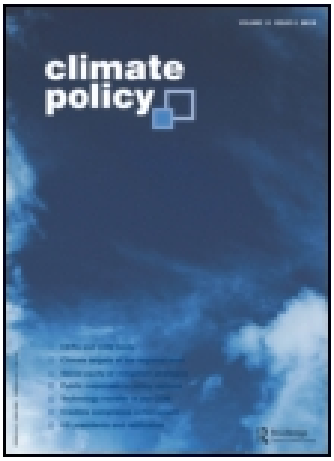

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Consumption-based GHG emission accounting: a UK case study

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Consumption-based GHG emission accounting: a UK case study

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Global GHG emissions continue to rise, with nearly a quarter of it due to trade that is not currently captured within global climate policy. In the context of current trade patterns and limited global cooperation on climate change, the feasibility of consumption-based emissions accounting to contribute to a more comprehensive (national) policy framework in the UK is investigated. Consumption-based emissions results for the UK from a range of models are presented, their technical robustness is assessed, and their potential application in national climate policy is examined using examples of policies designed to reduce carbon leakage and to address high levels of consumption. It is shown that there is a need to include consumption-based emissions as a complementary indicator to the current approach of measuring territorial emissions. Methods are shown to be robust enough to measure progress on climate change and develop and inform mitigation policy. Finally, some suggestions are made for future policy-oriented research in the area of consumption-based accounting that will facilitate its application to policy.

Policy relevance

Emissions embodied in trade are rapidly increasing and there is thus a growing gap between production emissions and the emissions associated with consumption. This is a growing concern due to the absence of a global cap and significant variation in country-level mitigation ambitions. Robust measurements of consumption-based emissions are possible and provide new insights into policy options. This includes trade-related policy (e.g. border carbon adjustments) and domestic policies (e.g. resource efficiency strategies). As climate policy targets deepen, there is a need for a broad range of policy options in addition to production and technological solutions. Consumption-based emissions are complementary to production-based emissions inventories, which are still the most accurate estimate for aggregated emissions at the global level. However, without consumption-based approaches, territorial emissions alone will not provide a complete picture of progress in regional and national emissions reduction.

Keywords: carbon leakage; consumption-based emissions; greenhouse gas emissions; policy appraisal; sustainable consumption

1. Introduction

Recent studies have found that 20–25% of CO_2 emissions are from the production of internationally traded products (Davis & Caldeira, 2010; Peters & Hertwich, 2008a, 2008b). These emissions are

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growing by, on average, 3.4% per year (1990–2008), increasing from around 20% (4.3 $GtCO_2$) in 1990 to 26% (7.8 $GtCO_2$) in 2008 (Peters, Minx, Weber, & Edenhofer, 2011). The change in net emissions transfers, from developing to developed countries, offsets territorial emissions reductions achieved by the Annex B countries of the Kyoto Protocol by a factor of five (Peters et al., 2011). Within the aggregated group of Annex B, the individual country profiles vary from net exporters (e.g. Australia and Canada) to net importers (e.g. most of the EU-27, Japan, and the US). These results have been found to be robust across independent studies (Peters, Davis, & Andrew, 2012).

Although these studies have shown the importance of consumption-based accounting for understanding emissions growth in individual countries, few governments have actively considered using consumption-based approaches when forming and appraising policy. In the UK, growing concerns about the effectiveness of domestic and European climate policy to deliver an absolute reduction in emissions led the Energy and Climate Change Select Committee (a parliamentary scrutiny panel of elected ministers) to launch an inquiry and investigate the case for UK consumption-based GHG emissions accounting (ECCC, 2012). Using the UK as a case study, the Committee examined consumption-based reporting, its practical feasibility, whether emissions reduction targets might be adopted on a consumption basis, and what the implications might be for the international climate change negotiations on climate change if the UK and others were to take this approach (CSC, 2011). This article provides the necessary background on the various accounting methods for allocating GHG emissions to countries. The consistency of different data sets on consumption-based emissions is then presented together with an assessment of uncertainty. This is followed by exploring the policy application of the data beyond just an indicator of progress for the UK. The article then summarizes some of the policy options available both domestically and internationally to address GHG emissions embodied in trade. Finally, it considers the research required to ensure that options to reduce consumption-based emissions can be considered alongside the traditional climate policy that predominately focuses on technological domestic solutions.

2. Background

GHG emissions can be allocated to countries in different ways. At present, there are three allocation methods in common use: territorial-based, production-based, and consumption-based.

- *Territorial-based*. The United Nations Framework Convention on Climate Change (UNFCCC) requires countries to submit annual National Emissions Inventories and follows the guidelines from the Intergovernmental Panel on Climate Change (IPCC) regarding the allocation of GHG emissions: 'emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction' (IPCC, 1996, p. 5). However, GHG emissions that arise in international territories, including those from international aviation and shipping, are only reported as a memo and are not allocated to individual countries. Such a system can be called a 'territorial-based emissions inventory'.
- *Production-based*. Some countries also report GHG emissions allocated using the same system boundary as the System of National Accounts (SNA), as is already done with gross domestic product (GDP).[1] The GHG emissions inventories are sometimes called National Accounting

Matrices including Environmental Accounts (NAMEAs). In the EU, NAMEAs are reported to Eurostat. Although most other developed countries create NAMEAs, they do not report them internationally. In the SNA, unlike the UNFCCC territorial-based system, emissions from international aviation and shipping are typically allocated to the country of the relevant vessel's operator. Similarly, emissions from international tourism are allocated based on where individual tourists are resident, rather than their destination. The NAMEAs system can be called a 'production-based emissions inventory'.

- *Consumption-based*. Emissions are allocated according to the country of the consumer, usually based on final consumption (as recorded in the SNA) or as trade-adjusted emissions (Peters, 2008). Conceptually, consumption-based inventories can be thought of as 'consumption equals production-based emissions minus the emissions from the production of exports, plus the emissions from the production of imports' (Consumption = Production − Exports + Imports). Such a system can be called a 'consumption-based emissions inventory'.

Recently, so-called 'extraction-based emission inventories' have been developed (Davis, Peters, & Caldeira, 2011), which allocate emissions according to where fossil fuels are extracted. Such inventories are relevant because around 37% of global emissions are from traded fossil fuels, and 23% from the production of traded goods and services. It is possible to consider the entire supply chain of CO_2 from the point of extraction, via production, and ultimately to consumption of goods and services. There are several advantages of an extraction-based emissions system, the key advantage being that global emissions can be regulated with only a few participants (Harstad, 2012; Whalley & Wigle, 1991).

A number of statistical offices and other government agencies have started to calculate consumption-based emissions, predominately in Europe, Australia, and Canada.[2] However, these are rarely treated as 'official statistics' and few countries, with the exception of Australia (see Hao, Legoff, & Mahadava, 2012) and the UK, have committed to either annually updating the indicator or providing an official statistical release of the data (Edens, Delahye, van Rossum, & Schenau, 2011).

The UK has adopted a consumption-based emissions system as an official government indicator and has commissioned numerous reports that use it to evaluate the effectiveness of mitigation measures beyond those afforded by technology. These include assessments of the role of resource efficiency in climate change mitigation policy, as well as the role of services and an understanding of drivers of GHG emissions between 1992 and 2004 (Baiocchi & Minx, 2010; Barrett & Scott, 2012; Minx, Baiocchi, Wiedmann, & Barrett, 2009; Scott, Barrett, Baiocchi, & Minx, 2009). The UK has thus been selected as a case study to explore a number of issues surrounding consumption-based emissions accounting.

In this article, consumption-based emissions are used to complement the current territorial accounting system, rather than as a replacement for the existing internationally recognized system. This article explores whether attributing emissions to the consumer generates robust results that are useful in the formulation of climate policy, beyond those that can be offered using territorial accounting. No attempt is therefore made to allocate responsibility for those emissions.

The UK case study starts by exploring the variation in consumption-based emissions in some of the prominent global models used for this purpose, followed by an assessment of the robustness of the data.

3. UK case study

3.1. Headline indicator

Figure 1 illustrates the latest time-series results published by the UK Government (Defra, 2012) for the three main approaches (i.e. territorial-, production-, and consumption-based). Although there have been a number of other estimates of the UK's consumption-based GHG emissions, the results from the official headline indicators for the UK Government are provided.[3] Growth in consumption-based GHG emissions grew by 20% between 1990 and 2008, followed in 2008–2009 by a 9% reduction, predominately due to the global financial crisis (Wiedmann et al., 2008, 2010).[4]

The UK GHG emissions reported to the UNFCCC (i.e. their 'territorial emissions') show a 27% reduction in territorial GHG emissions between 1990 and 2009, which represents an annual decline of around 1.4% per annum. GHG emissions are 212 million tonnes lower in 2009 than in 1990, and the UK Government achieved its target established under the Kyoto Protocol. The production-based GHG emissions reduced by 24%. There has thus been a greater reduction in emissions as accounted for under the Kyoto Protocol than in those that are not. In fact, GHG emissions from production not originally accounted for under the Kyoto Protocol (i.e. the difference between the territorial- and production-based emissions) increased by 75% between 1990 and 2009, from 25 million tonnes to 44 million tonnes of CO_2e emissions. From a consumption perspective, the UK's GHG emissions rose at a rate of over 1% per annum between 1990 and 2008 (with a 9% reduction from 2008 to 2009).

These figures stand in stark contrast to the 1.4% decrease each year in territorial GHG emissions. The gap between consumption-based and territorial emissions has continued to grow year on year with the exception of 2009 (when a comparatively large reduction was recorded).

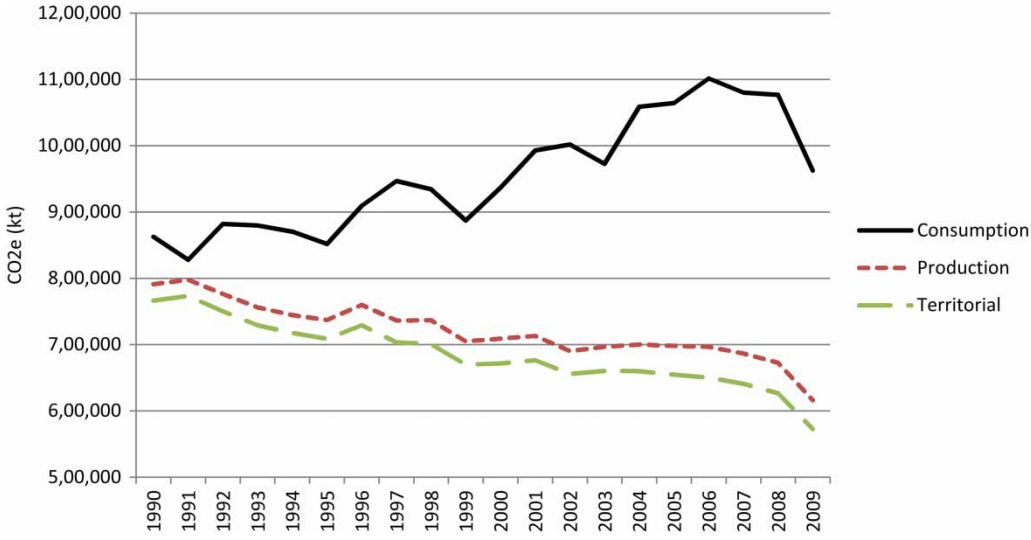

Figure 1 UK GHG emissions, 1990–2009
Source: Defra (2012).

Figure 2 shows the GHG emissions embedded in imports and domestic production for final consumption in the UK and in direct household emissions. In 1990, 60% of GHG emissions associated with goods and services to satisfy UK consumption were emitted inside the UK. However, in 2001, a crossover occurred, and GHG emissions embodied in imports (which ultimately occur to satisfy UK consumption) were greater than emissions due to domestic production.

There have been several other relevant independent global studies. For example, Peters et al. (2011) estimated the consumption-based CO_2 emissions for 113 world regions. A key finding of their work was that, although many developed countries have stabilized their territorial emissions, there has often been an associated increase in the emissions of developing countries who are producing the imported goods and services (Peters, 2010a, 2010b). This is also the case for the UK, consistent with the findings shown in Figure 1. Another study has been undertaken within the scope of the Eora MRIO project (Kanemoto, Lenzen, Moran, & Geschke, 2011). The Eora MRIO tables feature high country and sector resolution (187 countries, spanning a total of 15,909 sectors). Results from the Eora study confirmed the findings from the aforementioned studies and clearly show the divergent trajectories of territorial and consumer emissions (Figure 2). Although there is clearly some variation in total CO_2 emissions, the emissions trajectories appear consistent, particularly between 1993 and 2009.

Although there have been other assessments of the UK's consumption emissions, they cover different time periods and so have not been included in Figure 3. For example, Druckman and Jackson (2009) used a quasi-multiregional input–output model to calculate consumption-based CO_2 emissions from 1990 to 2004 and found that emissions attributable to UK households rose by 15% between 1990 and 2004 and were aligned with the other trajectories (see also Helm, Smale, & Phillips, 2007, who found that emissions grew by 19% from 1990 to 2003).

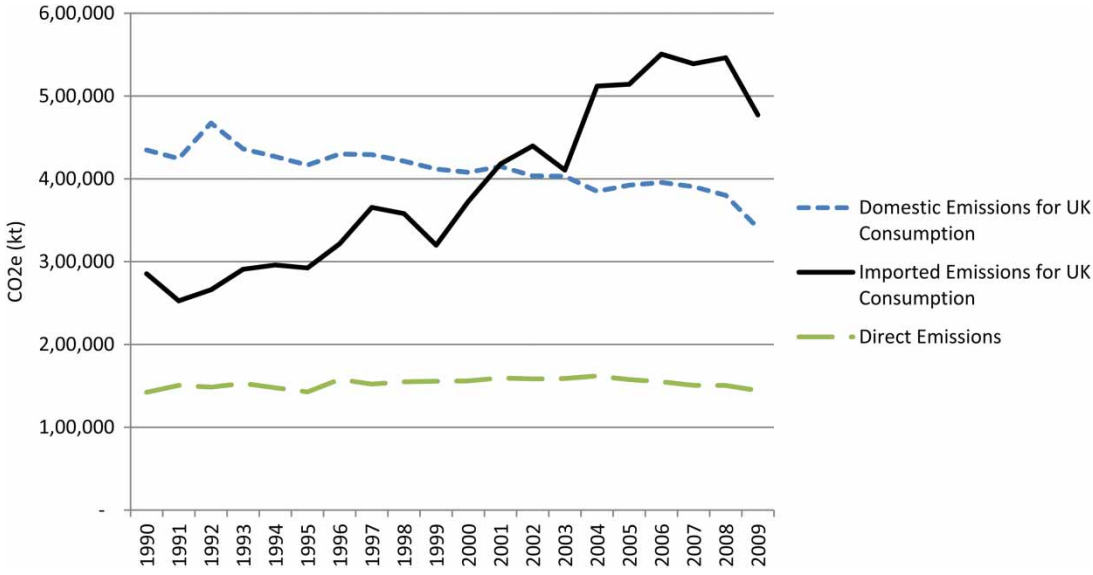

Figure 2 UK consumption-based GHG emissions by origin, 1990–2009
Source: University of Leeds.

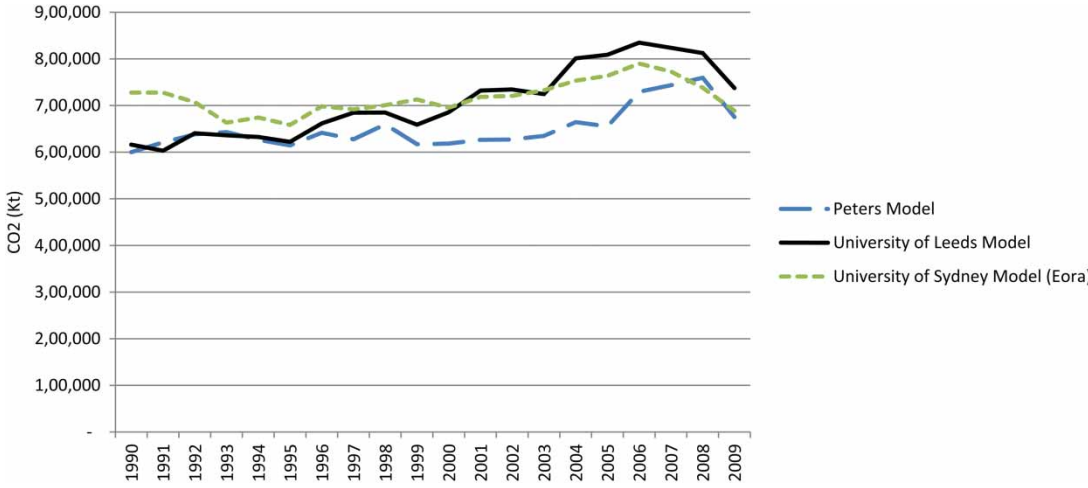

Figure 3 Comparison of UK consumption-based CO_2 emissions
Sources: Peters et al. (2011); University of Leeds with the Centre for Sustainability Accounting; Kanemoto et al. (2011).

The results from the different studies all have small differences in the estimates, but show similar trends over time. Each of the studies shows that territorial/production emissions have decreased (despite the use of different figures for these emissions), while consumption-based emissions have increased. The differences in the estimates of each study could relate to the use of different definitions, data, methods, and assumptions (Peters et al., 2012; Peters & Solli, 2010), rather than uncertainty in the consumption-based emissions (see Section 3.2). It is not the aim of this article to fully understand these differences, but rather to confirm that the trends from the different studies are reliable, and to support the view that there has been an increase in consumption-based emissions and a reduction in territorial emissions, and also that the various methods, despite using different data, nevertheless yield consistent conclusions.

3.2. Uncertainty associated with consumption-based emissions

This section considers whether the results provided by consumption-based emissions reporting are robust and defensible to adequately describe the situation for the UK in terms of emissions. The UK Government required confirmation of the robustness of the approaches to measure the headline result of consumption-based emissions for the UK and to compare these results with territorial estimates of GHG emissions. It is important to define and clarify what is meant by 'robustness', which is highly dependent on the purpose a consumption-based emissions inventory may serve. In the present context, it will be taken to imply providing the motivation for further improvements in data and methods, and the design and potential implementation of new policies. It is hoped that the methods used here are adequate to provide robust and comparable information on consumption-based emissions given the multitude of independent studies with consistent results and related trends. The last ten years in particular has seen a substantial increase in both the UK's carbon footprint

and related studies that aim to allocate consumption-based GHG emissions. These studies have developed methodologies with a particular emphasis on robustness and reducing uncertainty.

A European project (Wiedmann et al., 2009) identified Environmentally Extended Multi-Region Input–Output (EE-MRIO) analysis as a favourable approach for the assessment of environmental impacts of trade. The studies described in Figure 3 all used this methodology, although different data sources were used for some elements of the models. EE-MRIO analysis is emerging as a comprehensive, versatile, and compatible approach for consumption-based accounting of GHG emissions and has already become the norm in the literature (Davis & Caldeira, 2010; Peters & Hertwich, 2008a, 2008b; Peters et al., 2011; Wiedmann, 2009; Wiedmann, Wilting, Lenzen, Lutter, & Palm, 2011). Strengths and weaknesses of the EE-MRIO approach were assessed in the European EIPOT project (Wiedmann et al., 2009).

Although all emissions inventories have some uncertainty, including territorial emissions, consumption-based estimates will have larger uncertainty due to the incorporation of more input data, each with various levels of uncertainty. A detailed uncertainty analysis of the UK national carbon footprint calculations using EE-MRIO modelling was undertaken for the Department for Environment, Food and Rural Affairs (Defra; Lenzen, Wood, & Wiedmann, 2010). Figure 4 provides

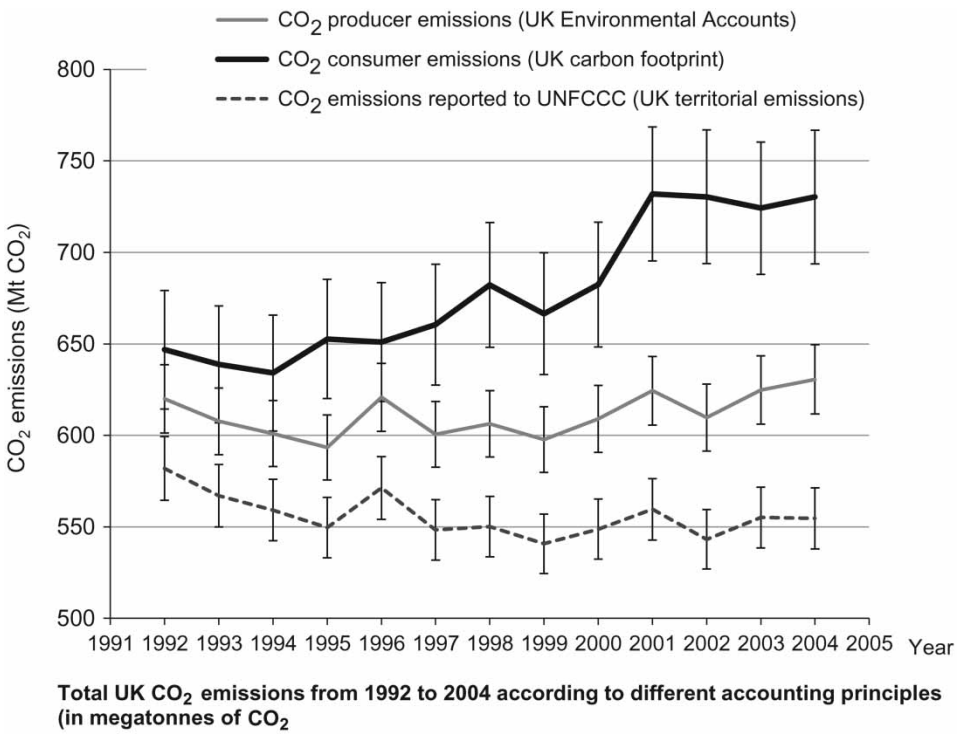

Figure 4 Uncertainty associated with UK consumption-based CO_2 emissions
Note: Figures calculated using EE-MRIO analysis.
Source: Lenzen et al. (2010).

the results of this uncertainty analysis and demonstrates that there is an additional uncertainty of the headline results, in the region of 3%, between consumption- and production-based accounting. It is clear that the trends in consumption-based emissions, unlike those in territorial-based emissions, are robust despite the small increase in uncertainty. Thus, such additional uncertainty should not be used to justify a lack of political action.

The key reason for the increased uncertainty is that MRIO data sets combine data from large and often incoherent data sets. The uncertainties relate to issues including calibration, balancing, and harmonization, the use of different time periods, different currencies, different country classifications, levels of disaggregation, inflation, and raw data errors (Lenzen, Dey, & Murray, 2004; Lenzen et al., 2010; Peters, 2007; Weber & Matthews, 2008). Many of these manipulations reflect inconsistent reporting practices in different countries and regions, and a process of harmonization can greatly reduce the necessary manipulations and, therefore, uncertainties (Peters & Solli, 2010).

However, it is possible to account for such uncertainties by applying error propagation methods to determine their influence on the analytical results of carbon footprint studies, for example by using Monte-Carlo simulation techniques. Even though single data items may be associated with a high degree of uncertainty, aggregate measures such as emissions embodied in imports into the UK, or emissions from domestic production, are usually known with much more certainty. This situation can be quantitatively expressed by using standard error estimates, and visualized with error bars. These approaches were used by Lenzen et al. (2010) to demonstrate that the increase in the UK's carbon footprint was statistically significant.

The results in Figure 4 show the uncertainty, via Monte-Carlo analysis, in a single study. An alternative approach is to consider the variation between estimates from independent studies. Although studies can never be classed as truly independent, the underlying data manipulations and harmonization methods can differ substantially. Peters et al. (2012) have found that estimates for embodied CO_2 emissions from several independent studies and their models are robust, and that differences between them are predominantly a result of their use of different production-based emissions input data and definitions for allocating emissions to international trade. Using the same economic data, Peters et al. (2012) found that the variation in consumption-based emission estimates was, paradoxically, less than the variation in production-based estimates, which signifies that the manipulations in an input–output analysis tend to reduce variations through averaging (Peters, 2007). However, there may be less uncertainty than is commonly assumed, because the many differences between studies can be controlled for (such as consistent emissions data and definitions).

4. Policy applications to address consumption-based emissions

It should be recognized that reducing the emissions embodied in trade is complex and requires an understanding of how each policy affects the different determinants of international emissions transfers. Clearly, the picture is more complex than simply implementing polices to reduce trade, thereby leading to a reduction in emissions. This is clearly illustrated by Jakob and Marschinski (2012), who define four key determinants that explain net emissions transfers: the trade balance, energy intensity of production, carbon intensity of energy, and specialization of countries. The policies considered below to reduce emissions embodied in trade would affect some or all of these factors. It is, however,

beyond the scope of this article to provide an understanding of how these determinants, considered individually and as a collective, would be affected.

In the following sections, the complementary nature of consumption-based emissions and their role in setting targets, and how trade and domestic policies might change emissions embodied in trade, are examined. Note, however, that a complete and comprehensive assessment of each policy is not provided.

4.1. Complementary nature of consumption-based emissions

Consumption-based emissions inventories should not be considered as the solution for climate policy, but instead should be regarded as providing additional information that has relevance to it. Different emissions inventories, such as those that are territorial-, production-, or consumption-based, have different system boundaries, placing the focus on alternative mitigation strategies, so different emissions inventories therefore contain complementary information. Thus, consumption-based emission inventories should be considered together with the other types of inventory, rather than as an alternative to them.

Because of issues of national sovereignty, binding agreements on emissions may focus primarily on production-based emissions estimates. However, for global environmental problems, such as climate change, the impacts are largely independent of where the emissions occur. Taking a production perspective may give the impression of progress towards the global environmental objective, while a consumption perspective may suggest the opposite (see Figure 1). In the UK, the reality is that consumption activities are increasing global emissions, and the growth of consumption-based emissions has outpaced the emissions reductions from production efficiency gains (Minx, Baiocchi, et al., 2009).

Given the global differential levels of economic development, globally harmonized climate policies are unlikely in the short or long term. Rather, for the foreseeable future, it seems that fragmented, sub-global climate policies will have to do. In this context, consumption-based accounting becomes even more important as a policy tool. If there were globally harmonized climate policies in place, linked to a mitigation pathway to avoid a more than 2 °C rise in global temperature, the need for consumption-based emissions would diminish (as there would be no potential for carbon leakage).

However, the benefits of consumption-based emissions accounting need to go beyond merely highlighting the gap between territorial- and consumption-based emissions (Minx, Wiedmann, et al., 2009). A focus on consumption-based emissions must highlight new policy options that may not have been realized from a production perspective. These have been categorized into three distinct groupings: setting emission targets, international trade policies, and domestic consumption policies.

4.2. Setting targets

The key aim of climate policy in the UK is to establish a climate mitigation strategy that limits the growth of GHG emissions, thus contributing to avoiding dangerous levels of temperature increase. If the UK were to consider mitigation strategies that affected both consumption and production emissions, then the scope for emissions reduction would increase. Territorial emissions targets in isolation can unintentionally lead to weak carbon leakage (see below) through imports from non-Annex I countries (Peters & Hertwich, 2008a, 2008b). In 2004, 67% of the 143 $MtCO_2$ of net imported emissions

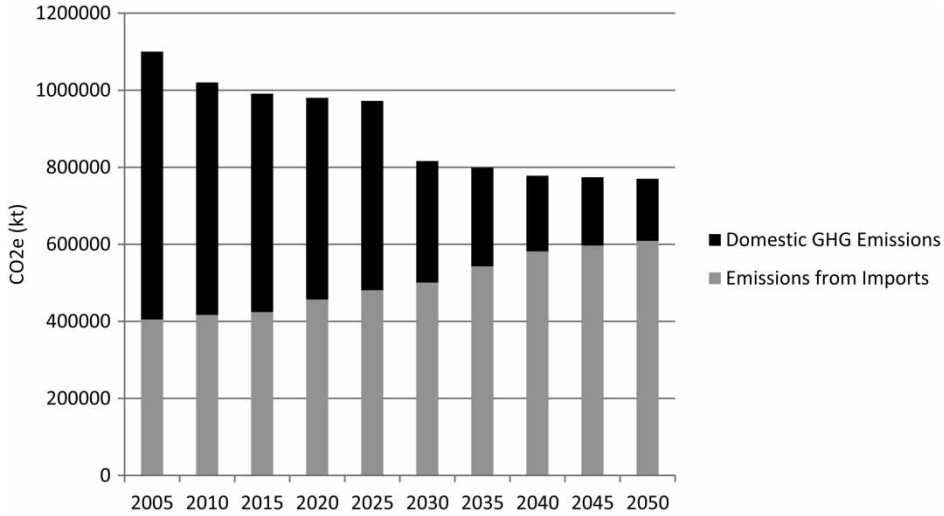

Figure 5 Projection of UK consumption-based GHG emissions to 2050

was due to imports from countries without binding and ratified emissions limitations under the Kyoto Protocol and which, therefore, were not covered by global emissions reduction commitments (Carbon Trust, 2009). Thus, as long as Annex I countries remain net importers of emissions, consumption-based emissions inventories are a powerful way to expand the base of existing climate policies.

Figure 5 shows a simple UK GHG emissions scenario from a consumption-based perspective that embodies two key assumptions: (i) that emissions embodied in trade will continue in line with historical growth rates for the past 20 years, and (ii) that the UK achieves its territorial emissions reduction target of 80% by 2050 based on 1990 levels. Although the scenario is only illustrative and not a detailed forecast of future emissions, it serves to demonstrate the potential scale of emissions embodied in trade without either a radical change in global production efficiency or specific policies to address consumption. In Figure 5, domestic emissions comprise less than 20% of total UK emissions by 2050, and UK consumption-based emissions in 2050 may only be 27% lower than in 2005.

Illustrations such as Figure 5 show that without due attention to consumption-based emissions, it is likely that the scope of existing territorial emissions reduction strategies will be significantly undermined over time.

4.3. Trade responses

Climate change legislation has mainly operated from a territorial perspective, and emissions reductions have traditionally focused on domestic policies (Droege, 2011; UN, 1992, Article 12). However, with carbon leakage and competitiveness concerns high on the policy agenda, policies that transgress EU territories are becoming increasingly important. One clear way to address emissions embodied in trade is to consider trade-related policies to tackle such concerns.

Carbon leakage can be separated into two distinct categories: weak and strong (Peters & Hertwich, 2008a, 2008b).

- *Strong carbon leakage* occurs when there is an increase in global emissions specifically due to climate policy (e.g. a UK climate change policy).
- *Weak carbon leakage* occurs when there is an increase in global emissions due to increased consumption (rather than one due to a specific government policy).

The scale of weak carbon leakage is particularly important in the UK compared to other large emitters. The difference between growth in consumption-based and territorial-based emissions was the largest for the UK when compared to the other industrial nations in the top ten CO_2 emitters, with a 23% growth difference in 2008 from 1990 (for CO_2 only), compared to 8% for the US, 7% for Canada, and decreases in other countries (see Figure 6).

Strong carbon leakage is considered to be generally small at today's carbon prices (Carbon Trust, 2008, 2010). By contrast, weak carbon leakage (essentially the difference between production and consumption emission accounting) is considered to be large (see Figure 1; Peters et al., 2011). When weak carbon leakage is large and strong carbon leakage is small, it is implied that another country has increased its production (and emissions) to meet the increased consumption in the relevant country, in this case the UK. The increased exports from China to the UK appear to be a particularly important factor underlying the large increase in the UK's consumption-based emissions (Baiocchi & Minx, 2010).

One of the most significant international implications of the UK considering taking a consumption-based approach to emissions accounting would be to allow the UK to avoid weak carbon leakage and

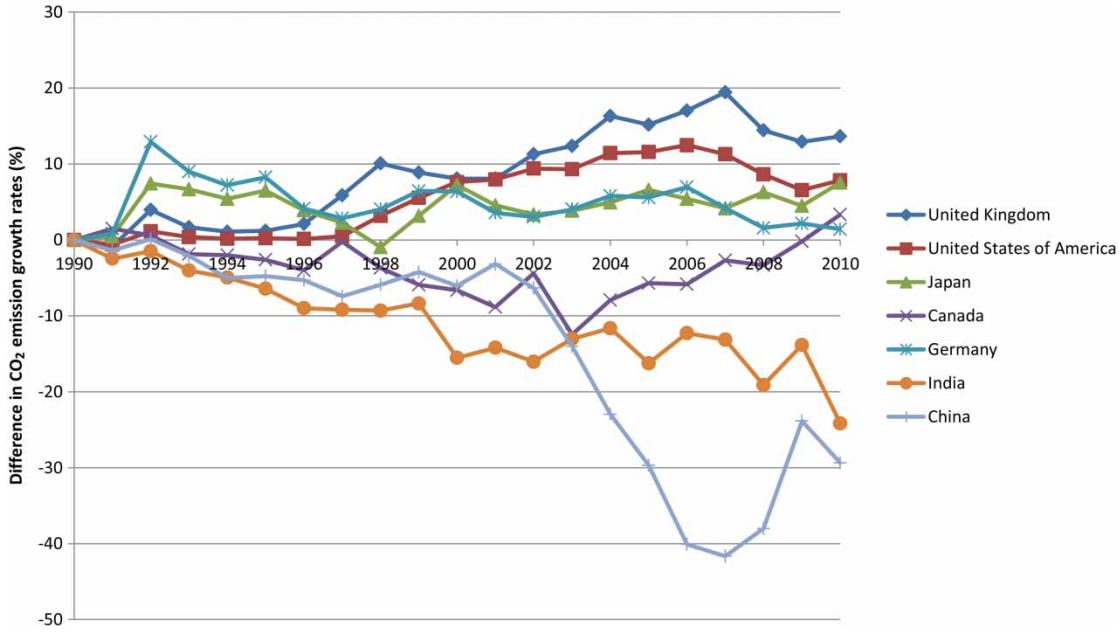

Figure 6 Growth differences between consumption-based and territorial-based CO_2 emissions from 1990 for China, India, and industrial nations in the top ten emitters
Source: Peters et al. (2011).

explicitly recognize its own influence on the emissions of other countries. As Barrett (2011) has argued, trade mechanisms are a key component of an effective climate agreement. Furthermore, inclusion of trade, via a border tax adjustment, may even force a global agreement (Helm, 2012). Extensive analysis of the role of border tax adjustments can be found in the literature (Dröge & Cooper, 2009; Fischer & Fox, 2012).

Although not a global example, the EU Emissions Trading Scheme (EU ETS) acts as a mechanism to reduce carbon leakage within Europe. A new analysis of the UK is represented in Figure 7 and demonstrates that the four most significant countries for embodied emissions are not covered by European climate policy.

Only 25% of embodied emissions in imports occur inside the EU, and only 17% are captured under the EU ETS (and, hence, 83% of emissions embodied in trade due to consumption in the EU are not accounted for under the EU ETS). Measures such as carbon border taxes have been proposed to complement the EU ETS, although they have, in turn, been subject to criticisms of discrimination or protectionism and of threatening trade relations. Debate remains on the issues of equity and the differential responsibility assigned to developed and developing countries, but there are indications to suggest that policies such as border levelling – whereby the costs of carbon are equalized between domestic and imported products – are more politically acceptable and increase global welfare (Gros & Egenhofer, 2011; Grubb, 2011; Ismer & Neuhoff, 2004). Barrett, Vaner, Sakai, and Owen (2012) considered the percentage of embodied emissions that would be captured, taking different sensitivities into account, and demonstrated that it would be extremely difficult to extend the coverage of the EU ETS to imports. This was mainly because, even without accounting for the embodied emissions in finished products as opposed to capturing the emissions related to the raw materials currently priced, it would fail to cover 95% of emissions embodied in trade (Barrett et al., 2012). For example, European countries do

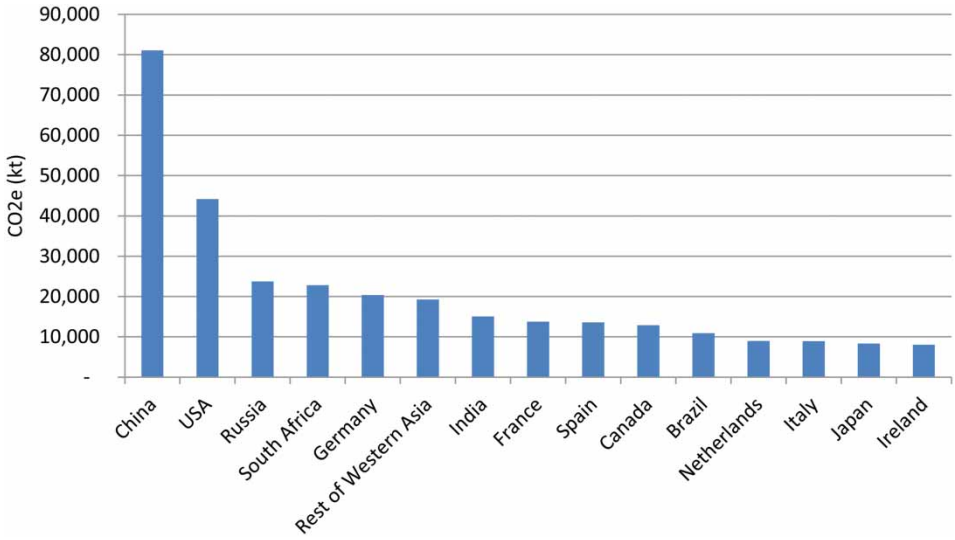

Figure 7 Origin of CO_2e emissions to satisfy UK consumption in 2007
Source: University of Leeds.

not import electricity from China, but the emissions from Chinese electricity are embodied in many of the products consumed. Accounting for this requires understanding the complete supply-chain emissions of finished products. No GHG emissions accounting can accurately and robustly measure the emissions associated with individual products and take into account global supply chains and individual country efficiencies at a low cost. This does not mean that border carbon adjustment schemes are impossible, but rather that any suggested scheme must consider the percentage of embodied emissions in imports that is captured, and overcome significant methodological hurdles or, at the least, simplify the scheme.

There are clearly further options available beyond border carbon adjustments. Policies that allow climate-compatible development should be given significant attention to ensure that imports are produced using the best available technology. This requires a stronger focus on the carbon intensity of imports (Davis et al., 2011). This could involve the extension of EU ETS-type schemes, border carbon adjustments, and improved technology transfer. With time such an important issue, schemes that can be implemented in the near term are a priority. The EE-MRIO model, which calculates consumption-based emissions, could act as a useful tool with which to assess the ability of different schemes to capture the emissions embodied in trade. It allows adjustments to be made to the level and composition of consumption, production structure and efficiency, as well as different trade patterns between countries. This would allow a further assessment of options to improve carbon intensity through the introduction of financial schemes and programmes involving technology transfer.

4.4. Domestic consumption responses

A production perspective on emissions may identify energy production, energy-intensive industries, and transportation as dominant sources of emissions, but a consumption perspective reveals the role of manufactured products, such as electrical appliances and furniture, food, clothing, and services. A consumption approach may lead to different policy instruments, and highlight more effective policies (i.e. implementable quickly at lower cost). In the UK, this has been clearly demonstrated in the major study undertaken for the Waste and Resources Action Programme (WRAP), which explored 13 different resource efficiency strategies for the UK (Barrett & Scott, 2012).

Consumption-based emissions demonstrate the need for comprehensive roadmaps on key products that cannot be tackled purely by UK production-based measures (Sinden, Peters, Minx, & Weber, 2011). Figure 8 shows whether the emissions from different product groups occurred inside or outside the UK.

Domestic policies on electricity generation would clearly be effective and responsive. However, such policies would barely tackle the emissions associated with the production of electronic equipment, vehicles, and textiles. Different policies that effect different country efficiency improvements and demand-side strategies could affect these emissions (Barrett & Scott, 2012). Sinden et al. (2011) have suggested that the production-based EU ETS could miss around 50% of the emissions associated with the consumption of aluminium and derived products in the EU alone (Sinden et al., 2011).

Further research is required on the mitigation costs and benefits of consumption-based measures, but some preliminary research suggests that a number of strategies could boost national growth. The comprehensive study by WRAP has demonstrated that strategies such as extending the lifetime of products, lean design techniques, reducing food waste, dietary changes, and product durability could boost the service-based economy in the UK and reduce weak carbon leakage (Barrett & Scott, 2012).

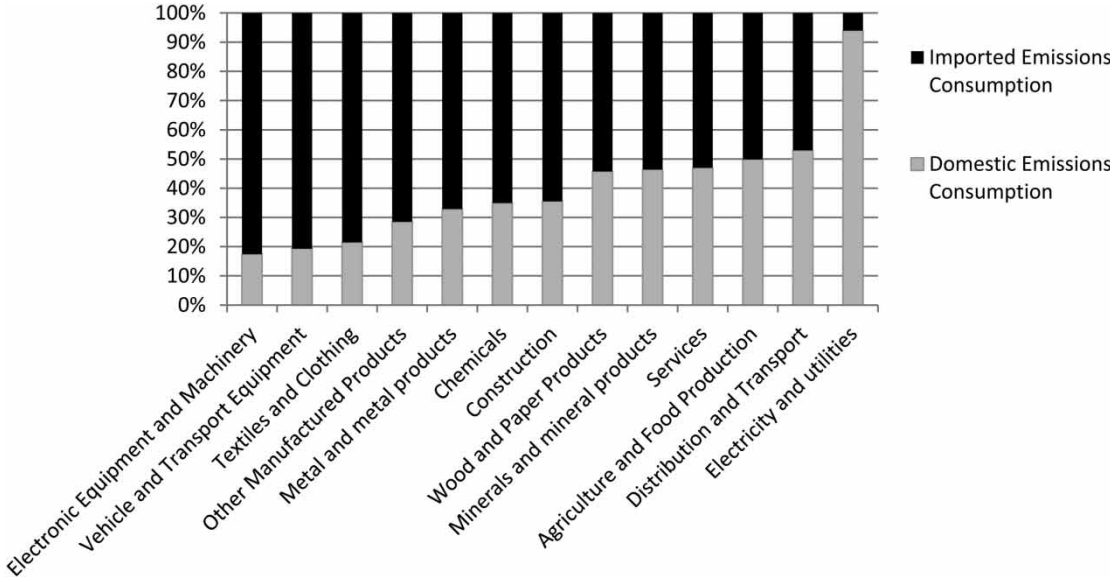

Figure 8 Percentage of GHG emissions in the UK associated with different groups
Source: Barrett, Owen, and Sakai (2011).

Many studies have demonstrated the role of resource efficiency in climate mitigation (e.g. Barrett & Scott, 2012). Vringer et al. (1995), and others, have concluded that influencing lifestyle decisions that change longevity of use, substitution, and shifts to services could each contribute to emissions reduction. However, many of these options have not been translated into policies for climate mitigation. At best, information saving and voluntary schemes have been used by governments with limited or no effect.

Considering consumption-based emissions aids in understanding the indirect impacts embodied in the supply chain of organizations (described as Scope 3 emissions by the GHG Protocol, the emerging global standard in carbon accounting for organizations; see Wiedmann, Lenzen, & Barrett, 2009). Scope 3 emissions include indirect emissions from activities such as the extraction and production of purchased materials and fuels. In some sectors these emissions represent a significant proportion of total supply chain emissions. For example, in the case of the publishing sector, Scope 1 and 2 emissions account for only 6% of total emissions in Australia and just over 13% in the US. In the case of the data-processing sector, Scopes 1 and 2 account for 17% of all emissions in the US and just less than 23% in Australia (Huang, Lenzen, Weber, Murray, & Matthews, 2009). These examples show that consumption-based approaches provide information that is not available in standard production-based approaches.

Many of the policy options that change the composition of consumption could have indirect rebound effects such that the saved revenue is allocated to another good or service. It is essential that these rebound effects are considered to avoid an overly optimistic picture of the scale of possible emissions reduction.

4.5. Political responses to consumption-based emissions and climate policy

The policy response in the UK has been to consider its options under the umbrella heading of 'Sustainable Consumption and Production' (SCP). There has been a clear division between SCP policy and climate change policy. In the UK, climate change policy is under the administration of the Department of Energy and Climate Change (DECC), whereas SCP is the responsibility of Defra. This has created a clear divide between the two agendas, which has led to the current UK 'Climate Plan' (DECC, 2012) completely ignoring the existence of SCP.

There have also been clear moves by DECC to ensure that this division remains in the future. Comments by the current Minister of State for Climate Change, Gregory Barker, at the inquiry by the Energy and Climate Change Select Committee, labelled consumption-based emissions as 'a purely academic exercise', a 'distraction at best' and of 'limited policy application' (House of Commons, 2012). However, the conclusions of the inquiry will make it more difficult for DECC to ignore both trade policies and consumption-based measures in future climate mitigation plans. The Committee's report calls for DECC to establish targets for consumption-based emissions and suggests that such an approach would help in the development of new climate policies.

4.6. Research requirements to improve the policy application of consumption-based emissions

As well as the political issues that surround the acceptance and application of a consumption-based emissions system, the translation of consumption-side strategies into clear policy instruments is still in its infancy. So far, SCP policies in the UK have relied on voluntary, soft policy measures. Some of the research requirements to ensure that consumption-based emissions have a more dominant role in guiding climate policy are listed below:

- *Harmonization of methods*. With the UK Government taking a global lead in assessing their consumption-based emissions, it could establish standards – in conjunction with other institutions – for the harmonization of methods to ensure robustness and consistency between country estimates. One reason for the UK to take a lead on this is that the UK is especially vulnerable to criticism from the international community in relation to the large amount of leakage that occurs relative to other large industrial nations. The UK thus has a credibility problem in the international climate change negotiations, despite its demonstrative progress in reducing territorial GHG emissions. Although not standardized, the use of Environmentally Extended Input–Output analysis has become the *de facto* standard (Wiedmann, 2009).
- *Policy-orientated research*. There is a strong need for consumption-side solutions that clearly define the policy instruments that will be used to reduce emissions. There is a considerable need for the visualization of demand-side strategies, and insights into how they will play out in the real world. There are some examples of this in the literature (in particular Barrett & Scott, 2012; Sinden et al., 2011), although there is a need for more. The research on consumption-based emissions has yet to demonstrate a clear transition or roadmap for how a national government could apply a broader mitigation agenda that includes policies that both affect total final demand of households and the composition of consumption.

- *Consumption-based emissions scenarios*. There is a need to build EE-MRIO modelling of consumption-based emissions into the commonly used scenario generating models for climate mitigation policy. One of the disadvantages of using EE-MRIO for assessments of consumption-based emissions is the static nature of its models. Linking results to the dynamic models used in climate policy assessments would raise less of a challenge for national government departments, who are comfortable with such modelling conventions. This also provides a framework for understanding the growing importance of imported emissions. Further work is currently being undertaken to link the results from EE-MRIO models of the upstream impacts on energy technologies with energy system models. These approaches can help to break down some of the polarized opinions within the UK Government, which rejects the application of consumption-based accounting and brings such approaches into the mainstream.
- *Economic assessments of consumption-based policies and strategies*. Measures related to demand-side strategies should be assessed with the same criteria as supply-side measures. An economic assessment of the cost-effectiveness of the various strategies should consider using a similar approach to appraising territorial methods as taken by the Committee on Climate Change, who have used Marginal Abatement Cost (MAC) curves to assess whether various strategies are revenue-generating or a cost.

Further analysis of the range of policy options is required. Such analyses would need to consider the underlying drivers of emissions and offer an interpretation of each policy, individually and collectively. It should not rely exclusively on consumption-based accounting, but rather should use econometric analysis to establish the dynamic relationships that drive emissions.

5. Conclusions

This article has demonstrated the role that consumption-based emissions could play in monitoring progress in reducing emissions and its ability to introduce and quantify additional climate mitigation strategies. The methodology is robust enough to support both roles. Consumption-based emissions are complementary to production-based emissions inventories, which are still the most relevant and accurate estimates for aggregated emissions at the global level and are an important starting point for the study of the climate system. However, without consumption-based approaches, territorial emissions alone do not provide a complete picture of progress in regional and national emissions reduction. With fragmented climate policy, consumption-based emissions are an essential tool for extending and widening the policy options. As climate policy targets deepen, there should be a broad range of policy options in addition to those that focus on the production and technological solutions.

At the same time, evaluations of the policy options, political responses, and institutional and governance issues associated with consumption-based emissions are still in their infancy. There is a need to understand the policy instruments available to implement consumption-side measures, beyond voluntary and information-sharing approaches. Additionally, there has only been limited research into consumption-based emissions scenarios.

However, despite the need for further research, consumption-based emissions act as an important reminder of the global challenge of climate change and demonstrate the need for cooperation, innovative mitigation strategies, and the inherent link between consumption, the economy, and emissions.

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Notes

1. This allocation is necessary to make the emissions statistics consistent with the economic data used in economic modelling.
2. See Edens et al. (2011), who provide a brief history of the countries (namely Denmark, the Netherlands, Germany, Sweden, France, and the UK) that have calculated consumption-based emissions (see also Lennox et al., 2010; Nijdam, Wilting, Goedkoop, and Madsen, 2005).
3. Consumption-based emissions were calculated by the University of Leeds and the Centre for Sustainability Accounting for Defra, using EE-MRIO.
4. Initial calculations suggest that 55% of the reduction was related to the economic downturn seen in the UK.

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