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China's carbon emissions and international trade: implications for post-2012 policy

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Growing international trade has been one of the most important drivers for China's recent economic growth. This growth has fed rapid increases in energy demand and carbon emissions since 2000. China is now the world's largest emitter of carbon dioxide. There is mounting pressure from some in the international community for China to take specific actions to mitigate its emissions as part of a post-2012 climate regime. However, emissions embodied in internationally traded goods have not been given enough attention in this debate. This article discusses the results of research to quantify the emissions stemming from goods that are exported from China to other countries. It finds that these emissions accounted for 23% of China's national total in 2004. The article sets out how this result has been obtained and compares it to the results of several other pieces of research to demonstrate the importance of this issue. Some pointers for international climate policy are then discussed, including the advantages and difficulties of moving to consumption-based emissions accounting, and implications for international trade rules.

Keywords: China; climate policy; competitiveness; consumption-based emissions; embodied carbon; emissions accounting; international trade; post-2012

Le commerce international croissant a été l'un des moteurs les plus importants de la croissance économique en Chine. Cette croissance a nourri une croissance rapide de la demande en énergie et des émissions de carbone depuis 2000. La Chine est maintenant le plus grand émetteur du monde en dioxyde de carbone. La communauté internationale exerce une pression croissante sur la Chine pour qu'elle agisse spécifiquement pour réduire ses émissions dans le cadre d'un régime climatique post 2012. Cependant, les émissions intrinsèques aux biens échangés à l'international n'ont pas reçu assez d'attention dans ce débat. Ce papier illustre les conclusions de recherche dans la quantification des émissions issues de biens exportés de la Chine vers d'autres pays. Il montre que ces émissions représentent 23% du total national pour la Chine en 2004. Ce papier montre comment cette conclusion a été obtenue et la compare aux conclusions de plusieurs autres pièces de recherche démontrant ainsi l'importance de cette question. Quelques indications pour la politique climatique internationale sont ensuite discutées dans la partie finale de cet article, y compris les avantages et difficultés liées au passage à une comptabilisation des émissions sur la base de la consommation, et les conséquences sur les règles internationales du commerce.

Mots clés: carbone intrinsèque; Chine; commerce international; compétitivité; comptabilisation des émissions; émissions liées à la consommation; politique climatique; post-2012

1. Introduction

International trade has experienced unprecedented growth over the last few decades as part of the ongoing process of globalization. Many regions have benefited from the relocation of production as multinational companies move around the world looking for better resources and production efficiency. However, as demonstrated by the controversy surrounding each round of international

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trade negotiations, there are many questions about the impact of international trade on the environment and equality (Wyckoff and Roop, 1994; IPCC, 1996; Copeland and Taylor, 2003). The environmental consequences of international trade have been highlighted further by the emergence of climate change as an urgent issue that requires international action.

Against this background, this article discusses the implications of a recent Tyndall Centre analysis of China's carbon emissions, which focused on the extent to which China's emissions are due to traded goods. The article describes the impacts of international trade on national emissions, with a particular focus on China. Our results are discussed alongside the results of several other similar pieces of research. We then consider whether these impacts should lead to a change in emissions accounting. Should accounting focus on a country's consumption of goods and services rather than the traditional production-based method? Finally, we examine some further implications of this analysis of China for the post-2012 international framework.

2. Trade and carbon emissions

Since only some countries are required to reduce their carbon emissions under the Kyoto Protocol, 'carbon leakage' from the export of emissions to countries without emissions caps has become a focus of concern (Wyckoff and Roop, 1994; Peters and Hertwich, 2006; Wang and Watson, 2007). Carbon leakage is defined in various ways (Mongelli et al., 2006; Barker et al., 2007; Peters, 2008). The IPCC definition of carbon leakage is 'the increase in non-Annex I emissions divided by the reduction in Annex I emissions' (IPCC, 2001). In reality, it is difficult to identify the causality between reductions in Annex I and increases in non-Annex I emissions. Therefore, this article uses the broader definition of carbon leakage used by Peters and Hertwich (2006) and Mongelli et al. (2006), which is the emissions embodied in non-Annex I exports to Annex I countries.

The United Nations Framework Convention on Climate Change (UNFCCC) defines emission mitigation and responsibility boundaries by 'includ[ing] all greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction' (IPCC, 1996). This boundary is criticized for missing two important components of a nation's carbon emissions: international transport and emissions embodied in imports. The problem of international aviation and shipping has been discussed extensively (Bows and Anderson, 2007; den Elzen et al., 2007) and remains an important area of media and public debate. However, less attention has been given to the emissions embodied in internationally traded goods and services.

Previous research has investigated the embodied carbon emissions (or other forms of pollution) due to international trade in the context of different countries and regions, mostly using input–output (I–O) analysis. Early research by Wyckoff and Roop (1994) estimated the emissions embodied in manufactured imports for six OECD countries. These accounted for about 13% of their total emissions at the time. Nearly 10 years later, Ahmad and Wyckoff (2003) came up with a figure of over 50% for some OECD countries, a figure that they noted was still rising. Peters and Hertwich (2008a) estimated that the CO_2 emissions embodied in international trade in 2001 were over 5.3 Gt, and discussed the impacts on global climate policies. A report from WWF (2008) concluded that carbon emissions from the EU would be about 500 million tonnes higher in 2001 if emissions embodied in imports were included – more than the total emissions of Italy. Similar calculations have also been carried out separately for specific regions or countries in Europe, and also for the USA (Ghertner and Fripp, 2007; Norman et al., 2007; Weber and Matthews, 2007; Wiedmann et al., 2007; WWF, 2007). But the case of China probably illustrates this issue more acutely than any other country. Analysis of the contribution of international trade – particularly exports – to China's carbon footprint illustrates the need for trade to be taken into account.

3. The case of China

Exports are an increasingly important driver for China's economy, particularly since it joined the WTO in 2001. In 2004, exports accounted for 34% of China's total GDP. A shift of manufacturing to China is also observable: 58% of China's exports were from multinational ventures in China in 2006,[1] and more than 70% of actual foreign direct investment (FDI) in China went to manufacturing industries in 2005 (National Bureau of Statistics, 2006). As a result, China's manufacturing exports and overall trade surplus have accelerated sharply. In 2004, China's trade surplus was $32 billion. In 2005 the trade surplus tripled to $102 billion, and it rose still further to $177 billion in 2006. In 2007, China overtook Germany to become the world's largest exporter.[2] Figure 1 shows both the trends in China's exports and increases in CO_2 emissions in recent years.

The rise of China as a global trading power has led to tensions with the EU and the USA over competitiveness and safety issues. In addition, there is increasing emphasis on the effect of China's economic growth on its carbon emissions. China is now believed to be the world's largest emitter of carbon dioxide (CO_2).[3] What happens in China is therefore regarded as critical to the success of the international effort to combat climate change. Carbon emissions in China have been rising as quickly as the economy since the start of the new millennium. Although the Chinese government has shown a more serious and open attitude to climate change in recent international talks, it refuses to accept a cap on its carbon emissions on the grounds that that industrialized countries are responsible for the majority of emissions to date. Chinese officials have also argued that the steep rise in China's emissions has been partly fuelled by exports of cheap goods from its factories to Western consumers. According to Foreign Ministry spokesman Qin Gang: 'The developed countries move a lot of manufacturing industry into China … A lot of the things you wear, you use, you eat

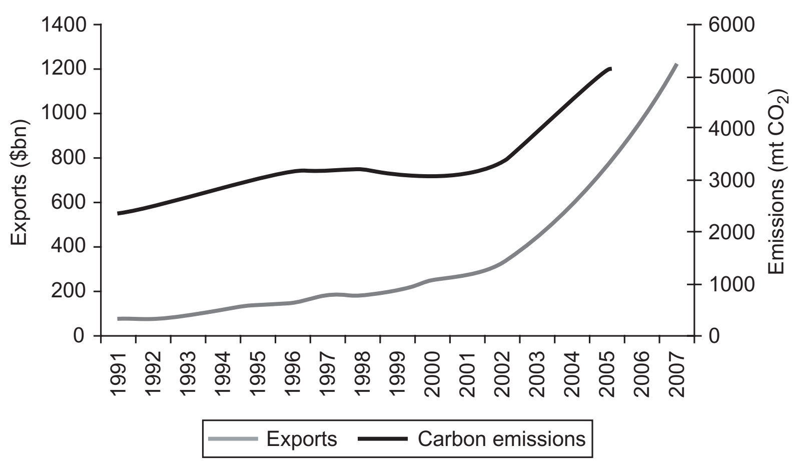

FIGURE 1 China's exports and CO_2 emissions since 1990.

Source: CO_2 emissions data from IEA (2007) and online statistical database; export data until 2004 from *China Statistical Yearbook 2006* (National Bureau of Statistics, 2006); subsequent data from statements by China Statistical Bureau.

are produced in China. On the one hand, you shall increase the production in China, on the other hand you criticize China on the emission reduction issue' (Associated Press, 2007).

Arguably, while the developed world is becoming ever more reliant on importing goods from China, it is also becoming more reliant on 'exporting' carbon to China to achieve carbon reduction targets (nef, 2007; Li and Hewitt, 2008; WWF, 2008). In a Tyndall Centre Briefing Note (Wang and Watson, 2007), we set out an initial assessment that looked at this issue in more detail. This concluded that international trade accounted for 23% of China's total carbon emissions in 2004. This is due to China's large trade surplus, but is also due to the relatively high level of carbon intensity within the Chinese economy. This figure is comparable to Japan's total CO_2 emissions and is more than double the UK's emissions in the same year (see Figure 2). The equivalent emissions figures for 2005 and 2006 could be larger, as China's trade surplus has grown sharply since 2004.

This result is based on a relatively simple calculation using available, aggregated trade and emissions data from IEA and Chinese official statistics. The direct CO_2 emissions embodied in products that are exported from China were estimated, and then this result was reduced by the direct emissions avoided by China through imports, to obtain the estimate of net carbon emissions embodied in China's international trade. Our results are for the year 2004, the most recent year for which comprehensive figures were available at the time we conducted our analysis. The calculations used official Chinese data for trade values. It combined these values with national average figures from the International Energy Agency (IEA) for CO_2 emissions per unit of GDP for China and for China's trade partners (IEA, 2006). The trade values are expressed in actual terms instead of purchasing power parity (PPP). This is because the monetary values of internationally traded goods are recorded at international, not domestic, prices. So it makes sense to use a consistent monetary unit across countries.

Unlike other studies, this calculation estimated embodied CO_2 using the monetary value of traded goods instead of a full input–output analysis for physical products or industry-specific processes. There are benefits, as well as disadvantages, of using monetary data in this way. Three benefits are worth noting. First, using the final value of the traded product includes the 'added value' of

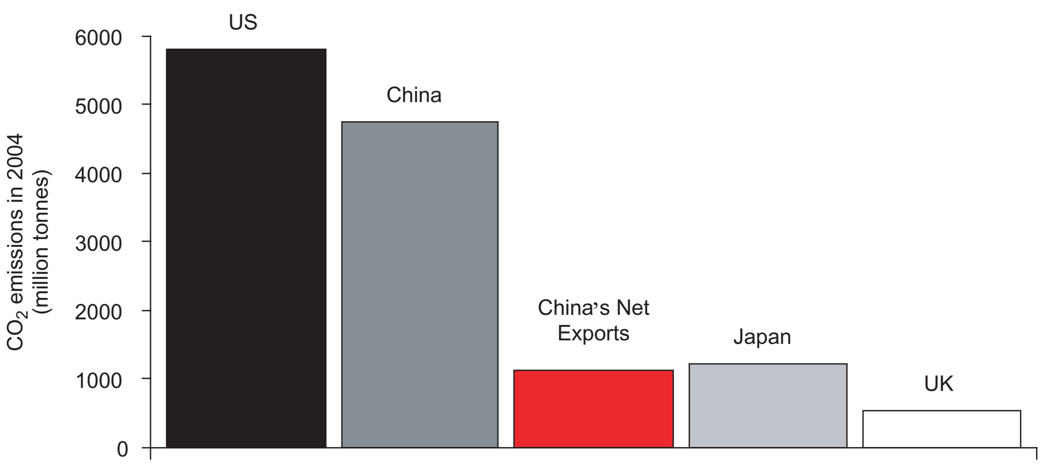

FIGURE 2 CO_2 emissions from China's net exports in 2004 in comparison with total emissions from China and other countries.

Source: Wang and Watson (2007).

indirect inputs along the manufacturing chain, although it does not differentiate between the added value from manufacturing and the costs of activities such as branding and marketing. Another benefit of using monetary data is aggregation. This allows a simpler analysis that does not need the same amount of detailed data as input–output analysis. Thirdly, since our analysis used national figures for the carbon intensity of GDP, it takes some account of the technology differences between domestic production and production in other countries that export to China.

Although some research assumes (due to a lack of reliable data) that imports are produced by using domestic technology (Munksgaard and Pedersen, 2001; Mongelli et al., 2006; Ípek Tunç et al., 2007), this assumption has been criticized as being unrealistic and a potential cause of significant errors (Ahmad and Wyckoff, 2003; Wiedmann et al., 2007). For example, Peters et al. (2007) estimated that carbon emissions embodied in imports accounted for 34% of China's total emissions in 2002 by assuming that imports were produced by Chinese domestic technologies. A later estimate (Peters and Hertwich, 2008b), based on the technology level in each exporting country, gave a value of 6.6% for 2001. The most important results from these and other studies are summarized in Table 1.

TABLE 1 Results from different studies of emissions embodied in China's trade

Study	Year of estimate	Total CO_2 emissions (IEA, 2007)	CO_2 emissions embodied in: Exports (% of total)	Imports (%)	Net (%)	Data source
Ahmad and Wyckoff, 2003	1997	3,133 Mt	463 Mt (15%)	102 Mt (3%)	360 Mt (12%)	OECD; IEA
Peters and Hertwich, 2008a	2001	3,123 Mt	803 Mt (24.4%)[a]	217 Mt (6.6%)[a]	586 Mt (17.8%)[a]	GTAP data
Peters et al., 2007	2002	3,364 Mt	(32%)	(34%)[b]	(–2%)[b]	China I–O and energy statistics; Lawrence Berkley Lab
Wang and Watson, 2007	2004	4,769 Mt[c]	1,490 Mt (31.5%)	381 Mt (8.1%)	1,109 Mt (23.4%)	IEA and China Statistical Yearbook
IEA, 2007	2004	4,769 Mt	1,600 Mt (34%)			IEA data
Shui and Harriss, 2006	1997–2003	3,133–3,871 Mt	213–497 Mt (7–14%)[d]			US Census Bureau and EIO-LCA[e]
CASS, 2007[f]	2006	Not available	1,846 Mt	800 Mt	1,000 Mt	Chinese I–O database and UN trade data

[a] This is the percentage of national production-based total emissions, which is different from UNFCCC values (see Peters and Hertwich, 2008, for details).
[b] This is estimated based on assumption that imports are produced using Chinese domestic technology, which is unrealistic and can cause significant error.
[c] The IEA data was revised from 4,732 to 4,769 million tCO_2 after our calculations.
[d] This refers to embodied emission in China's exports to the USA alone.
[e] Economic Input Output–Life Cycle Assessment (EIO-LCA) software developed based on US economic input and output data.
[f] 'WWF: Don't ignore the net export of embodied energy from China', Press release at WWF's Emissions Reduction Pathways for Emerging Economies side event at the UNFCCC Summit in Bali [available at www.wwfchina.org/english/loca.php?loca=496].

Some problems of using monetary data and national average carbon intensity of GDP are also clear. First, national average carbon intensity data ignores the differences in the emissions intensity of trade goods, which can be large. In addition, this data does not fully capture structural change in trade patterns. It also does not take into account the different values added by different manufacturers. Second, imports to China via freight centres such as Hong Kong and Singapore were unable to be traced back to their original source due to insufficient data. Therefore, errors may be present because these imports were treated as if they were locally produced in these areas. However, this data problem could be solved by extending the region of analysis. Thirdly, when imported goods are re-exported after being processed in China (so-called 'processing trade'), the embodied emissions from China should only be derived from the value added by processing instead of the final price. This cannot be separated from trade data.

One aspect of our analysis that needs to be tested is the extent to which the 23% figure might be inaccurate due to the composition of imports and exports. Our results suggest that although those sub-sectors that account for the largest export values (e.g. electronics, machinery and textiles) are likely to have a low or medium level of carbon intensity, their carbon intensity is still likely to be higher than the national average when agriculture and service sectors are included. A significant underestimate could be possible if China's exports were mainly derived from carbon-intensive goods such as steel and cement. But, currently, the majority of China's exports are not in this category (Wang and Watson, 2007). This also applies to imports from other countries.

As stated above, our result would be more accurate if sectoral carbon emissions intensities could be obtained, and there are also potential inaccuracies due to the treatment of 'processing trade'. Due to these above uncertainties, it is hard to tell exactly whether the 23% figure is under- or overestimated. Our conclusion is that the overall CO_2 emissions figure for China's net exports is not likely to be significantly different from this figure unless trade patterns change dramatically. However, the margin of error due to these uncertainties needs to be investigated further with more detailed data and more sophisticated methods.

Given this observation, it is useful to compare our result to those from other studies. A number of studies have attempted to measure the resources and pollution embodied in traded goods to and from China in more detail than our work, such as those of Ahmad and Wyckoff (2003) and Peters and Hertwich (2008a). As stated previously, many other studies have used input–output (I–O) analysis (Suh, 2007; Wiedmann et al., 2007). Despite the fact that I–O analysis has been used since the early 1970s to quantify embodied resource use (Leontief, 1970), only in the 1990s (Wyckoff and Roop, 1994; Kondo et al., 1998) have improvements in I–O analysis made it possible to carry out multi-region and multi-sector studies (Wiedmann et al., 2007).

Table 1 shows some results from these studies. Although they use different datasets and methods, many of the results are of a similar order to our study. One important trend is an increase in the embodied emissions in exports over time, from 1997 to 2006. This is in line with expectations, given the rapid increase in both Chinese international trade and emissions. This reinforces the need to consider the implications for national emissions accounting and for international climate policies.

4. Towards consumption-based emissions accounting?

In addition to those studies that have focused on China, many recent pieces of research that use I–O analysis have shown significant and increasing embodied energy or carbon emissions due to trade between Annex I and non-Annex I countries. The figures are so large for some countries that the UNFCCC approach based on the production of emissions within national borders can be significantly misleading. As noted above, this is the case for China. It is also true for Norway (Peters and Hertwich, 2006; WWF, 2008), the USA (Shui and Harriss, 2006; Weber and Matthews, 2007), as well as some other OECD countries (Ahmad and Wyckoff, 2003).

This has led to calls for consumption-based national emissions accounts instead of (or alongside) the production-based accounts that are currently used (Munksgaard and Pedersen, 2001; Ferng, 2003; Peters, 2008). For its advocates, consumption-based responsibility is believed to have several advantages, since it takes into account international trade, it emphasizes demand-side action to reduce emissions, it prevents carbon leakage, and could help to prevent trade protectionism with respect to 'green' technologies and products (Chatham House, 2007). It could also provide a stronger rationale for low-carbon technology transfer and deployment in developing countries such as China. A consumption-based emissions account might also help to make it easier for developing countries such as China to participate in an international post-2012 climate agreement, as it takes into account the 'external' driver of trade for China's emissions increases.

On the other hand, it may not be entirely fair for countries that produce goods for export – and enjoy the gains from this economic activity – to take no responsibility for the associated emissions. A shared responsibility between those that produce goods causing emissions and those that consume them may be more politically acceptable. However, this leads to difficult questions about how to determine the weighting of each (Gallego and Lenzen, 2005; Peters, 2008). Furthermore, any shift towards consumption-based accounting has significant data requirements. International trade flows are complex and involve multiple countries and sectors as part of product supply chains. Data availability for a fully multi-regional I–O analysis, especially in developing countries, is a big challenge. So is the need for a consistent approach to data across different regions and sectors (Wiedmann et al., 2007).

In addition to these uncertainties and challenges for data, consumption-based responsibility also has difficulties when it comes to reality. A national government can act most effectively within its sovereign boundary. Therefore any action to mitigate embodied emissions from its imports would have to rely on bilateral or multilateral negotiation and collaboration. This brings in more uncertainties and possible political trade-offs. Another concern is that if the country producing the exported goods were not held responsible for the embodied emissions, it would be reluctant to improve the environmental performance of its industries, as this would be the importing country's responsibility. A consumption-based emissions account is also less straightforward because it is inconsistent with mainstream accounting for the economy (e.g. measures such as GDP) and other environmental issues.

5. Implications for international policy post-2012

In spite of apparent ethical advantages, it is unlikely that consumption-based accounting will overturn the dominant production-based approach for the post-2012 regime. However, as argued by Peters (2008), it could be at least used as a 'shadow' indicator in post-2012 climate talks to inform the negotiations over how differentiated responsibilities should be catered for. Taken together with other studies, our analysis could be used to suggest some pointers for the policies that might follow from this. More specifically, it suggests that there is some merit in considering international approaches to some sectors or classes of product.

Sectoral climate change agreements have been discussed extensively in recent years. One of the main rationales for exploring these has been concerns that comprehensive climate change agreements such as the Kyoto Protocol affect the competitiveness of key industries. For many advocates, sectoral approaches are designed to square meaningful emissions reduction commitments with the realities of international trade. According to a recent analysis by the World Resources Institute (WRI), sectoral agreements also have other advantages (WRI, 2007). They could extend the coverage of future international agreements beyond the 27% of global emissions covered by Kyoto. Furthermore, they could help to target efforts at sectors such as iron and steel, which are thought to be difficult to decarbonize.

Although these advantages are important, the WRI report also highlights a number of drawbacks. It argues that sectoral agreements should not be seen as an alternative to nationally based targets, and will therefore need to be compatible with a primary global regime that sets national goals. The report also shows that there are many different definitions of a 'sectoral agreement', which vary in their scope. While some proposals are for mandatory efficiency standards or overall emissions caps backed by governments, others include softer, more voluntary, agreements led by industries themselves.

Our analysis of China shows that the sectors that contribute most to the emissions embodied in net exports from that country have a relatively low carbon intensity (Wang and Watson, 2007). These include consumer goods such as textiles, footwear and electronics, as well as industrial goods such as machinery. Production by these sectors is very likely to be more carbon-intensive than equivalent sectors in Annex I countries, due to China's high-carbon energy system. However, many of these sectors do not readily lend themselves to sectoral agreements – though some consumer electronic products could be subject to international power consumption standards (WRI, 2007).

Alternative options are available that would involve producers and consumers taking joint responsibility for the emissions from the manufacture of these products. One of these would be to use information or economic instruments to internalize the embodied carbon cost within Annex I countries. In a recent speech, the President of the European Commission, Jose Manuel Barroso, proposed that importers of goods to the EU could be required to purchase emissions permits to reflect their embodied carbon (Barroso, 2008). Similar policies have also been put forward by politicians in the USA (Houser et al., 2008). These proposals have provoked the inevitable charge of 'protectionism', and may be subject to challenge within the World Trade Organization. Any move in this direction would therefore need to be evaluated with care. If implemented, these would need to treat developing countries and Annex I countries differently in order to ensure consistency with the principle of 'common but differentiated responsibilities'. This could be partly achieved by coupling such a policy with compensatory financial and technological assistance for industries in non-Annex I exporting countries.

As already mentioned, much of the debate on sectoral agreements focuses on carbon-intensive industries that are exposed to international competition (WRI, 2007). Despite the fact that exports by these industries are important sources of emissions within China, their export value is still a small proportion of overall trade. This proportion is growing, however. This has prompted the Chinese government to try and slow overall growth as by cutting the export rebate three times in 2007 alone. For these industries, a sectoral approach could offer a great deal. Their energy intensity (and carbon intensity) is generally much higher than the equivalent industries in Annex I countries (Watson et al., 2007). A sectoral agreement that places a cap on global emissions – or sets an energy intensity target – could provide an incentive for efficiency improvements through a combination of domestic action and international technology transfer. But, again, the politics of this would need to be considered – particularly given the likely resistance from companies in the OECD to the provision of assistance to potential competitors.

6. Conclusions

This article has analysed the implications of growing international trade for the traditional nationally based approach to international climate policy. By highlighting the case of China, it has shown that the contribution of internationally traded goods to global greenhouse gas emissions is substantial. The article then explored some of the consequences of this contribution.

For some analysts, the emissions embodied in internationally traded goods together with emissions from international transport point to the need for a new approach to international action. Instead of focusing on emissions produced within different countries' borders, they argue that a consumption-based approach would be more equitable as the necessary deep cuts in emissions are discussed. While this argument has merits, it is unlikely that such a consumption-based approach will be implemented in practice. This is due to a combination of historical inertia and the difficulty of identifying and attributing emissions to consumers.

Despite these problems, this article has highlighted some important implications for international policy. This is particularly the case in the short to medium term, when it would not be fair to expect that rapidly developing countries such as China take on mandatory national targets. The case of China shows that there may be some merit in exploring sectoral agreements – particularly for carbon-intensive industries that underpin much of the recent growth that the country has experienced. Such agreements could help to improve energy efficiency if they include meaningful incentives for technology transfer and innovation. The lack of progress to date on technology transfer shows that this will be far from easy (Ockwell et al., 2006). Such incentives would also be needed alongside any requirement that exporters to Annex I countries should be subject to regulation of their embodied carbon.

The EU's recent proposal that importers buy Emissions Trading Scheme allowances to reflect embodied carbon is an interesting attempt to deal with international trade within the partial climate agreement that is currently in force. While this proposal will be seen by some as protectionist, it highlights the need to integrate these two areas of policy in innovative ways. This is a welcome change to the common view that climate policy should work around trade policy – and that it should not unduly affect competitiveness of carbon-intensive industries.

Notes

1. Mr Bo Xilai, Minister of Commerce of China, speech at the ASEAN Economic Ministers Meeting, 26 August 2007.
2. See 'China beats Germany to take world trade crown' [available at www.telegraph.co.uk/money/main.jhtml?xml=/money/2007/10/25/cnchina125.xml].
3. See Netherlands Environmental Assessment Agency (MNP) 'China contributing two-thirds to increase in CO_2 emissions', Press Release, 13 June 2008 [available at www.mnp.nl/en/service/pressreleases/2008/20080613ChinacontributingtwothirdstoincreaseinCO_2emissions.html]. This argument was first made by MNP in another press release a year earlier.

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