production and supply
53	Water production and supply
54	Commerce
55	Finance, Insurance and real estate
56	Transport
57	Commuication and broadcasting
58	Offical business
59	Other public services
60	Other business services
61	Other personal services