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The effect of trade between China and the UK on national and global carbon dioxide emissions

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Abstract

We estimate the amount of carbon dioxide embodied in bi-lateral trade between the UK and China in 2004. Developing and applying the method of Shui and Harriss [2006. The role of CO_2 embodiment in US–China trade. Energy Policy 34, 4063–4068], the most recently available data on trade and CO_2 emissions have been updated and adjusted to calculate the CO_2 emissions embodied in the commodities traded between China and the UK. It was found that through trade with China, the UK reduced its CO_2 emissions by approximately 11% in 2004, compared with a non-trade scenario in which the same type and volume of goods are produced in the UK. In addition, due to the greater carbon-intensity and relatively less efficient production processes of Chinese industry, China–UK trade resulted in an additional 117 Mt of CO_2 to global CO_2 emissions in the same one year period, compared with a non-trade scenario in which the same type and volume of goods are produced in the UK. This represents an additional 19% to the reported national CO_2 emissions of the UK (555 Mt/y in 2004) and 0.4% of global emissions. These findings suggest that, through international trade, very significant environmental impacts can be shifted from one country to another, and that international trade can (but does not necessarily) result in globally increased greenhouse gas emissions. These results are additional to the environmental consequences of transporting goods, which are not robustly quantified here.

Keywords: Carbon dioxide; Trade; Greenhouse gases

1. Introduction

Globalization of trade in goods has a number of significant environmental implications, including the potential to geographically relocate pollutant emissions. The developed economies of the world are becoming increasingly more service oriented and accordingly increasingly dependent on the import of manufactured goods from developing economies. This allows developed countries to partially de-couple their domestic economies from their environmental performance (Nordstrom and Vaughan, 1999; Machado et al., 2001; Ahmad and Wyckoff, 2003).

Attempts have previously been made to discuss one aspect of this effect of globalization, the relocation of "greenhouse gas" (GHG) emissions (Bastianoni et al., 2004), by estimating the embodiment of carbon dioxide (CO_2) emissions in international trade (e.g. Wyckoff and Roop, 1994; Schaeffer and Leal de Sá, 1996; Machado et al., 2001; Ferng, 2003), CO_2 being the principal GHG that is causing climate change. Wyckoff and Roop (1994) found that, on average, about 13% of the total CO_2 emissions of six of the largest OECD countries was embodied in manufactured imports, and they concluded that importation of carbon-rich products is a problem that should be addressed in GHG emissions abatement policies. Schaeffer and Leal de Sá (1996) estimated the embodiment of carbon associated with imports and exports to and from Brazil. Their findings reveal an increasing transfer of CO_2 emissions from developed countries to developing countries with the liberalization of international trade. Similarly, Machado et al. (2001) also examined the total impacts of international trade on energy use and CO_2 emissions of the Brazilian economy, and suggested that Brazilian policy-makers should be concerned about the impacts that international trade policy may have on energy

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use and carbon emissions of the country. Ahmad and Wyckoff (2003) calculated the CO_2 emissions embodied in international trade of goods for 24 counties, and explored the impacts of trade-driven geographical movement of industries on global emissions.

Rapid economic growth has made China a major player in the world economy, with concomitant effects on the global natural environment. However, quantitative evaluation of the environmental repercussions of China's international trading activities has only recently begun. Hayami and Kiji (1997) studied China's energy usage and air pollutant emissions; Gerilla et al. (2002) studied carbon emissions resulting from trade between China and Japan; Ma et al. (2006) analysed commodity flows in Chinese trade; Feenstra et al. (1998) evaluated the size of the US–China trade balance, from which economic benefits and environmental costs might be estimated; Peters et al. (2004, 2006) and Peters and Hertwich (2006) carried out a structural analysis of the environmental impacts of international trade and looked specifically at Chinese emissions. Recently, Shui and Harriss (2006) estimated that between 7% and 14% of China's current CO_2 emissions are the results of producing goods for export to the USA. In addition, due to China's extensive use of coal and less efficient manufacturing technologies, they estimated that US–China trade has increased global CO_2 emissions by around 720 million tonnes (Mt) during the period 1997–2003.

Bilateral trade between the United Kingdom (UK) and China is growing fast. In 2004 the UK became China's fourth largest trading partner after Japan, the US and Germany. According to the United Nations Commodity Trade Statistics (UN Comtrade, 2006), this trade was worth £17.8 billion in 2004, which was an increase of 24% on the previous year (BRCCWTO, 2005). However, there is a large and growing trade imbalance between the two countries, with the UK importing much more than it exports to China (BRCCWTO, 2005).

Here we quantify the effects of the bilateral UK–China trade on CO_2 emissions. We develop and apply the accounting method of Shui and Harriss (2006) to estimate: (1) the amount of CO_2 emissions avoided by the UK by the importing of goods from China in the year 2004; (2) the amount of CO_2 emissions generated in China as a result of the production of goods for exports to the UK in the same year; and (3) the impacts of UK–China trade on CO_2 emissions domestically and globally. We do not attempt to quantify the amount of CO_2 emitted as a result of transporting these goods to the UK but make a first-order estimate of this parameter only. As a backdrop to this study it is worth noting that the UK is a United Nations Framework Convention on Climate Change Kyoto Protocol Annex I country and has committed to reduce emissions of a basket of six GHGs by 12.5% below 1990 levels over the period 2008–2012. Additionally, the UK government has gone beyond its Kyoto Protocol commitments and has set domestic goals of reducing CO_2 emissions by 26–32% by 2020 and by at least 60% by 2050 against a 1990 baseline (Defra, 2008).

2. Methodologies

2.1. The input–output framework

The fundamental framework for estimating the CO_2 emissions embodied in the import of goods is to multiply the vector of imported commodities by the corresponding flow of CO_2 emissions generated from the production of the same or similar category of commodities in the exporting country (Machado et al., 2001). However, the flow of CO_2 emissions from each individual category of goods cannot generally be directly observed, since the CO_2 is emitted not only from the final manufacturing process of the exported commodities, but also from all processes associated with making and delivering the inputs of those commodities. A strategy for tracing the total CO_2 emissions attributed to the production of each commodity category is to employ an input–output (I–O) methodology, which can be used to map the CO_2 emissions onto final demand commodity sectors.

The input–output analysis was introduced by Leontief in the 1930s and has been applied to describe and analyse economic-environmental relationships since the 1960s (e.g. Hayami and Kiji, 1997; Forssell and Polenske, 1998; Lenzen, 1998, 2001a; Machado et al., 2001; Hubacek and Giljum, 2003; Lenzen et al., 2004; Wiedmann et al., 2007). This strategy allows the environmental impact (in this case CO_2 emissions), both direct and indirect, to be explicitly determined through the matrices which express the environmental impact generated per unit of product output, valued in money, and the volume of goods produced and traded. This method has been applied to estimate the embodied energy, CO_2 emissions, pollutants and land appropriation associated with products sold in national or international markets (e.g. Wyckoff and Roop, 1994; Schaeffer and Leal de Sá, 1996; Lenzen, 1998; Machado et al., 2001; Shui and Harriss, 2006). Wiedmann et al. (2007) conducted a comprehensive survey of the input–output models used to assess the environmental impacts associated with international trade, including a number of multi-region, multi-sector approaches which have emerged only in the last few years.

In our study, the method of Shui and Harriss (2006), using a single-region model, was adopted. Applying the input–output method to calculate the CO_2 emissions embodied in UK–China trade involves populating the matrix C_t of monetary unit coefficients with CO_2 emissions coefficients:

$$C_t = EA^{-1}, \tag{1}$$

where C_t with units of tonnes of CO_2, represents the total CO_2 embodiment in imports from China to the UK in the year 2004; E is a vector $(1 \times n)$ of direct and indirect footprint coefficients, established with units of tonnes of

CO_2 emissions per unit monetary value of domestic output by production industry in the export country; A is an $n \times 1$ vector of the monetary value, with units of millions of GBP (£), of Chinese exports by product categories. The values for factor E were obtained from a ready environmental input–output table (EIOT) where a domestic direct requirement matrix was used to describes the value of domestically produced inputs going into the production of each commodity, not industries, and the entries are in monetary units. This method does not necessarily account for all inputs into a production process, for example where raw materials and components are imported prior to manufacture of goods for export.

2.2. Environmental input–output tables

EIOTs play an important role in economic policy analysis (e.g. Imura and Tiwaree, 1994) and are available for many economically important countries of the world (e.g. Hubacek and Giljum, 2003). The UK has adopted the European Union's Eurostat (Haan, 2001) guidelines for providing an integrated set of economic and environmental accounts (Office of National Statistics, 1997). For this research we use the UK EIOT of 1993, from which direct and indirect emissions of CO_2 for 91 industrial production sectors in the UK can be linked to economic data. The direct and indirect emissions intensity matrices are intended to express the full environmental pressure of product production, i.e. all emissions arising during the manufacture, production and transport of goods, including emissions produced by road vehicles, per £1 million of product output, valued at basic prices. However, as noted above, the EIOTs for the UK are based on economic data for 1993, so were updated for this study.

Unfortunately, although some efforts have recently been made to construct EIOTs for China, these data are not freely available and are not well documented. Without access to EIOTs for the Chinese economy to assess the environmental impacts of Chinese manufacturing, this current study is based on EIOTs for the UK economy, from which the CO_2 emissions ratios for the Chinese economy were derived by adjusting the differences in the energy requirements in different industrial sectors between China and the UK. Although prone to uncertainties and errors, this method has previously been applied by Shui and Harriss (2006) for the estimation of CO_2 emissions emboded in US–China trade.

2.3. Updating the UK's 1993 EIOTs

Since the fuel mix (and hence relative CO_2 emission rates) used have changed in the UK since 1993, it was necessary to update the CO_2 emissions coefficients in the 1993 EIOTs using

$$F_y = \frac{\sum(F_i; 2004 \times C_i)}{\sum(F_i; 1993 \times C_i)}, \quad (2)$$

where F_y is the ratio of carbon content intensity in the fuel mix of the UK's industrial sector in 2004 compared to that in the fuel mix of the UK's industrial sector in 1993, F_i represents the CO_2 emissions from the UK industrial sector by fuel type in the years 1993 and 2004 (NAEI, 2005a), and C_i is the carbon coefficient associated with each fuel type for UK industry (NAEI, 2005b). Since data were not available for 2004, it was assumed that the CO_2 emissions by fuel type from each UK industrial sector in 2004 were the same as in 2003. Table 1 presents the data required for calculation of F_y. The calculated carbon emission ratio F_y for 2004 compared with 1993 is 0.94.

The EIOTs for 1993 are, of course, based on UK economic data for 1993, but changes took place within the structure of the UK economy between 1993 and 2004, and the real purchasing ability of the same amount of monetary value also changed. Thus the consumer price index (CPI: Rushton and Knipe, 2006), which tracks the prices of a specified set of consumer goods and services in the economy, as a measure of inflation, was employed to normalize the economic information from the 1993 baseline year to 2004.

2.4. Estimating CO_2 emission factors for Chinese industry

Due to the absence of comparable environmental accounting data for China, the method of Shui and Harriss (2006) was used to derive the CO_2 emissions associated with Chinese exports, based on UK-adjusted sectoral emission intensities for the Chinese economy. The CO_2 emissions associated with each Chinese industrial process

Table 1
Fuel mix used by the UK's industrial sector, in 1993 and 2004, and the UK carbon emission factors by fuel type (NAEI, 2005a, b)

Year	Fuel type								
	Coal (%)	Petroleum (%)	Natural gas (%)	Gas oil (%)	Fuel oil (%)	Burning oil (%)	Other gases (%)	Other fuels (%)	Total (%)
1993	31	13	24	5	6	1	7	13	100
2004	23	11	37	4	2	2	7	14	100
Emission factor (tCO_2/TJ)	92.75	93.84	57.17	73.81	77.81	71.76	107.68	61.58	–

Table 2
Fuel mix used by China's industrial sector, in 2004, and the Chinese carbon emission factors by fuel type (Shui and Harriss 2006; Tonooka et al., 2003)

Year	Fuel type							
	Coal (%)	Petroleum (%)	Electricity (%)	Coke (%)	Natural gas (%)	Coke oven gas (%)	Heat (%)	Total (%)
2004	22	10	50	12	1.4	1.2	3.4	100
Emission factor ($t$$CO_2$/TJ)	92.5	93.8	307	103.5	50.3	45.1	113	–

were estimated by using a CO_2 emissions ratio based on the fuels used in each industrial sector for China and the UK:

$$F_{ad} = \frac{\sum(\text{China}_{fm} \times \text{China}_{Cm})}{\sum(\text{UK}_{fn} \times \text{UK}_{Cn})}, \tag{3}$$

where F_{ad} is the ratio of carbon emissions resulting from the fuel mix used by Chinese industry compared to the carbon emissions resulting from the fuel mix used by the UK's industrial sector in the year 2004; China_{fm} refers to the CO_2 emissions in each Chinese industrial sector by fuel type m in 2004 (Shui and Harriss, 2006); China_{Cm} is the CO_2 coefficient by Chinese fuel type m (see Table 2: Tonooka et al., 2003); UK_{Fn} represents the CO_2 emissions by each UK industrial sector by fuel type n in the year 2004; UK_{Cm} is the CO_2 coefficient by UK fuel type m (see Table 1). The assumption was made that the CO_2 emissions from the Chinese industrial sector by fuel type in 2004 were the same as in 2003. The calculated carbon emission ratio F_{ad} is 2.68 for the year 2004: i.e. Chinese industry is 2.68 times more carbon-intensive relative to industry in the UK.

2.5. Trade data—allocation of imports into industry groups of EIOTs

The data for traded commodities between China and the UK were obtained from the United Nations Commodity Trade Database (UN Comtrade, 2006), where the unit of trade value is US$. In this database, all traded commodities are apportioned to one of 98 main categories, with a more detailed commodity classification of nearly a thousand sub-groups. For the UK, 1993 EIOTs are produced on a 91 product-by-product basis, not all of which involve international commerce (e.g. education, research and development etc.). Hence, there is a need to match the Comtrade categories with the sectoral breakdown of the UK environmental accounting system. In this study, the commodities were classified and grouped into sectors according to their nature. The commodities traded between China and the UK, of total value $26.3 billion, were allocated to 46 of the 91 possible industrial sectors, with units of GBP (£). The UK's exports to China, which were worth $4.36 billion, were also grouped into 46 of the 91 sectors.

2.6. Estimation of the CO_2 emissions avoided in the UK by importing goods from China

The amount of CO_2 emissions "avoided" by the UK by importing goods from China was calculated as follows:

$$C^{\text{Avd}}_{\text{Tot}} = \sum X_i \times C_i \times F_y \times \frac{CPI_i; 1993}{CPI_i; 2004} \times RPPP, \tag{4}$$

where $C^{\text{Avd}}_{\text{Tot}}$, with units of tonnes of CO_2 emissions, represents the amount of CO_2 emissions if the same quantity of Chinese goods had been produced in the UK in the year 2004; X_i represents the monetary value of Chinese exports by industry sectors $i = 1,\ldots,n$ (million GBP, £); C_i, with unit of tonnes, refers to the corresponding coefficient of CO_2 emitted per £million in the consumption of goods from the UK industry sector i in the year 2004, and the factor F_y was used here to update the CO_2 emission data from 1993 to 2004. The CPI was used to update the economic information of the 1993 EIOTs. (CPIi_i;1993/CPIi_i;2004) represents the price inflation indicator for a UK commodity i in the same or similar category of Chinese export i in 2004. The trade data in monetary units of the United Nations UN Comtrade (2006) provided the value of trade flows in US$ and reflects only the base price of goods produced in China. Values expressed in the Chinese and UK currencies must therefore be converted. One method to do this is to employ the Market Exchange Rate (MER) which refers to the market price of one currency in terms of another. However MER alone does not necessarily reflect the relative prices of goods and services between countries (Lafrance and Schembri, 2002), since the same monetary value of goods produced in one country will represent different quantities of goods of the same category or type produced in another. For example, £1 may indicate the production cost of 1 kg of apples produced in the UK but of 10 kg of similar apples produced in China. Therefore purchasing power parity (PPP), which compares the prices of a basket of common household goods between countries, must also be taken into consideration. Thus, relative purchasing power parity (RPPP) was used to translate the GBP value of a Chinese export into the actual quantity of UK goods. RPPP is the ratio between the exchange rate of a UK pound relative to the Chinese currency (RMB) and the PPP conversion factor (Shui and Harriss, 2006). The RPPP in the equation represents the relative PPP of the UK to China in 2004.

Table 3
China's relative purchasing power parity in 2004 (World Bank, 2005)

Monetary indicator	US$/GBP	RMB/US$	GBP/RMB
Exchange rate	0.54618	8.276801	15.15398
PPP conversion factor	0.638208	1.916346	3.002698
RPPP	–		5.046788

Since there is no direct exchange rate and PPP conversion factor for these two currencies, data for the United States currency was used to derive the UK–China RPPP value. Table 3 shows the required monetary indicator data for calculation of the RPPP.

2.7. Estimating CO_2 emissions embodied in UK exports to China

The CO_2 emissions embodied in the UK exports to China were estimated from

$$\mathrm{UKC}^{\mathrm{embd}}_{\mathrm{Tot}} = \sum X_i \times C_i \times F_y \times \frac{\mathrm{CPI}_i; 1993}{\mathrm{CPI}_i; 2004}, \qquad (5)$$

where $\mathrm{UKC}^{\mathrm{embd}}_{\mathrm{Tot}}$, with units of tonnes, represents the CO_2 emissions embodied in the UK exports to China in the year 2004.

2.8. Estimating CO_2 emissions embodied in Chinese exports to the UK

The CO_2 emissions embodied in the Chinese exports to the UK were estimated from

$$\mathrm{ChinaC}^{\mathrm{embd}}_{\mathrm{Tot}} = \sum X_i \times C_i \times F_y \times \frac{\mathrm{CPI}_i; 1993}{\mathrm{CPI}_i; 2004} \times RPPP \times F_{\mathrm{ad}} \qquad (6)$$

where $\mathrm{ChinaC}^{\mathrm{embd}}_{\mathrm{Tot}}$, with units of tonnes, represents the total CO_2 emissions embodied in Chinese exports in the year 2004; F_{ad} was found from Eq. (3).

2.9. Carbon-intensity comparison

To assess the impacts of international trade on global CO_2 emissions, the differences in carbon intensities of the different industrial sectors of the UK and Chinese economies were examined. A simple way to make a broad comparison of the carbon intensities of production processes of different economies is to investigate the amount of CO_2 emissions embodied in traded goods for final demand per GBP (at 2004 values) input in the equivalent industry sectors. The carbon-intensity factor can be derived by dividing the calculated CO_2 embodiment of each industry by the trade value responsible for that part of the CO_2 embodiment. Although not perfect, due to its aggregate nature, this comparison can provide an insight into how carbon-intensive production processes are in each industry in each country.

2.10. Consideration of the CO_2 emissions resulting from the international transport of traded goods

The transport of goods from China to the UK and *vice versa* obviously contributes to the CO_2 embodied in this trade. Most of this trade is by ship. Few studies to date have attempted to quantify the CO_2 emissions resulting from the transport of goods, due to the difficulties of impact allocation resulting from the international nature of the shipping industry (Peters et al., 2004), although this topic is rapidly attracting great attention (e.g. through the concept of "food-miles" and "carbon footprints"). Wenzel (1999), using Germany as a case study, estimated that the CO_2 emissions resulting from the transport of goods form a relatively minor part of total emissions associated with their production (1–2% for cars and computers, and around 6% for food items). Here, we make a crude first-order approximation of the CO_2 emissions resulting from the international transport of traded goods between China and the UK by multiplying the total CO_2 emissions resulting from global shipping by the fraction of global shipping due to bilateral China–UK trade. Globally, shipping emits about 208 Mt of CO_2 per year (Marland and Boden, 2005), but unfortunately data on the transport of goods between China and the UK as a fraction of world shipping are not readily available. Bilateral UK–China trade accounts for less than 0.5% of global trade (World Trade Organization, 2005). Allowing for the great distance between China and the UK relative to most other bilateral trade routes, we assume that shipping of goods between China and the UK probably results in less than 5% of the global total, or 10 Mt of CO_2 per year. However, we emphasis that this is a first-order approximation only.

3. Results

3.1. CO_2 emissions avoided in the UK through importing goods from China

We estimate (Eq. (4)) that the UK avoided emitting 69 Mt of CO_2 in 2004 as a result of importing goods from China, rather than manufacturing the same type and quantity of goods domestically. This reduced the UK's national potential CO_2 emissions by 11% (total UK CO_2 emissions for the year 2004 were 555 Mt; Defra, 2007).

3.2. The CO_2 embodied in the export of goods from the UK to China

For comparison, the CO_2 emissions embodied in the manufacture of goods in the UK and exported to China in 2004 were estimated, using the adjusted UK 1993 EIOTs, to be 2.3 Mt of CO_2, or 0.4% of total UK emissions for the year.

3.3. The CO_2 embodied in Chinese exports to the UK

China emitted 4707 Mt of CO_2 in 2004 (Energy Information Administration, 2008), a fraction of which was associated with the manufacture of goods subsequently exported to the UK. We estimate (Eq. (6)) that the manufacture of these goods resulted in CO_2 emissions of approximately 186 Mt in 2004. In other words, 4% of China's CO_2 emissions in 2004 were as a result of producing goods for the UK market. This quantity of CO_2 is greater than the 69 Mt of CO_2 required to manufacture the same goods in the UK, due to the greater relative carbon intensity of Chinese industry, through its greater use of coal and less efficient manufacturing methods compared with the UK.

3.4. CO_2 emissions resulting from the transportation of goods between the UK and China

As mentioned above, a first-order preliminary estimate indicates that the sea transport of goods between the UK and China and *vice versa* resulted in emissions of less than 10 Mt of CO_2 in 2004.

4. Discussion

4.1. The impacts of bilateral UK–China trade on national and global CO_2 emissions

By importing goods from China, the UK avoided emitting 69 Mt of CO_2 in 2004. This equates to a 11% reduction in the UK's potential emissions of CO_2 in 2004, assuming the same quantity and types of goods had been manufactured in the UK instead of being imported from China. At the same time, the UK increased its actual emissions of CO_2 by about 0.4% as a result of manufacturing goods for the Chinese market, highlighting the trade (and carbon) imbalance between the two countries.

Importantly, the production of goods in China and their export to the UK, which "saved" the UK potential emissions of 69 Mt CO_2, actually resulted in the emission of about 186 Mt of CO_2 in China in 2004, because of the less efficient manufacturing processes and carbon-intensive energy sources (mainly coal) used in China. Thus, by buying (cheaper) goods from China, rather than the same type and quantity of domestically manufactured goods, UK consumers were responsible for the emission of an additional 117 Mt CO_2 in that year (117 Mt being the difference between 186 and 69 Mt). Although this represents a small additional increment (0.4%) to the global CO_2 emissions of 29003 Mt in 2004 (Marland and Boden, 2005) it substantially increased the "carbon footprint" of UK consumers by 19%. To this should be added the CO_2 cost of transporting goods from China to the UK, although preliminary estimates suggest this is low relative to the manufacturing carbon-costs.

4.2. Uncertainties in the CO_2 emissions calculations

There are several uncertainties in the calculation of the CO_2 emissions embodied in traded goods. This study was conducted using the UK's EIOTs, based on data for 1993, but updated to account for changes in the fuel mix used in the UK and changes in the economy reflected in the CPI between 1993 and 2004. However, the CPI is an aggregate metric and does not give commodity sector-specific information. Due to the lack of EIOTs for China or an I–O-like model for the Chinese economy, the CO_2 emission data for the UK for 1993 were adjusted using fuel use differences in the industrial sectors of the UK and China to give an estimate of CO_2 emissions in China (Shui and Harriss, 2006). This method, based on the UK EIOT, allows an estimate to be made of the emissions incurred in China during the production of goods for export to the UK. However it does not necessarily fully account for all CO_2 emissions resulting from the import of materials or goods to China required for the production of goods for export to the UK and truncation errors of this kind may be significant in single-region input–output-based studies (Lenzen, 2001a, b). Even if truncation errors do not occur, it is impractical in general to find information on the spatial origin and hence CO_2 cost of every raw material or component used (Lenzen et al., 2004). Moreover, using a single-region input–output model that uses emission factors derived from a different region will inevitably lead to unquantifiable errors in the CO_2 multipliers used (Lenzen et al., 2004; Peters et al., 2004; Shui and Harriss, 2006).

In 2004, the currency exchange rate equivalent of GBP to RMB (15.2) was significantly higher than in previous years (previous highest in the period 1995–2003 being 13.7) (World Bank, 2005), which may result in an overestimation of CO_2 emissions embodied in traded goods. Furthermore, our analysis assumed coherence in the classifications of industrial sectors and traded goods and commodities, based on the nature of the goods, rather than the stage of production (UN Comtrade, 2006). Hence, without further investigation, it is difficult to ensure consistency in both data sets.Additionally, as mentioned above, we do not have robust estimates of the CO_2 emissions resulting from the transport of goods between the two countries.

In summary, for several reasons, we are not able, at present, to fully quantify the precision or accuracy of our CO_2 emission estimates and so present them here as current best-estimates only.

4.3. Policy implications

The results presented here have clear implications for national and international environmental policy. The CO_2 emissions embodied in international trade are one example of how consumption choices in one country can affect the environmental performance of another (e.g. Munksgaard and Pedersen, 2001; Munksgaard et al., 2005; Nijdam et al., 2005; Hoekstra and Janssen, 2006). Current environmental policies and obligations, such as the Kyoto Protocol, are framed in such a way that it is possible for developed (Annex I) countries to move towards their domestic and international commitments by shifting their carbon-intensive industries overseas and to depend on the enhancement of international trade to meet the expectations and demands of their consumers. This can result in even higher global CO_2 (and other pollutant) emissions if the imported goods use more GHG-intensive production processes than the domestically produced goods that they displace. Therefore, a consumption-based CO_2 accounting system, which subtracts the emissions embodied in exports from domestic production-based inventories and adds the emissions embodied in imports to the consumer economies, would be a fairer method of allocating responsibility for GHGs. For example, the CO_2 emitted in China as a result of producing goods for UK consumers could be attributed to the UK's national CO_2 emissions inventory. On the other hand, the allocation of GHGs embodied in trade without careful monitoring may undermine climate policy, acting as a disincentive to the reduction of CO_2 emissions in countries, such as China, with a large trade surplus. Care must be taken to avoid disincentives to the modernization and development of more efficient and less GHG-intensive production methods, wherever they are located. Much further analysis of the environmental costs of international trade is required to allow effective and fair policies to be developed in this field. Notwithstanding this requirement, consumers should be aware of the full environmental implications of their choices.

5. Conclusions

Despite the considerable uncertainties in our analysis, in part resulting from the use of trade data for one year only, we conclude that bilateral trade between China and the UK in 2004 had the effect: (i) of reducing the apparent CO_2 emissions of UK consumers by about 11%, compared to a non-trade scenario, where the same quantity and type of goods are manufactured in the UK instead of being imported from China; (ii) of increasing the carbon footprint of UK consumers by about 19%, due to the carbon inefficiencies of Chinese industrial processes relative to those of the UK, and (iii) of increasing global CO_2 emissions by about 0.4%. In addition, shipping of goods from China to the UK in 2004 resulted in the emission of an unquantified amount of CO_2, possibly around 10 Mt. It is clear from this analysis that simple consumer choices can greatly affect national and global CO_2 emissions and that international GHG accounting policies lag behind the economic realities of global trade.

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