

Consumption-based GHG Emission Accounting in Climate Policy – A UK Case Study

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Abstract

Global greenhouse gas emissions continue to rise. Emissions from trade represent nearly a quarter of global emissions and are currently not captured within global climate policy. In the context of current trade patterns and limited global cooperation on climate change this paper investigates the feasibility of consumption-based emission accounting to contribute to a more comprehensive (national) policy framework in the UK. It presents consumption-based emission results for the UK from a range of models; assesses the technical robustness of the approaches taken; and explores their application in national climate policy using examples of policies designed to reduce carbon leakage and to address high levels of consumption. The paper demonstrates the 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, the paper outlines future policy-orientated research in the area of consumption-based accounting that will facilitate their application to policy in the future.

Key Words

Consumption-based emissions, carbon leakage, policy appraisal, greenhouse gas emissions, sustainable consumption

1. Introduction

Recent studies have found that 20-25% of carbon dioxide emissions are from the production of internationally traded products (Peters and Hertwich 2008; Davis and Caldeira 2010). These emissions are growing on average at 3.4%/yr (1990-2008), increasing from around 20% (4.3GtCO₂) in 1990 to 26% (7.8GtCO₂) in 2008 (Peter et al, 2011). The change in net emission transfers from developing to developed countries offsets territorial emission reductions achieved by the Annex B countries of the Kyoto Protocol by around five times (Peters et al 2011). Within the aggregated group of Annex B, the individual country profiles vary from net exporters (like Australia and Canada) to net importers (most of the EU27, Japan, and the USA). These results are found to be robust across independent studies (Peters et al, 2012).

Whilst 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 in policy formation and appraisal. Growing concern in the UK

about the effectiveness of domestic and European climate policy to deliver an absolute reduction in emissions lead the UK Energy and Climate Change Select Committee (parliamentary scrutiny panel of elected ministers) to launch an inquiry to investigate the case for consumption-based GHG emissions accounting in the UK.¹ The Committee examined the case for adopting consumption-based reporting in the UK, whether it would be feasible to do this in practice, whether emissions reduction targets might be adopted on a consumption basis, and what the implications for international negotiations on climate change might be if the UK and others took this approach.²

This paper provides insight into these issues using the UK as a case study. It provides the necessary background on the various accounting methods for allocating GHG emissions to countries. The consistency of different datasets on consumption-based emissions is then presented along 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 paper then summarises some of the policy options available both domestically and internationally to address GHG emissions embodied in trade. Finally the paper considers the research required to ensure that options to reduce consumption-based emissions can be considered alongside traditional climate policy that predominately focuses on technological domestic solutions.

2. Background

GHG emissions can be allocated to countries in different ways. Three different methods of allocating emissions are now in common use: 1) territorial-based, 2) production-based, and 3) consumption-based.

- 1) The United Nations Framework Convention on Climate Change (UNFCCC) requires countries to submit annual National Emission Inventories. The UNFCCC follows the Intergovernmental Panel on Climate Change's guidelines in term of the allocation of GHG emissions which is, "emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (IPCC, 1996, pp.5). According to this definition, however, GHG emissions emitted in international territory, international aviation and shipping, are only reported as a memo and not allocated to individual countries. We call these "territorial-based emission inventories".
- 2) Some countries also report GHG emissions allocated using the same system boundary as the System of National Accounts (SNA), such as are already done with Gross Domestic Product (GDP). This allocation is necessary to make the emission statistics consistent with economic data used in economic modelling. These inventories are often called "National Accounting Matrices including Environmental Accounts (NAMEAs)". In the EU, NAMEAs are reported to Eurostat, though most other developed countries develop NAMEAs but do not report them internationally. The main difference between NAMEAs and the UNFCCC territorial emissions is the allocation of emissions occurring in international territory, and the allocation of tourist activities. In the SNA, international aviation and shipping are typically allocated to countries based on the operator of the vessel, likewise, international tourists are allocated emissions

¹ <http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/inquiries/parliament-2010/consumption-based-emissions-reporting>

² <http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/news/new-inquiry-consumption-based-emissions-reporting>

based on where they are resident and not where they are travelling. We call the NAMEAs “production-based emission inventories”.

- 3) Consumption-based emissions allocate emissions to the consumers in each country, usually based on final consumption as in the SNA but also 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). We call these “consumption-based emission inventories”.

Recently, “extraction-based emission inventories” have been developed (Davis et al, 2011). Extraction-based inventories allocate emissions to the point of extraction of fossil fuels and around 37% of global emissions are in traded fossil fuels, compared to 23% from the production of traded goods and services. It is possible to consider the entire supply chain of CO₂ from the point of extraction, via production, and ultimately to consumption of goods and services. The advantage of extraction-based emissions is that a large share of global emissions can be regulated with only a few participants, and by revenue recycling, fossil-fuel extractors will have a higher welfare if they collect the carbon tax income (Harstad, 2012; Whalley and Wigle, 1991).

A number of statistical offices and other government agencies have started to calculate consumption-based emissions. This has predominately happened in Europe and also Australia and Canada. Edens et al (2011) provides a brief history of the countries that have calculated consumption-based emissions, these being Denmark, Netherlands, Germany, Sweden, France and the UK (Nijdam et al, 2005; Lennox et al, 2010). However, as Edens et al (2011) points out, these are rarely seen as “official statistics” meaning that there is no clear commitment to annually update the indicator and provide an official statistical release of the data. Using these criteria, there appears to be only two countries that have made this commitment, these being Australia (see Hao et al, 2012) and the UK.

The UK has adopted consumption-based emissions as an official government indicator and having undertaken numerous reports that uses the approach to evaluate the effectiveness of climate mitigation measures beyond technological solutions. These include an assessment of the role of resource efficiency in climate change mitigation policy, the role of services and an understanding of drivers of GHG emissions between 1992 and 2004 (Scott et al, 2009; Barrett and Scott, 2012; Minx et al, 2009a; Baiocchi and Minx, 2010). For these reasons the UK has been selected as the case study to explore a number of issues surrounding consumption-based emission accounting.

It’s important to note that consumption-based emissions are seen as a complementary approach to the current territorial accounting system, as opposed to replacing the existing internationally recognised system. This is a view held by the authors. Another key point is to recognise the difference between attribution and responsibility. This paper explores whether attribution of emissions to the consumer generates robust results that are useful in the formulation of climate policy beyond what can be offered by territorial accounting. We do not therefore attempt to allocate responsibility for those emissions. The case study of the UK 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 provides the latest time-series results published by the UK Government (Defra, 2012) from the three perspectives (territorial, production, and consumption). While there have been a number of other estimates, figure 1 only provides the results from the official headline indicators for the UK Government. The consumption-based emissions are calculated by the University of Leeds and Centre for Sustainability Accounting for the Department for Environment, Food and Rural Affairs (Defra) using an environmentally extended multi-regional input-output model (EE-MRIO).

Figure 1 shows that growth in consumption-based GHG emissions by 20% between 1990 and 2008 followed by a decline of a 9% reduction in one year between 2008 and 2009, predominately due to the global financial crisis³ (Wiedmann et al. 2008; Wiedmann et al, 2010).

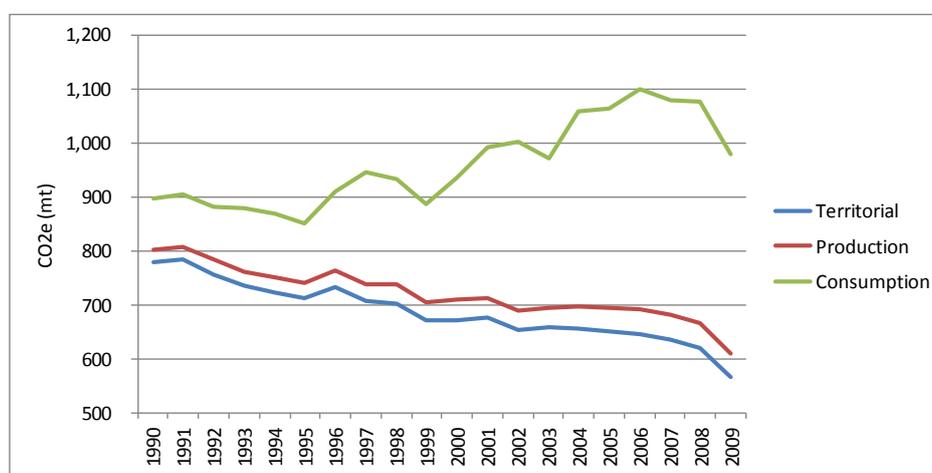


Figure 1: Comparison of UK consumption-based GHG Emissions with territorial GHG Emissions from 1990 to 2009 (Source: Defra 2012, University of Leeds)

The UK GHG emissions reported to the UNFCCC (territorial perspective) have shown a 27% reduction in territorial GHG emissions between 1990 and 2009, representing an annual decline of around 1.4% a year. GHG emissions are now 212 million tonnes lower in 2009 than they were in 1990 and the UK Government has achieved its target established under the Kyoto Protocol. From a production perspective, there has been a 24% reduction, meaning that greater reduction is achieved in emissions that are accounted for under the Kyoto Protocol than ones that are not. In fact, production GHG emissions that were not accounted for under the Kyoto Protocol (the difference between the territorial and production-based emissions) have increased by 75% between 1990 and 2009 from 25 million tonnes to 44 million tonnes of CO₂e emissions. The UK's GHG emissions from a consumption perspective are rising at a rate of over 1% a year between 1990 and 2008 and a 9% reduction in one year (between 2008 and 2009). This is in stark contrast with 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 comparative reduction was recorded.

³ Our initial calculations suggest that 55% of the reduction related to the economic downturn in the UK.

Figure 2 shows the GHG emissions embedded in imports and domestic production for final consumption in the UK and direct household emissions. In 1990, 60% of the GHG emissions associated with goods and services to satisfy UK consumption were emitted inside the UK. In 2001, a cross-over occurred where GHG emissions embodied in imports, which are ultimately caused in order to satisfy UK consumption, were greater than emissions due to domestic production.

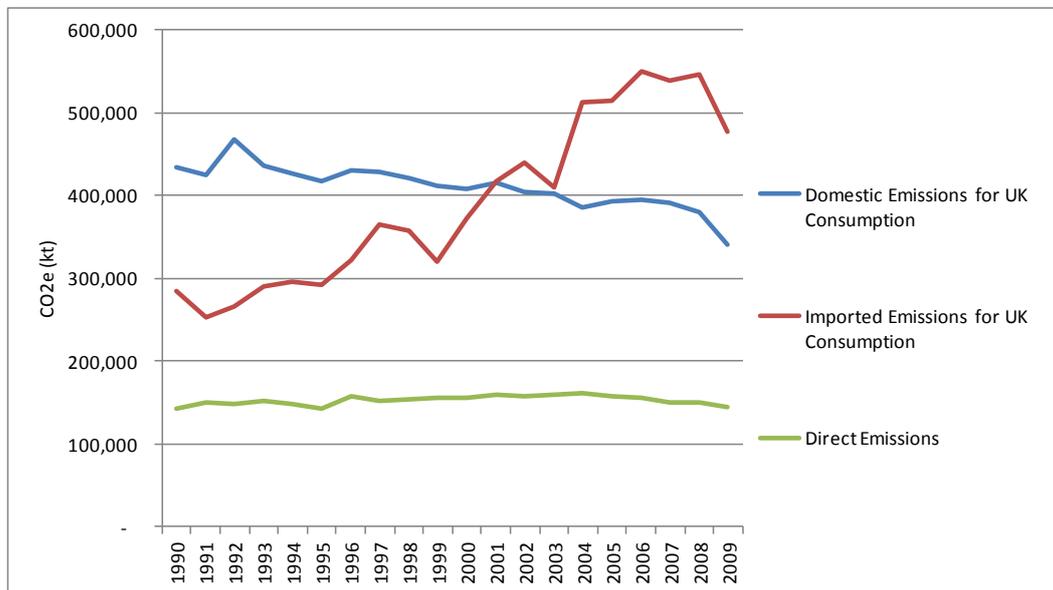


Figure 2: UK Consumption-based GHG Emissions by Origin (1990 to 2009)

Source: University of Leeds

Several other independent global studies have been performed and these also have UK results. Peters et al (2011) estimated the consumption-based carbon dioxide emissions for 113 world regions. A key finding was although many developed countries stabilised their territorial emissions, there was often an associated increase in emissions in developing countries through producing the imported goods and services (Peters et al, 2010). This was 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 *et al.* 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 studies mentioned above in that it clearly shows the divergent trajectories of territorial and consumer emissions (Figure 2).

While there is clearly some variation in the total CO₂ emissions, the emission trajectories appear consistent, particularly between 1993 and 2009.

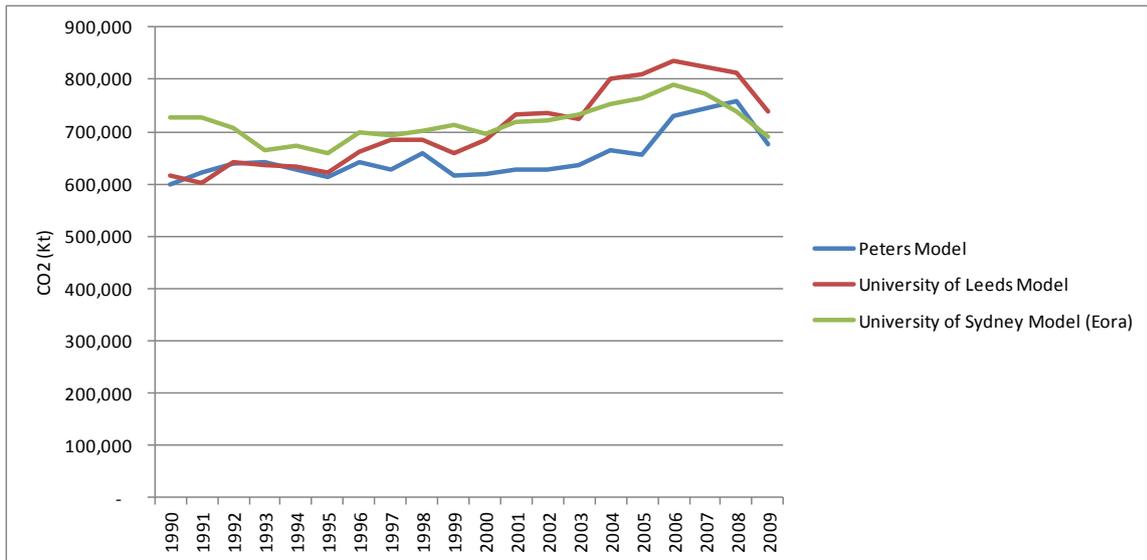


Figure 3: Comparison of UK consumption-based CO₂ Emissions between two different models (Source: Peters et al, 2011, University of Leeds with the Centre for Sustainability Accounting, Kanemoto et al., 2011.)

There have been other assessments of the UK's consumption emissions, which cover different time periods so have not been included in figure 3. Druckman and Jackson used a quasi-multi-regional input-output model to calculate consumption-based carbon dioxide emissions from 1990 to 2004 (Druckman and Jackson 2009). The study found that emissions attributable to UK households rose by 15% between 1990 and 2004, aligned with the other trajectories. Further evidence was provided by Helm et al (2007). The study found that emissions have grown by 19% from 1990 to 2003.

The results from the different studies have small differences in the estimates, but show similar trends over time. All the studies consistently show that territorial/production emissions have decreased (despite the use of different territorial/production emissions), while consumption-based emissions have increased. The differences between the studies may relate to different definitions, data, methods, and assumptions (Peters and Solli 2010; Peters et al, 2012), and not necessarily represent uncertainty in the consumption-based emissions. It is not the aim of the paper to fully understand these differences but to confirm that the trends from different studies are reliable to support the conclusion that there has been an increase in consumption-based emissions and a reduction in territorial emissions and that varying methods using different data draw consistent conclusions. The following section provides insights into where uncertainty may exist with EE-MRIO models.

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”, and this is highly dependent on the purpose the consumption-based emission inventories may serve. In the context of this paper, “robust” implies providing the motivation for further improvements in data and methods, and the design and potential implementation of new policies. For this specific purpose, we would suggest that the methods are adequate to provide robust and comparable information on consumption-based emissions given the multitude of independent studies with consistent results and trends. The last ten years in particular has seen a substantial increase in carbon footprint and related studies that aim to allocate GHG emissions on a consumption basis. 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 three studies described above have both used this methodology, although different data sources for some elements of the models were used. EE-MRIO is emerging as a comprehensive, versatile and compatible approach for consumption-based accounting of greenhouse gas emissions and has already become the norm (Davis and Caldeira, 2010; Peters and Hertwich, 2008; Peters et al., 2011; Wiedmann, 2009; Wiedmann et al, 2011). Strengths and weaknesses of the EE-MRIO approach were assessed in the European EIPOT project (Wiedmann et al., 2009).

A detailed uncertainty analysis of the UK national carbon footprint calculations using EE-MRIO modelling was undertaken for Defra (Lenzen et al, 2010). Figure 4 below provides the results of this uncertainty analysis. While all emission inventories have some uncertainty, including territorial emissions, consumption-based estimates will have a larger uncertainty due to the incorporation of more input data with varying levels of uncertainty. Figure 4 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, and different with the territorial-based emissions, are robust despite the small increase in uncertainty. Thus, additional uncertainty can't be used to justify a lack of political action. Additional uncertainty arises for the more detailed results, such as, the sector level or emissions in regional emissions due to imports.

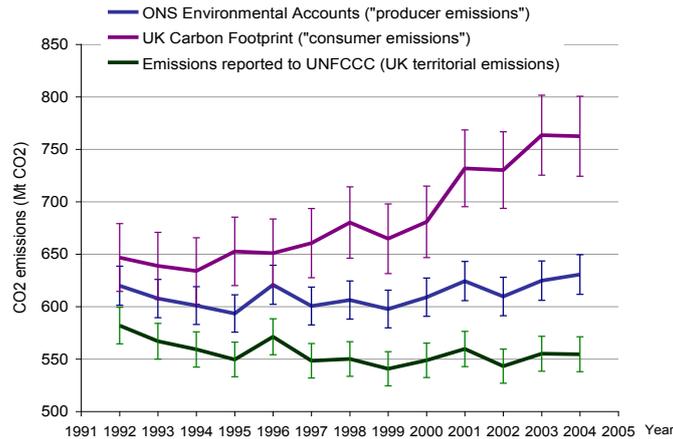


Figure 4: Uncertainty Associated with UK consumption-based CO2 Emissions (as calculated using EE-MRIO analysis). Source: Lenzen et al., 2010

The key reason for increased uncertainty is that MRIO datasets combine data from large and often incoherent data sets. The uncertainties relate to issues including calibration, balancing and harmonisation, use of different time periods, different currencies, different country classifications, levels of disaggregation, inflation, and raw data errors (Lenzen et al., 2004; Peters, 2007; Weber, 2008; Lenzen et al., 2010; Peters, 2012). Many of these manipulations reflect inconsistent reporting practices in different countries and regions, and a process of harmonisation can greatly reduce the necessary manipulations, and hence, uncertainties (Peters and 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 employing 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 circumstance can be quantitatively expressed by using standard error estimates, and visualised with error bars. These approaches were used by Lenzen et al. (2010) to demonstrate that the increase of the UK's carbon footprint was statistically significant.

The results in Figure 4 show the uncertainty via Monte-Carlo analysis in one single study. An alternative approach is to consider the variation between estimates from independent studies. While studies can never be classed as truly independent, the underlying data manipulations and harmonisation methods can differ substantially. Peters et al, 2012 found that that estimates for embodied CO₂ emissions from several independent studies and models are robust, and that differences between individual studies are predominantly a result from the use of different production-based emissions input data and different definitions for allocating emissions to international trade. Using the same economic data, the authors found that the variation in consumption-based emission estimates was paradoxically less than then the variation in production-based estimates, signifying that the manipulations in an input-output analysis tend to reduce variations through averaging (Peters, 2007). The authors also argue that since many differences between studies can be controlled (such as consistent emissions data and definitions) then uncertainty may be less than commonly assumed.

4. Policy Applications to address Consumption-based Emissions

This section explores the complementary nature of consumption-based emissions and their role in setting target followed by a consideration of both trade and domestic policies that would, in some way, change emissions embodied in trade.

We recognise that reducing emissions embodied in trade is complex and requires an understanding of how each policy affects the different determinants of international emission transfers. Clearly, the picture is more complex than implementing policies to reduce trade that would lead to a reduction in emissions. This is clearly illustrated in Jakob and Marschinski (2012) that define four key determinants that explain net emission transfers. These determinants include the trade balance, energy and carbon intensity and specialisation of countries. The policies considered below to reduce emissions embodied trade would affect some or all of these contributing factors; however it is beyond the scope of this paper to provide an individual and collective understanding of how these determinants would be affected.

The aim of this section is to consider the role of consumption-based accounting in bringing new and additional strategies to consideration and it does not provide a complete and comprehensive assessment of each policy.

4.1 Complementary nature of Consumption-based Emissions

Consumption-based emission inventories should not be considered as the single solution for climate policy; they provide additional information that has application to climate policy. Different emission inventories, such as territorial, production, and consumption-based, have different system boundaries which will place focus on alternative mitigation strategies. The different emissions inventories therefore contain **complementary** information and thus, consumption-based emission inventories, should be considered together with others. The choice is not either/or.

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

Given differential levels of economic development globally, it is unlikely in the short or long-term to have globally harmonised climate policies; thus, fragmented climate policies are likely to exist in the foreseeable future. In this fragmented setting consumption-based accounting becomes even more important as a policy tool. If there were globally harmonised climate policies in place, linked to a mitigation pathway to avoid a more than two degree rise in global temperature, then the role of consumption-based emissions would be diminished as there would be no potential for carbon leakage.

However, the benefits of consumption-based emission accounting need to go beyond merely highlighting the gap between territorial and consumption-based emissions (Minx et al., 2009). A focus on consumption-based emissions must highlight new policy options that may not have been

realised from a production perspective. These have been categorised into three distinct grouping below; 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 of emission reduction is increased. Territorial emission targets in isolation can unintentionally lead to weak carbon leakage (defined below) through imports from non-Annex I countries (Peters and Hertwich, 2008). In 2004, of the 143 MtCO₂ of net imported emissions, 67% were from imports from countries without binding and ratified emission limitations under the Kyoto Protocol and therefore, not covered by global emissions reduction commitments (Carbon Trust, 2009). Thus, as long as Annex I countries remain net importers of emissions, consumption-based emission inventories are a powerful way to expand the base of existing climate policies.

Figure 5 shows a simple scenario of UK GHG emissions from a consumption-based perspective considering two key assumptions. Firstly, that emissions embodied in trade continue in line with historical growth rates for the past 20 years and secondly that the UK achieves its territorial emission reduction target of 80% by 2050 based on 1990 levels. This is clearly an illustration as opposed to a detailed forecast of future emissions; however it serves to demonstrate the potential scale of emissions embodied in trade without either radical change in global production efficiency or specific policies to address consumption. In this illustration, domestic emissions by 2050 represent fewer than 20% of the UK emissions. By 2050, UK consumption-based emissions could only be 27% lower than 2005.

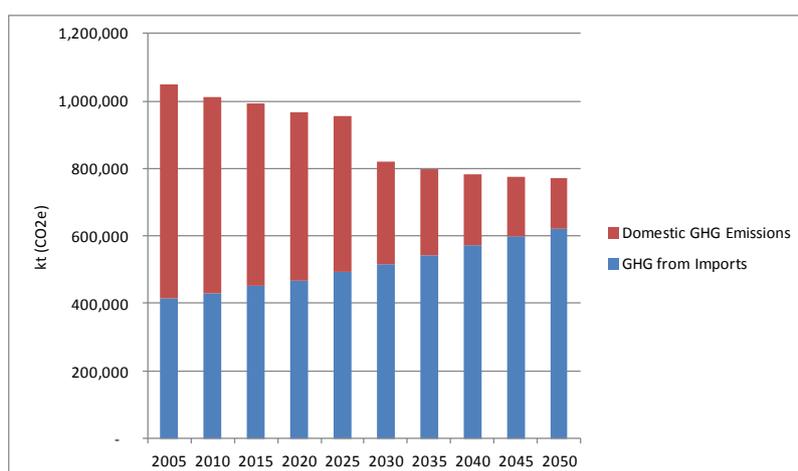


Figure 5: Projections of UK Consumption-based GHG Emissions

Such illustrations show that without due attention paid to consumption-based emissions, the environmental effectiveness of existing territorial emission reduction strategies could be significantly undermined over time.

4.3 Trade Responses

Climate change legislation has mainly operated from a territorial perspective and emission reductions have traditionally focused on domestic policies (United Nations, 1992, Article 12, p.15 and Droege, 2011). However with carbon leakage and competitiveness concerns high on the policy agenda, policies transgressing EU territories are becoming increasingly important. One clear way to address emissions embodied in trade is to consider trade related policies to tackle leakage and competitiveness concerns.

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

- *Strong carbon leakage* refers to an increase in global emissions due specifically to climate policy (e.g., UK Climate Change policy).
- *Weak carbon leakage* refers to an increase in global emissions due to increased consumption (that is, no specific government policy is isolated as the causing factor).

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 compared to industrial nations in the top ten CO₂ emitters, with 23% growth difference in 2008 from 1990 (for CO₂ only), compared to 8% for the US, 7% for Canada, and decreases in other countries (Figure 6).

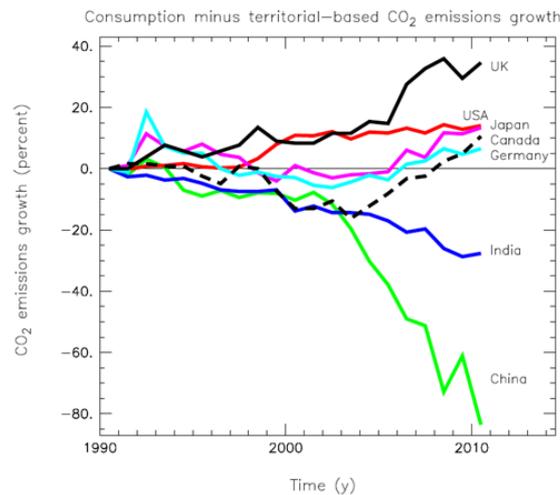


Figure 6. Growth difference between consumption-based and territorial-based CO₂ emissions from 1990 for China, India, and industrial nations in the top ten emitters. Data from Peters et al. (2011).

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

One of the most significant international implications of the UK considering a consumption-based approach to emissions accounting would be the avoidance of weak carbon leakage and the recognition of the influence the UK has on emissions in other countries. It has been argued that key components of effective climate agreements are the direct inclusion of trade mechanisms (Barrett, 2011). It has further been argued that the 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 (Fischer and Fox, 2012; Droge et al, 2009).

While not a global example, the EU Emissions Trading Scheme does act as a mechanism to reduce carbon leakage within Europe. To illustrate its ability in achieving this, a new analysis of the UK is represented in figure 7. The analysis demonstrates that the four most significant countries in relation to embodied emissions are not covered by European climate policy . .

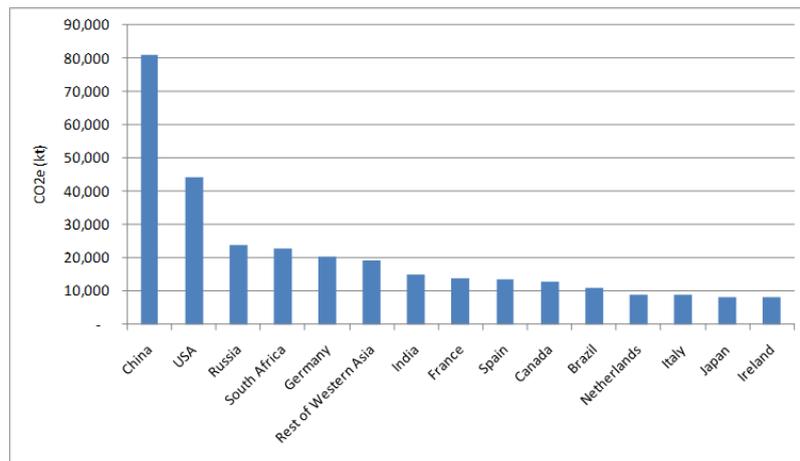


Figure 7: Origin of CO2e Emissions to satisfy UK Consumption in 2007

Source: University of Leeds

Only 25% of embodied emissions in imports occur inside the EU and 17% are captured under the EU ETS, meaning that a total of 83% of emissions embodied in trade are not captured in the EU-ETS due to consumption in the EU. Measures such as carbon border taxes have been proposed to complement the EU ETS, which in turn are subject to criticisms of being discriminatory or protectionist and threaten trade relations. Whilst debate remains on issues of equity and the differential responsibility assigned to developed and developing countries, there are indications to suggest that policies such as border levelling, whereby the costs of carbon are equalised between domestic and imported products, seem to prove to be more politically acceptable and increase global welfare, (Grubb, 2011; Gros and Egenhofer, 2011 and Ismer and Neuhoff, 2004). Barrett et al (2012) undertake a study to consider what percentage of embodied emissions would be captured with different sensitivities taken into account. The analysis demonstrated that it would be extremely difficult to extend the coverage of the EU ETS to imports mainly because without accounting for the embodied emissions in finished products as opposed to capturing the emissions related to the raw materials currently priced, 95% of the emissions would not be captured (Barrett et al, 2012). By way of example, European countries don't import electricity from China, but the emissions from Chinese electricity are embodied in many of the products consumed. These would only be captured through understanding the complete supply chain emissions of finished products. No GHG emissions accounting can accurately and robustly measure the emissions associated with individual products taking into account global supply chains and individual country efficiencies at a low cost. This does not mean that border carbon adjustment schemes are impossible, just that any suggested scheme

must consider what percentage of embodied emissions in imports is captured and overcome significant methodological hurdles, or least simplify the scheme.

4.4 Clearly there are further options available beyond border carbon adjustments. Policies that allow climate compatible development need to be given significant attention to ensure that imports are produced using best available technology. This requires a stronger focus on the carbon intensity of imports, a point that becomes clear in Davis et al (2011). This could involve the extension of EU ETS schemes, border carbon adjustments and improved technology transfer. With time being such an important issue, schemes that can be implemented in the near term are a priority. EE-MRIO model that calculate consumption-based emissions could act as a useful tool by which to assess the ability of different schemes to capture the emissions embodied in trade. The model allows adjustments to be made in the level and composition of consumption, the production structure and efficiency along with 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. **Domestic Consumption Responses**

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

Consumption-based emissions have demonstrated the need for comprehensive roadmaps on key products that cannot be purely tackled by UK production based measures (Sinden et al. 2011). Figure 8 shows whether the emissions from different product groups occurred inside or outside the UK.

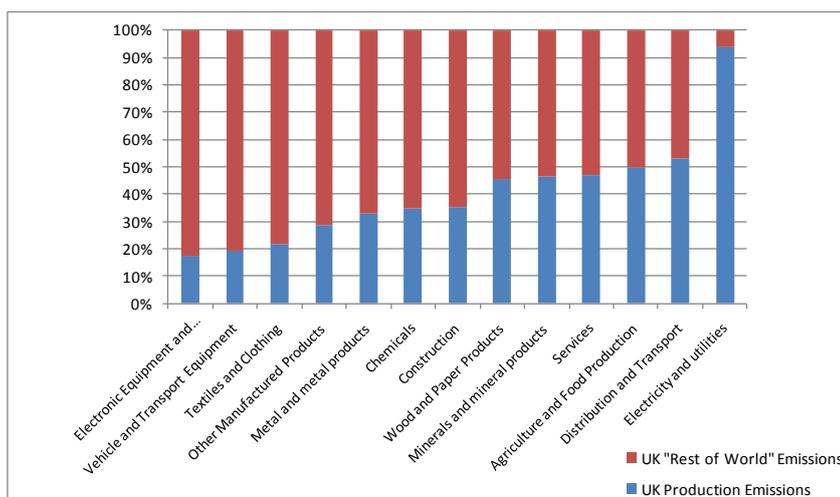


Figure 8: Percentage of GHG Emissions occurring in the UK associated with different group groups (Barrett, Owen and Sakai, 2011)

Domestic policies on electricity generation will 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 effecting different country efficiency improvements and demand side strategies could affect these emissions (Barrett and Scott, 2012). A recent study of aluminium production and consumption in the EU suggests 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 (Sinden et al 2011).

While further research is required on the mitigation costs and benefits of consumption-based measures some preliminary research suggests that there are a number of strategies that could boost national growth. The comprehensive study by WRAP demonstrated that strategies such as extending the lifetime of products, lean design techniques, reducing food waste, dietary changes and product durability could potentially boost the service-based economy in the UK and reduce weak carbon leakage (Barrett and Scott, 2011). The study undertaken by Barrett and Scott (2012) is one of many studies to demonstrate the role of resource efficiency in climate mitigation. Studies dating back to 1995 by Vringer et al (1995) concluded that influencing lifestyle decisions that change longevity of use, substitution and shifts to services could all contribute to emission reduction. However, many of these options have not been translated into policies for climate mitigation. At best, information saving and voluntary schemes have been employed by Governments with limited or no effect.

Another application of consumption-based emissions relates to understanding the indirect impacts embodied in the supply chain of organisations, described as scope 3 emissions by the GHG Protocol, the emerging global standard in carbon accounting for organisations (Wiedmann, Lenzen, and 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 et al. 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 where 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 emission reduction possible.

4.5 Political Responses to Consumption-based Emissions and Climate Policy

The policy response in the UK has been to consider these options under the umbrella heading of “Sustainable Consumption and Production” (SCP). There has been a clear division between SCP policy and climate change. In the UK, climate change policy is under the administration of the Department of Energy and Climate Change (DECC) whilst SCP is the responsibility of the Department for Environment, Food and Rural Affairs (Defra). This has created a clear divide between the two agendas meaning that the current “Climate Plan” (DECC, 2012) for the UK completely ignores the existence of SCP. There has also been clear moves by DECC to ensure that this division occurs in the future. Comments by the Minister for Climate Change, Gregg Barker, at the inquiry by the Energy and Climate Change Select Committee labelled consumption-based emissions as “a purely academic exercise”, “distraction at best” and with “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 suggest 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 political issues surrounding the acceptance and application of consumption-based emissions, 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. Below is a list of the future research requirements to ensure that consumption-based emissions have a more dominant role in guiding climate policy.

- The need for the harmonisation of methods - With the UK Government taking a global lead in assessing their consumption-based emissions, the UK Government, in conjunction with other institutions, could establish standards for the harmonisation of methods to ensure robustness and consistency between country estimates. One reason for the UK leading on this is that the UK is especially vulnerable to criticism from the international community because the leakage of its emissions is larger than that of other large industrial nations. The UK has thus a problem of credibility for the negotiations of international agreements on climate change, in spite of its demonstrated progress in territorial GHG emissions. While not standardised, the use of Environmentally Extended Input-Output analysis has become the de-facto standard (Wiedmann, 2009).
- The need for more policy orientated research – There is a need for a stronger orientation on consumption-side solutions that clearly define the policy instruments. There is a considerable need for the visualisation of demand side strategies and insights into how they play out in the real world. There are some examples of this in the literature, in particular Sinden (2011) and Barrett and Scott (2012), however there is a need for more. The research on consumption-based emissions has yet to demonstrate a clear transition or roadmap on how a national government applies a broader mitigation agenda than encompasses policies that both affect total final demand of households and the composition of consumption.
- Further evidence on scenarios related to consumption-based emissions - There is a need to build EE-MRIO modelling consumption-based emissions into commonly employed 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 the models. Linking results to dynamic models used in climate policy assessments would raise less of a challenge for national government departments that 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 results from EE-MRIO models on the upstream impacts on energy technologies with energy system models. These approaches help breakdown polarised opinions within the UK Government that rejects the application of consumption-based accounting and brings such approaches into the mainstream.
- Introduction of economic assessments of consumption-based policies and strategies - It is important that measures related to demand side strategies are 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 appraise territorial methods documented

by the Committee on Climate Change. This used “Marginal Abatement Cost Curves” (MACC) to assess whether various strategies were revenue generating or a cost.

Further analysis of the range of policy options is required. Such analysis would need to consider the underlying drivers of emissions and offer an interpretation of each policy individually and collectively. This analysis would not rely exclusively consumption-based accounting but also under econometric analysis to establish the dynamic relationships that drive emissions.

5 Conclusions

The paper demonstrates the role that consumption-based emissions could play in monitoring progress and its ability to introduce and quantify additional climate mitigation strategies. The methodology is robust enough to undertake both of these roles. Consumption-based emissions are complementary to production-based emission inventories that are still the most relevant and accurate estimate for aggregated emissions at the global level and an important as a 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 emission reduction. With fragmented climate policy, consumption-based emissions are an essential tool for extending policy options. There is clearly a need for consumption-based emissions to be seen as an opportunity to to consider wider range of policy options. As climate policy targets deepen, there is a need for 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 is still in its 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 been limited research on scenarios related to consumption-based emissions.

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

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