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Carbon Omissions

Consumption-based accounting for international carbon emissions

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Executive Summary

How valid are UK and EU claims to be leading the world in decarbonising their economies? Much of this answer depends upon how you allocate responsibility for carbon emissions between countries. Under the UN Framework Convention on Climate Change, countries are responsible for carbon emissions produced within their borders. But in an increasingly globalised world, citizens of wealthier countries are consuming a growing percentage of goods and services produced in developing countries. Are we simply off-shoring our carbon emissions?

This research note examines the record of, among others, the EU, China and the US from 1990 until 2006 (the most recent year for which data is available). We calculate estimates for the emissions *consumed* within each country, and compare these to the UNFCCC (Kyoto) carbon *production* emissions. Carbon consumption includes emissions embedded within traded goods and services.

Our analysis makes a number of assumptions and generalisations, but the findings are broadly in line with existing academic findings, where these exist.

Our analysis shows that carbon emissions consumed by the UK, by the largest EU members and by the US have risen significantly since 1990, and particularly since 2002. This is in contrast to generally flat or falling carbon production emissions reported in the major EU countries.

The 15 pre-2004 EU Member States (the EU-15) committed themselves to cutting total carbon production emissions by 8% from 1990 levels by 2008-2012 under the Kyoto Protocol. They may be on track to meet this goal, but by 2006, measured on a carbon consumption basis, the emissions of the EU's six largest member states (EU-6, making up 82.5% of EU-15 emissions), had not fallen, but risen. EU consumption emissions have risen by an astonishing 47% since 1990, and UK consumption emissions have risen by 30%.

In 1990, net carbon flows embedded in trade were an insignificant proportion of global carbon emissions, but have grown substantially, and particularly sharply since around 2002.

For the EU-6, by 2006, we estimate that a third of total (consumption-based) emissions were as a result of net imports of carbon, up from only 3% in 1990. This implies around 3 tonnes of net imported CO2e (carbon dioxide equivalent) per person. Our results also show that in 2006 the US net imported 20% of its consumption-based emissions, up from only 3% in 1990. Consistent with these findings, our analysis identifies that in 2006, 26% of the CO2e emissions produced in China were in fact exported, net, to consumers elsewhere.

Our analysis raises a number of important policy implications:

- The credibility of the UK's and EU's claims to 'leadership by example' on climate policy is open to question, given the 47% increase in the EU's carbon emissions consumed since 1990.
- Focusing resources on reducing (expensively) only domestic carbon production emissions within the EU (and UK), ignores the fast-growing impact which EU consumers are now having on the climate through carbon embedded in imported goods – now totalling a third of EU emissions.
- The rapid off-shoring of carbon emissions, which has already been seen, underlines the risk that substantial increases in energy costs in developed countries might cause further carbon leakage to the developing world.
- The scale and rapid growth of carbon embedded in trade makes negotiation of an international agreement on carbon reduction more difficult and complex, including making it hard to specify realistic and fair targets for rapidly growing developing countries.

We make the following recommendations:

1) Further research should be undertaken to understand the evolution of carbon consumption across countries and over time.
2) The Government, and the European Commission, should further investigate the trajectory of UK and EU carbon emissions, with the aim of publishing regular estimates of carbon emissions on a consumption basis in addition to existing production-based accounting methods.
3) The European Commission should give further serious consideration to the full range of mechanisms to address the risk of carbon leakage.
4) The EU and UK should prioritise support towards those low carbon technologies most likely to make a substantial contribution to *global* carbon reduction, in particular in those developing

countries from which the EU is importing substantial and increasing quantities of embedded carbon.

Introduction

The failure to reach an international climate agreement at Copenhagen in December 2009, despite the massive build up of expectations and political momentum led some observers to claim that "climate diplomacy had crashed"[1]. Certainly, the likelihood of securing a strong deal in the near future now seems slim.

One of a number of reasons for this failure has been disagreements over who bears responsibility for current carbon emissions. China produces high and rapidly-growing carbon emissions relative to its GDP, both because of its heavy use of coal to generate electricity, and because its economy is heavily weighted towards manufacturing. However, China exports a high proportion of its manufactured goods to developed world consumers. It may therefore be argued that a proportion of China's carbon emissions are the responsibility of developed world consumers- 'off-shored'.

The growth of off-shored carbon emissions also highlights that, in the absence of a strong global deal on carbon reduction, there is a significant risk of 'carbon leakage', as more carbon-intensive industries relocate from carbon-restricted economies to less restricted ones, potentially increasing overall emissions.

In this Research Note, we produce new quantitative analysis to shed light on how a range of countries' carbon *consumption* levels have evolved since 1990. Our analysis takes into account not only carbon emitted within a country, but also attempts to adjust this for the relative carbon content of countries' imports and exports, in order to estimate countries' overall carbon consumption. We compare our carbon consumption estimates with the more usual (Kyoto-based) carbon *production* statistics.

Understanding carbon consumption is important because it has implications for several areas of policy. First, understanding countries' relative performance on carbon consumption emissions is important in itself, because it informs understanding of countries' contribution to, and performance in reducing, carbon emissions.

Second, it may inform discussion of relative responsibility for carbon emissions and emissions reduction, and thus approaches to international negotiations. As Helm and Smale note, "From a global policy perspective, the allocation of the burden of carbon emissions involves international negotiations that necessarily include considerations of equity and fairness, as well as economic efficiency." China, for example, has argued[2] that a sizeable proportion of its emissions are produced on behalf of consumers in the developed world.

Third, it may also inform governments' policies to achieve carbon reduction, by shedding light on the carbon 'trade' and the scope for carbon leakage. These have implications for the relative prioritisation of carbon reduction policies and, for example, the case for carbon pricing to include imported goods.

Where does this analysis fit in with the previous landscape of research?

In recent years a number of studies have considered alternative ways of accounting for carbon emissions.

The conventional and most widely used accounting methodology for measuring greenhouse gas emissions is that defined under the UN Framework Convention on Climate Change (UNFCCC). Developed for the implementation of the Kyoto Protocol, it takes a geographical approach to emissions responsibility: a country's emissions total is the sum of all (and only) emissions generated from *productive* activities within its territory.

In a report in 2007, three UK economists, Dieter Helm, Robin Smale, and Jonathan Phillips[3] looked at the UK's record on climate change, exploring the differences between various accounting methodologies for measuring greenhouse gas emissions. As they noted, these differences can be substantial, comparing the UNFCCC approach with the UK's National Environmental Accounts to illustrate their point. In addition, their report, for the first time, accounted for carbon emissions not solely on a *production* basis, but also, importantly, on a *consumption* basis.

Helm & Smale's accounting for UK emissions on a consumption basis involved estimating the emissions embodied in trade (the net effect of imports and exports), tourism (emissions consumed by UK residents in non-UK territories, for example during business trips and foreign holidays) and bunker fuel emissions (carbon consumption in relation to travel between countries, for example through international aviation and shipping).

Helm & Smale found that, while the UK's record against its Kyoto target was good, exceeding its target of 12.5% reductions between 1990 and 2008, their calculations suggested that UK emissions on a consumption basis had been rising steeply – by 19% between 1990 and 2003.

In a paper published in January 2010 by the Carnegie Institution of Washington[4], authors Steven Davis and Ken Caldeira produced a carbon consumption-based account for world trade in a single year – 2004 – looking at 113 countries or regions and 57 industry sectors. They found that in 2004, 23% of global carbon dioxide (CO2) emissions were traded internationally, primarily as exports from China and other emerging markets to consumers in developed countries. In some countries, including Switzerland, Sweden, Austria, the UK and France, more than 30% of net consumption-based emissions were imported. In contrast, 22.5% of the emissions produced in China in 2004 were exported, net, to consumers elsewhere.

Davis and Caldeira's methodology was more detailed than Helm & Smale's, taking into account the

constituent traded goods and services and estimating their individual carbon content.

Davis and Caldeira concluded:

"Consumption-based accounting of CO2 emissions demonstrates the potential for international carbon leakage. Sharing responsibility for emissions among producers and consumers could facilitate international agreement on global climate policy that is now hindered by concerns over the regional and historical inequity of emissions".

What their report did not show was the way in which the pattern of emissions consumed has changed over time for a range of countries.

Our calculations are cruder than those of the Carnegie Institute, but the trends they reveal are nevertheless useful to inform debate and further study. In the words of Helm & Smale, *"crude calculations give some indication of the magnitude of the impact of taking this aspect of greenhouse gas consumption into account".*

Methodology

While Helm and Smale examined the evolution of UK carbon consumption over the period 1990-2003, we extend analysis to eighteen countries (see list of countries in the box below), both developed and developing. We also update the study by extending the time period to 2006, using the latest available data.

Helm & Smale estimated the carbon consumption impact of imports and exports, tourism and bunker fuel emissions. Our analysis focuses only on the carbon emissions embodied in international trade. This is a simplification of Helm & Smale's methodology. Helm & Smale found that tourism and bunker emissions accounted for roughly 20% of the difference between UK carbon production and consumption; the other 80% was trade.

To arrive at estimated carbon consumption, for each of the years 1990 to 2006, and for each of the eighteen analysed ("reporter") countries we:

- took the reported carbon production emissions;
- subtracted emissions estimated to be embodied in exports from the country in question; and
- added emissions estimated to be embodied in imports to the country in question.

We estimate the emissions embodied in exports and imports by applying the average carbon intensity (i.e. tonnes of CO2 per dollars GDP) of the originating country, in the relevant year, to the value of the traded goods or services.

Data

We used the following sets of data for each of the years 1990-2006:

- Total exports from each of the eighteen "reporter" countries, in US dollars;
- Imports to each reporter country from each of a set of 52 "partner" countries, in US dollars. Partner countries are a set of countries, including and extending beyond the reporter countries, which together account for around 80% of world trade. Export and import trade data were obtained from the International Monetary Fund (IMF) Direction of Trade Statistics (DOTS)[5];
- The carbon intensity of the reporter and partner countries' economies in megatonnes of CO2 equivalent emitted (MtCO2e) per dollar GDP. Emissions data was obtained from the Climate Analysis Indicators Tool (CAIT)[6], created by the World Resources Institute (WRI) in Washington, DC. CAIT provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators; and
- Population figures for some of the key countries/regions examined. Population data was obtained from the IMF's World Economic Outlook[7].

Countries studied

We looked at 18 reporter countries:

Australia	Mexico	United States
Canada	Netherlands	Brazil*
France	Republic of Korea	Russia*
Germany	Spain	India*
Italy	Turkey	China*
Japan	United Kingdom	South Africa*

*non-OECD members

NB: All of the above are members of the G20, except Spain and the Netherlands, which are members of OECD and EU only. Argentina, Indonesia, Saudi Arabia and the European Union were the four G20 members not included in the study.

We compared trade flows between each of the 18 reporter countries and the following partner countries.

1) Angola	2) Argentina	3) Australia*
4) Azerbaijan	5) Bangladesh	6) Brazil*
7) Canada*	8) Chile	9) China (Mainland) *
10) Congo, Democratic Republic	11) Czech Republic	12) Denmark
13) Egypt	14) France*	15) Germany*

16) India*	17) Indonesia	18) Iran
19) Ireland	20) Israel	21) Italy*
22) Japan*	23) Kazakhstan	24) South Korea*
25) Malaysia	26) Mexico*	27) Netherlands*
28) New Zealand*	29) Nigeria	30) Norway
31) Oman	32) Pakistan	33) Philippines
34) Poland	35) Portugal	36) Romania
37) Russia*	38) Saudi Arabia	39) Singapore
40) South Africa*	41) Spain*	42) Sweden
43) Switzerland	44) Syria	45) Thailand
46) Turkey*	47) Ukraine	48) United Arab Emirates
49) United Kingdom*	50) United States*	51) Venezuela
52) Vietnam		

* reporter country

Caveats

The results of our calculations are sensitive to the assumed level of carbon intensities of imports and exports between countries. An ideal study would estimate the individual carbon intensity for each good and service traded between each country. Davis & Caldeira come closer to this ideal with their study, which presents results "from a fully coupled multiregional input-output (MRIO) model constructed from 2004 global economic data disaggregated into 113 countries/regions and 57 industry sectors... emissions data for each sector were calculated... according to fossil fuel inputs". However, their study is only for a single year.

In our approach, based on Helm and Smale, we apply the average carbon intensity of a given country's economy (i.e. its average emissions per unit of GDP taken from CAIT) to all of its exports. As Helm and Smale observe, "It is not clear whether this assumption will bias the estimates upwards or downwards".

This approach is a substantial simplification, and has its risks. For example, Christopher Weber et al point out that, in the case of China, "Chinese production is more polluting [than the economy as a whole], due both to inefficient production systems and a coal-dominated electricity supply"[8]. In 2005, the biggest contributors to exported carbon by sector were: electronics (22%), machinery (19%), metal products (13%) and textiles (11%)[9]. We might expect Chinese exports to be more carbon intensive than the average for the Chinese economy as a whole. Our model may therefore underestimate the embedded emissions in China's exports, and thus over-estimate its carbon consumption.

While it is not one of the partner countries in this analysis, Mozambique illustrates a similar problem. The overall carbon intensity of its economy is quite high, but its exported steel is largely produced using electricity derived from hydro power[10]. In this case, our approach would overestimate the embedded emissions in Mozambique's exports.

Results

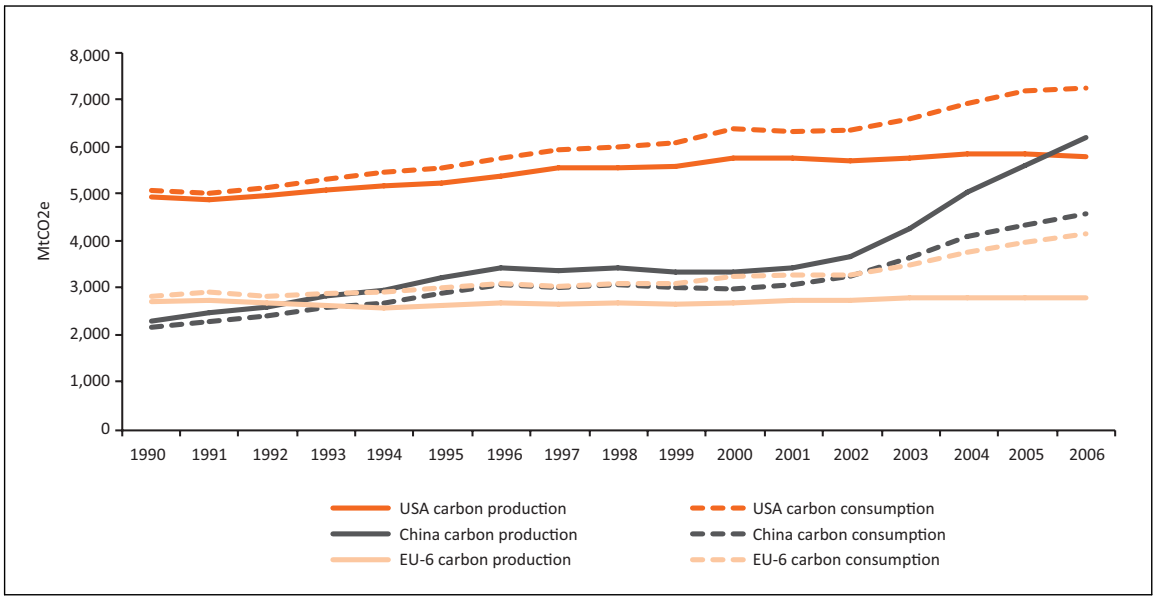
The European Union, United States and China

The USA, China and the EU are the three largest contributors to global carbon emissions, accounting for 51.8% of total world CO2 production in 2006 and an estimated 56% of world emissions on a consumption basis. For all of these countries/regions, consumption of carbon emissions has grown since 1990.

Figure 1 shows carbon emissions (in CO2 equivalent, CO2e), on a production and a consumption basis, for the USA, China, and the six largest members (EU-6) of the Kyoto-signatory EU-15: the United Kingdom, France, Germany, Spain, the Netherlands, and Italy. These six countries accounted for 82.5% of the EU-15's emissions in 2006.

China's carbon production has grown much more sharply than either EU or US carbon production, particularly since around 2002. In terms of China's estimated carbon *consumption*, emissions growth is substantially lower, while still growing faster than US or EU consumption. In contrast, EU and US carbon consumption growth is substantially above the change of reported carbon production emissions.

Figure 1. CO2e production and consumption: US, China, EU-6



The 15 pre-2004 EU Member States (the EU-15) committed themselves to cutting total carbon production emissions by 8% from 1990 levels by 2008-2012 under the Kyoto Protocol. They may be on track to meet this goal. However, measured on a carbon consumption basis (and based on the EU-6) EU emissions have risen by an astonishing 47%, not fallen, since 1990.

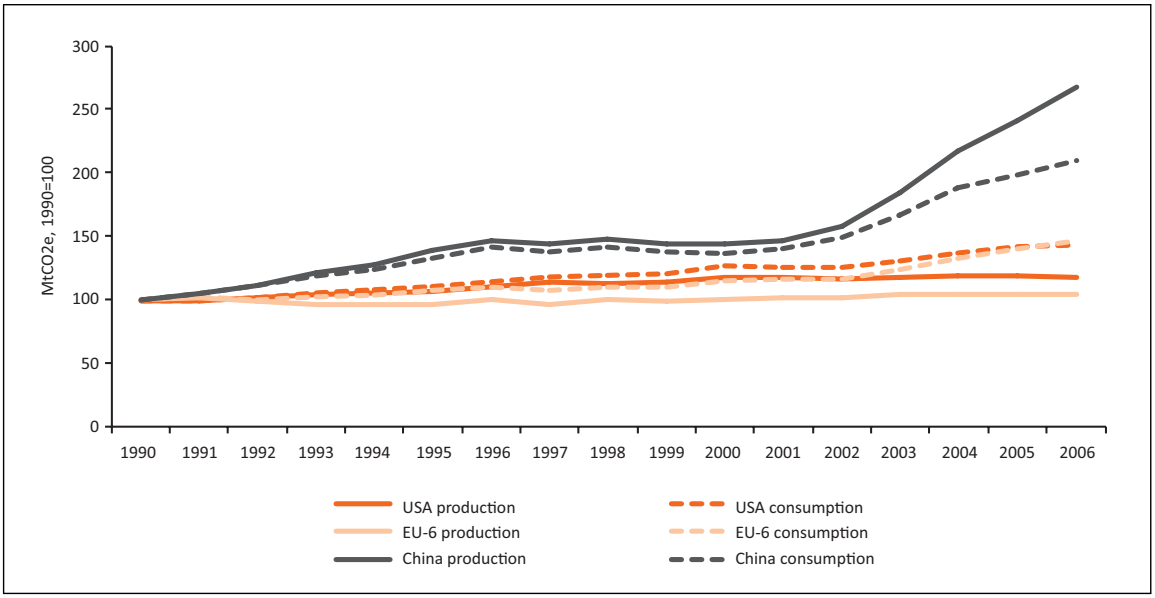
US carbon consumption is up a similar 43% in 2006 compared to 1990 (compared to a rise of 17% in carbon production emissions). So the growth of EU carbon consumption appears to have outstripped

the US, although it is important to recognise that the US started from a far higher base of emissions in 1990 - more than twice as great.

China's carbon consumption is up 110% since 1990 – far less than the rise in its reported carbon production emissions of 168%. Clearly China's emissions started at a far lower base than either the US or EU in 1990, before China's rapid economic growth had got fully underway.

Figure 2 looks at the same countries as Figure 1, but on an indexed basis, where 1990 = 100. This shows each country's emissions performance relative to its position in 1990. It highlights how, under carbon consumption accounting, the emissions performance of each of the three largest carbon-emitting blocs is more similar to each other than traditional carbon production accounting suggests.

Figure 2. CO2e production and consumption, indexed to 1990: US, China, EU-6



Clearly, any comparison between developed and developing world emissions trajectories must take into account the fact that the developing world is at a different stage in its economic growth and industrialization. If we look at emissions per person, the low base from which China has started is very clear (see Figure 3).

Comparing per capita emissions growth (in Figure 3, and indexed in Figure 4) with total emissions growth (see Figure 1), it is clear that the trend of per capita growth of emissions has been flatter for the EU, and particularly for the US and China, where there has been faster population growth than in the EU.

Most strikingly, in the US, while total carbon consumption grew by 43% since 1990, consumption emissions grew only 20% on a per capita basis (and US production emissions per capita were in fact 2% *lower* in 2006 compared to 1990, while the total increased by 17%).

Similarly, Chinese emissions have grown more slowly on a per capita basis than in absolute terms. Per capita carbon consumption emissions were up 83% in 2006 compared to 1990, compared to 110% higher total Chinese consumption emissions.

EU-6 carbon consumption emissions rose a little more slowly on a per capita basis (38% versus 47% rise in total emissions). But, on a per capita consumption emissions basis, the 1990-2006 performance gap between the EU and China closes (38% versus 83%). And the EU has a much higher per capita carbon consumption emissions growth than the US (38% versus 20%). Clearly, the US's much higher base level of per capita emissions (double the EU's) needs to be recognized.

Figure 3. Per capita carbon emissions: US, EU-6, China

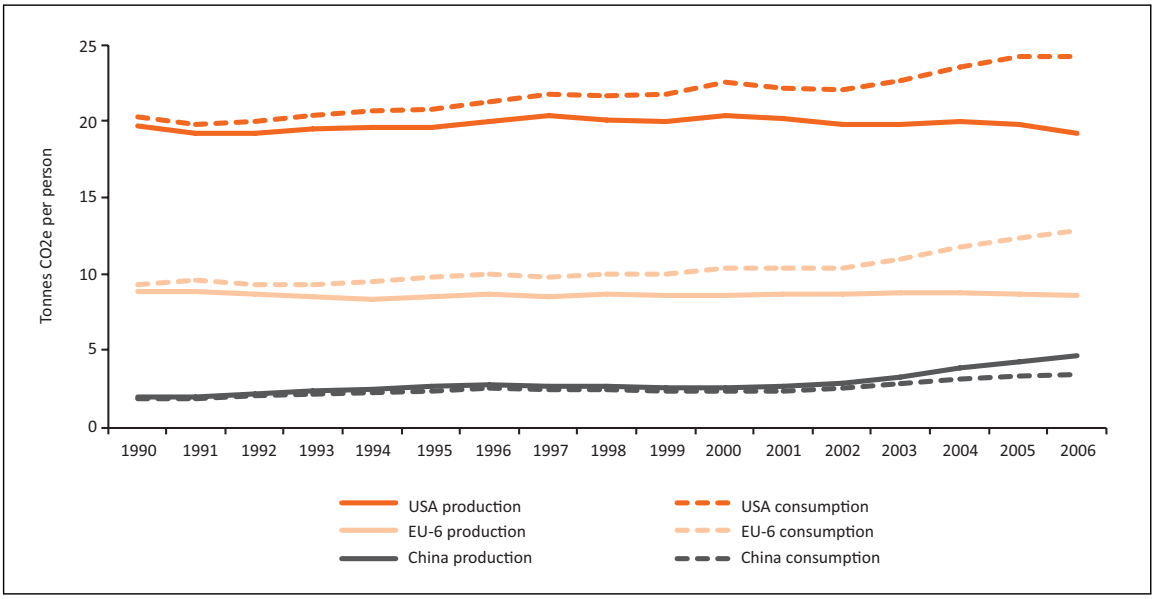
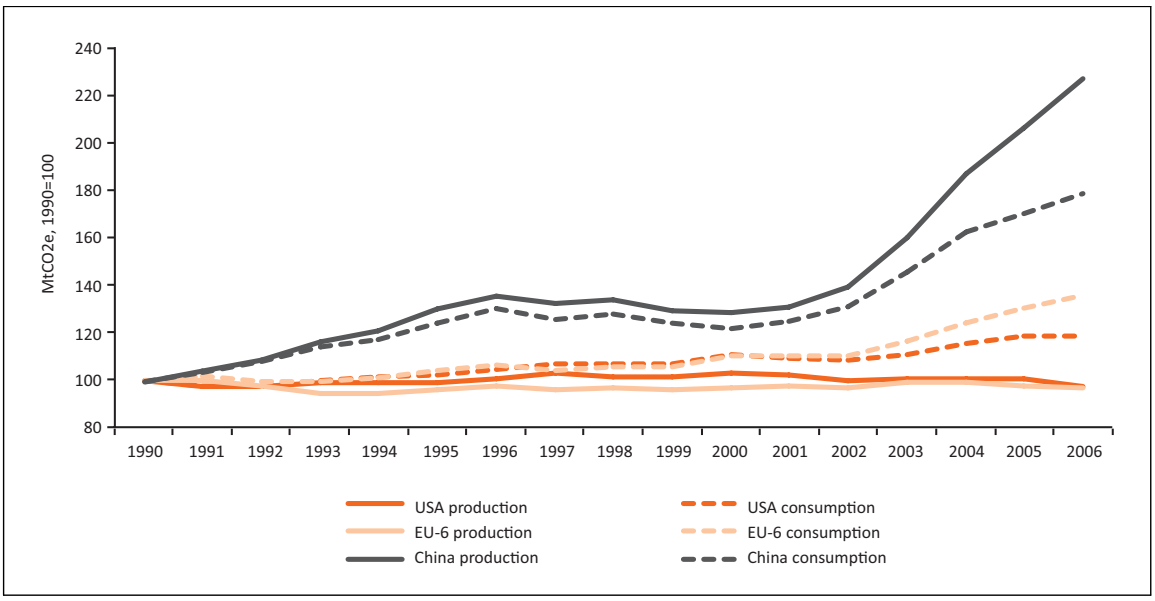


Figure 4. Per capita carbon emissions, indexed to 1990: US, EU-6, China



Looking at the single, latest year in our analysis, our results show that the US imported over 20% (net) of its consumption-based emissions, equivalent to nearly 5 tonnes of CO2e per person, and up from only 2.7% in 1990.

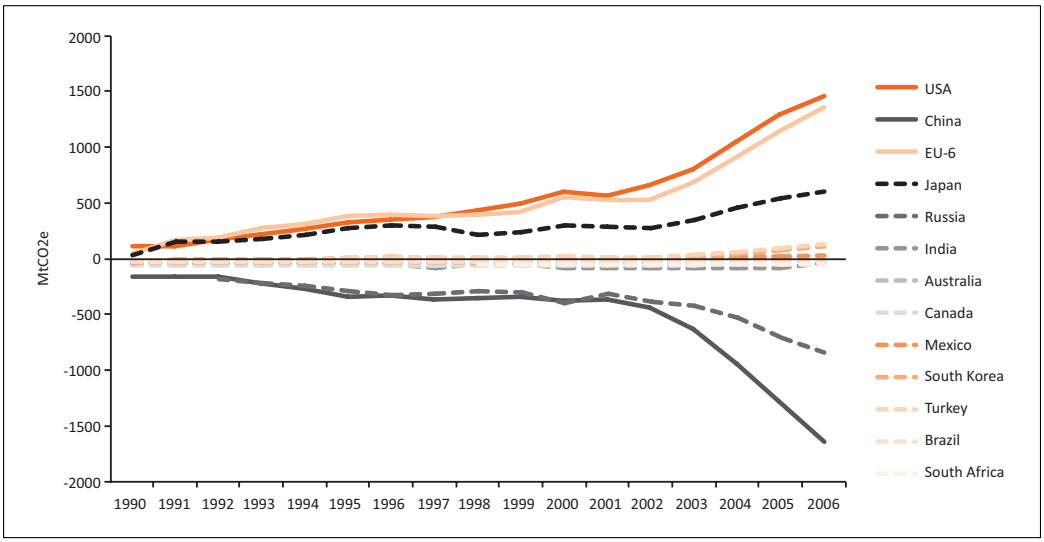
We also find that a remarkable 33% (net) of EU-6 consumption-based emissions were as a result of net imports of carbon, up from 3% in 1990. (The equivalent figures for the UK are 30% and 6%). EU net carbon imports are equivalent to 4.25 tonnes of CO2e per person. (The EU's percentage figure is higher than the US largely because the EU's baseline production emissions are lower than the US). Overall, a large and increasing proportion of the EU's global carbon impact is from imported goods rather than its own domestic carbon production.

Consistent with these findings – essentially the flip-side – is our finding that 26% of the CO2 emissions produced in China were exported, net, to consumers elsewhere.

Net carbon trade

Figure 5 shows the trend in "net carbon trade" since 1990. The numbers represent a carbon "balance of trade", showing to what degree a country exports or imports carbon emissions, and the trend over time. Positive numbers indicate net imports of carbon.

Figure 5. Net carbon trade across 18 countries, 1990-2006



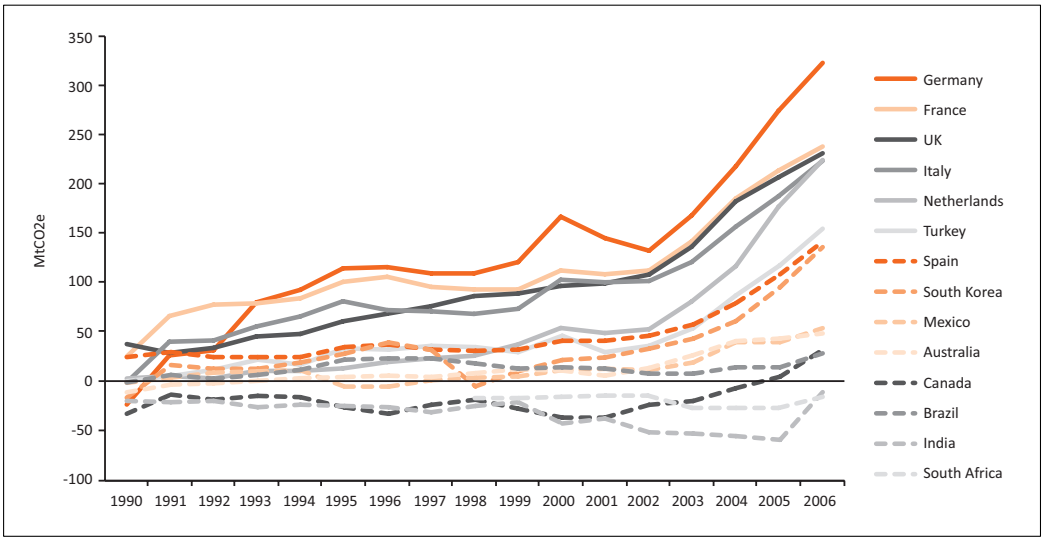
A key observation is that in the early 1990s, net imports and exports of carbon (i.e. embedded in traded goods and services) were relatively insignificant. But in later years, they have become a substantial part of global carbon emissions.

Almost all developed countries have imported increasing amounts of carbon since 1990, but developing country trends diverge. Some, like Russia and China, have become large net exporters of carbon, while others such as India and Brazil have becoming increasing net importers of carbon.

There appears to have been an acceleration of net import of carbon in a number of countries/regions, including the US, EU and India, since around 2002, corresponding with a sharp acceleration in China's net exports. We did not have later data to identify how this trend may or may not have changed as a result of the subsequent global downturn.

Figure 6 displays the same net carbon trade data on a larger scale, but excluding the US, China, India and Russia and displaying EU countries individually.

Figure 6. Net carbon trade across 14 countries, 1990-2006



The United Kingdom, France and Germany

Figures 7 and 8 show carbon production and consumption for the UK, France and Germany, indexed so that 1990 = 100 (in Figure 7), and on an absolute basis (in Figure 8). This highlights relative carbon emissions performance between key EU countries from 1990-2006. The ranking between countries remains the same whether on a production or consumption basis. Key observations include:

- France has had the biggest increase in emissions on a percentage basis since 1990, and shows a striking decoupling of emissions on a production and consumption basis since 2002. While emissions produced have roughly stabilised, emissions consumed grew rapidly by around 45%.

- UK emissions have fallen since 1990 on a production basis by 3%, though with no overall progress between 1997 and 2006. But UK emissions consumed have grown steadily since 1997, increasing by around 30% since 1997 over 1990. This trend has accelerated since 2002.

- Germany has the best performance on emissions of the EU countries we examine here. On a production basis, its emissions have fallen by around 13%, helped by the closure of former East German heavy industry. However, like the UK and France, Germany's performance in relation to carbon consumed is much less impressive, with growth of around 23% since 1990.

- Our findings suggest that other EU countries have even larger growth in carbon consumption over the period (see Table 1): Italy (over 50%), Spain (over 100%) and the Netherlands (almost 150%).

Figure 7. Carbon production and consumption indexed to 1990: UK, France, Germany

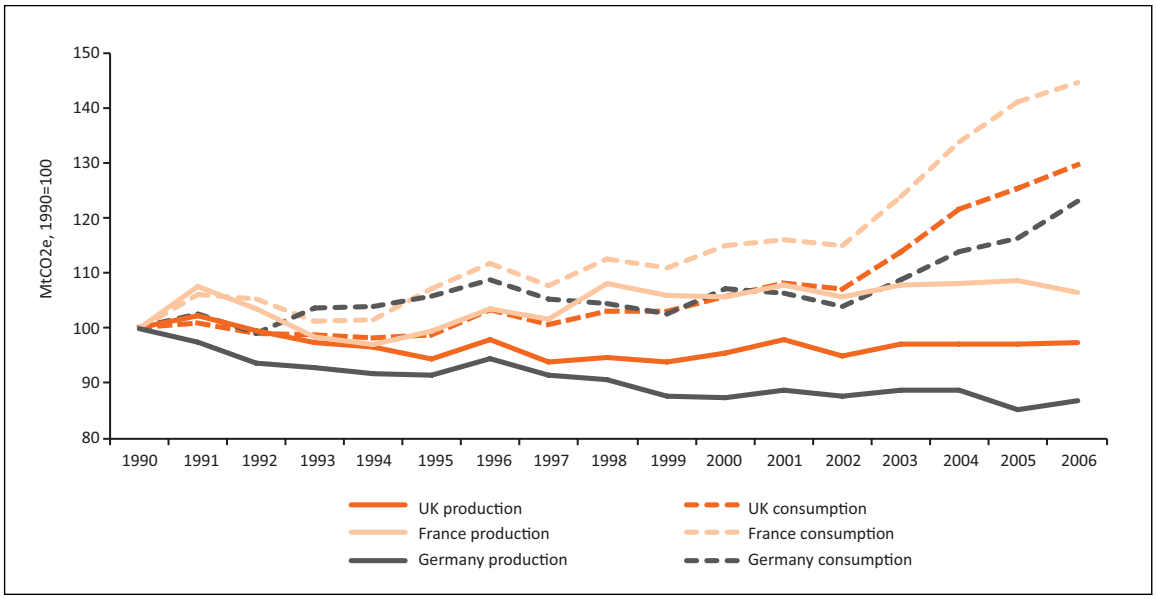
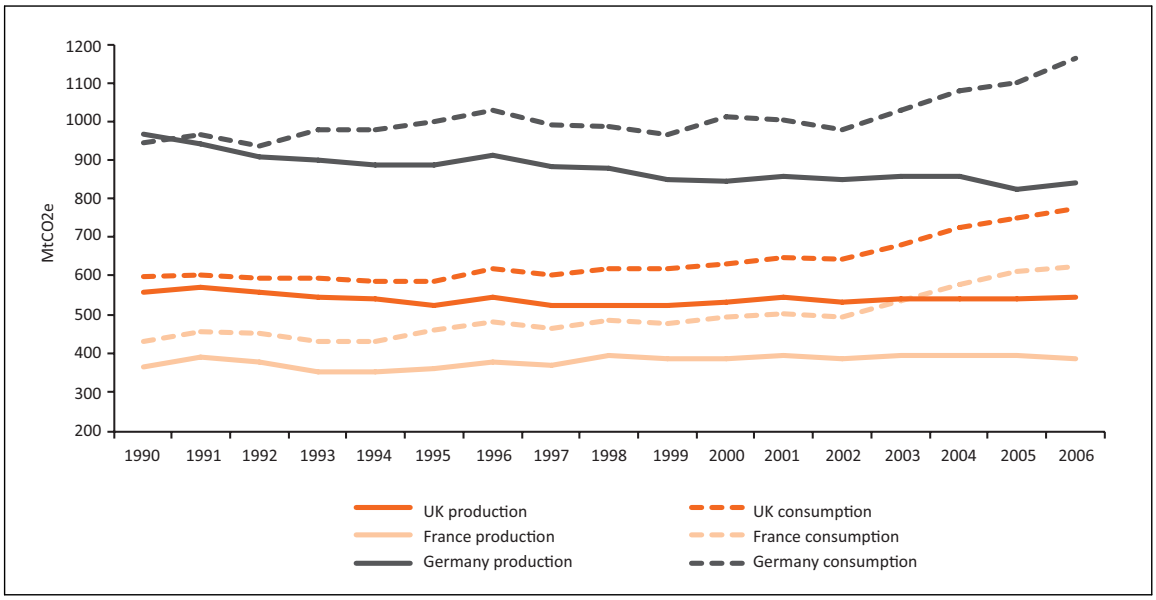


Figure 8. Carbon production and consumption: UK, France, Germany



The BRICs

Economic development proceeds at different rates and in different ways. This much is clear from looking at the carbon emissions of the "BRIC" nations (Brazil, Russia, India and China) in Figure 9 (indexed).

Assessing the carbon emissions trajectories of these four large developing nations compared to their

position in 1990, we find that:

- For most of the BRICs, differences between carbon production and consumption are not as significant a proportion of their total carbon production as for the developed countries. The exception is China, as discussed earlier.

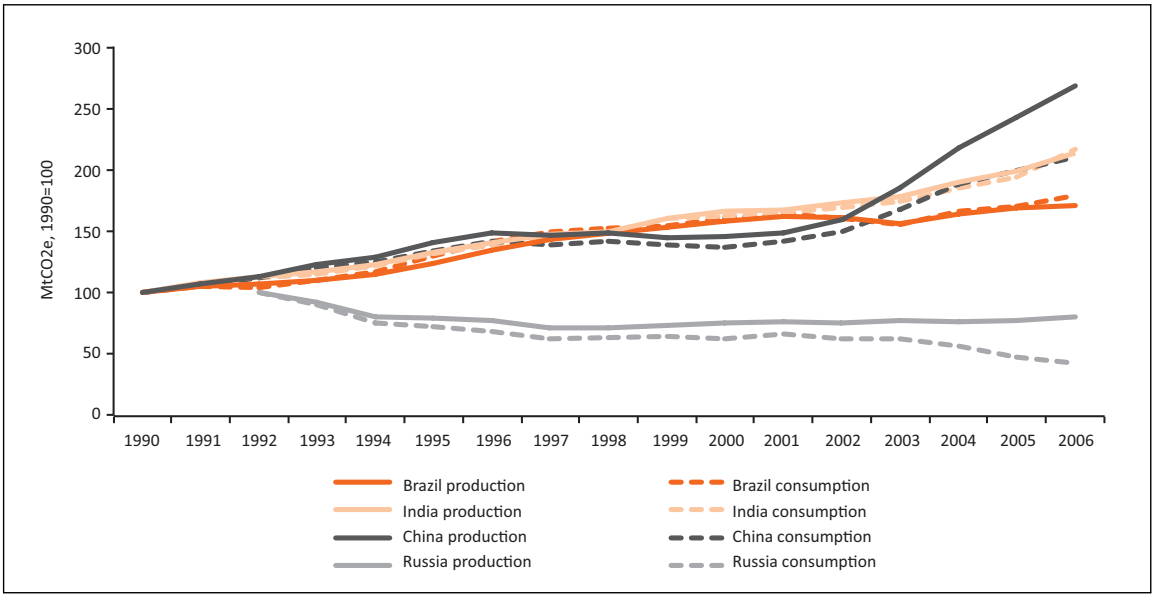
- In terms of overall emissions, China shared a very similar carbon production emissions trajectory to India and Brazil until 1998. But it then diverged, first dipping (possibly due to the Asian financial crisis), before rapidly accelerating ahead of the others since 2001.

- What is remarkable however, is that, while China's carbon production emissions accelerate ahead of India's after around 2001, its carbon consumption emissions remain on the same growth path as India's. To the extent that China's emissions have grown faster than India, this is almost entirely driven by superior export growth, with developed countries consuming most of these additional carbon emissions.

- It is also worth noting that Brazil, in contrast to the other BRICs, has a pattern more similar to developed countries: its emissions measured on a consumption basis have increased slightly more (74% over 1990) than on a production basis (71% increase)

- The reason for Russia's unusual carbon emission trajectory is well known: the collapse of its economy in the early 1990s was inadvertently the most successful decarbonisation of a major economy the world has seen so far.

Figure 9. Carbon production and consumption indexed to 1990: BRICs



Results summary

Table 1 summarises the growth in total carbon emissions produced and consumed for all of the eighteen 'reporter' countries in this study.

Table1. Percentage change in carbon emissions from 1990 to 2006

Percentage change in carbon emissions from 1990 to 2006		
	Consumption	**Production**
UK	+ 30	- 3
USA	+ 43	+ 17
China	+ 110	+ 168
EU-6	+ 47	+ 3
India	+ 116	+ 113
Germany	+ 23	- 13
Australia	+ 71	+ 51
Canada	+ 36	+ 24
France	+ 45	+ 6
Italy	+ 53	+ 13
Japan	+ 46	+ 12
Mexico	+ 61	+ 45
South Korea	+ 169	+ 105
Turkey	+ 185	+ 89
Brazil	+ 79	+ 71
Russia *	- 58	- 21
South Africa **	+ 12	+ 11
Netherlands	+ 149	+ 13
Spain	+ 103	+ 61
(*percentage change from 1992 -2006)		
(** percentage change from 1998 - 2006)		

Conclusions and policy implications

In 1990, net carbon flows embedded in trade were an insignificant proportion of global carbon emissions, but have grown substantially since, and particularly sharply since around 2002. By 2006, a large and growing proportion of the carbon *consumed* by the EU (33%) and UK (30%) was embedded in imports.

The performance since 1990 of developed countries on carbon reduction look less impressive on a carbon consumption basis than on the Kyoto production basis. We estimate that the EU-15's emissions grew by around 47% between 1990 and 2006 (rather than falling by 3% under the Kyoto production definition)[11], and the UK's emissions grew by 30% (rather than increasing by only 3%).

US carbon emissions have risen faster since 1990 than the EU on a production basis, and almost as fast (43%) on a consumption basis. But the US carbon consumption emissions have grown much slower than the EU's (20%) on a per capita basis, taking faster US population growth into account. (Note the US has a much higher per capita emissions baseline).

Growth in China's emissions is substantially moderated when examined on a consumption basis, rising by 110% between 1990 and 2006, compared to 168% on a production basis. This is because a large proportion of China's increased emissions are related to the manufacture of goods exported and consumed in developed countries. China's consumption emissions trajectory is no higher than India's, and its emissions growth is further ameliorated to 83% on a per capita basis.

It may be debated who is 'responsible' for emissions produced in one country to manufacture goods consumed in another. The consumer benefits from manufactured goods, and may thus be responsible for the embedded carbon emissions. On the other hand it may be argued that China bears responsibility for its emissions, as a consequence of exercising its competitive advantage (e.g. its artificially low exchange rate, cheap labour force, lack of regulation, lack of carbon price) to attract industries and jobs offshore.

But in either case, the existence of a large and growing proportion of carbon being 'off-shored' in this way raises a number of policy implications:

- The current focus of UK/EU policy is almost exclusively on the carbon emissions produced domestically within the UK/EU. This looks increasingly inadequate to address the UK/EU impact on the climate, given that, by 2006, 33% of EU emissions were imported.

- The credibility of the UK's and EU's claims to 'leadership by example' on climate policy is open to question, given the 47% increase in the EU's carbon emissions consumed since 1990. There is therefore a question about the value of seeking such leadership as an objective of climate policy.

- The rapid off-shoring of carbon emissions, which has already been seen, underlines the risk that substantial increases in energy costs in developed countries might cause further carbon leakage to the developing world. Movement of energy-intensive sectors to China would be likely to lead to increased carbon emissions, given China's more carbon-intensive economy.

- The scale and rapid growth of carbon embedded in trade makes negotiation of an international agreement on carbon reduction more difficult and complex, including making it hard to specify realistic and fair targets for rapidly growing developing countries. The direction in which international negotiations have been moving – towards focusing on reducing developing country carbon intensity – may be a more suitable approach.

Policy recommendations

These observations suggest a number of policy recommendations:

1) **Further research should be undertaken to understand the evolution of carbon consumption across countries and over time.**

Such work could build a more detailed and robust understanding than we have had the resources to undertake here.

2) **The Government, and the European Commission, should further investigate the trajectory of UK and EU carbon emissions, with the aim of publishing regular estimates of carbon emissions on a consumption basis in addition to existing production-based accounting methods.**

Our analysis of CO2 emissions, estimated on a consumption basis, tells a significantly different story about the carbon emissions trajectories of the UK, EU and US than the traditional, Kyoto, measure. The Department of Energy and Climate Change (DECC) should publish regularly its estimates of UK carbon emissions consumed. Making such data available would help to inform priorities for future climate change policies.

3) **The European Commission should give further serious consideration to the full range of mechanisms to address the risk of carbon leakage.**

For example, carbon emissions embedded in imports and consumed by EU countries could, in principle, be made subject to EU regulation. A border tax adjustment (BTA) might take the shape of a tax or a requirement to buy EU Emissions Trading System (EU ETS) permits for the estimated carbon content of imported goods. A BTA is an attempt to price the carbon in imports at a similar level to the carbon produced within the EU. Professor Dieter Helm discussed this approach in the recent Policy Exchange report '*Greener, Cheaper*'[12].

Designing a BTA is not without significant practical and legal difficulties, and could be seen as protectionism by developing countries, even if it aimed simply to level the carbon playing field. (One response could be to recycle proceeds from any border tax to the governments of the countries originating the imports, in the same way that the UK government receives the proceeds of auctioning EU ETS permits in the UK.) The recent Carbon Trust report, *Tackling Carbon Leakage,* discusses many of the issues in implementing measures to tackle carbon leakage[13].

Professor Michael Grubb has argued that border tax levelling is the "least bad way" to tackle carbon leakage from the EU ETS in certain industry sectors – specifically cement, and perhaps steel too. The problem of carbon leakage in relation to high-energy sectors is serious: a recent report suggested that between 5-10% of carbon emissions from cement and steel – up to 25 million tonnes – could leak overseas, undermining the effectiveness of the EU ETS[14]. Professor Grubb has said "It's time that border

taxation is taken off the index of forbidden thought in the UK, and subject to rigorous analysis alongside the other options."[15]

4) **The EU and UK should prioritise support towards those low carbon technologies most likely to make a substantial contribution to global carbon reduction, in particular in those developing countries from which the EU is importing substantial and increasing quantities of embedded carbon.**

UK and EU climate policy currently prioritises domestic carbon emissions reduction and technologies, such as off-shore wind, which are particularly relevant to the UK/EU. This priority is driven in part by the objective of demonstrating leadership by example to the rest of the world. But this report has highlighted the lack of demonstrable success in leading by example. It has also identified the large and growing proportion of imported EU carbon emissions (33%), which are not being addressed by domestic decarbonisation effort.

The EU and UK therefore need to consider the relative priorities within climate mitigation policy. A key role for developed countries must be to support R&D, demonstration and cost-reduction of those technologies which are likely to have a substantial future role in *global* carbon-intensity reduction. These may include, for example, Carbon Capture and Storage which has potential in future to reduce emissions from China's rapidly expanding coal-fired generation capacity.

Endnotes

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