Optimal Carbon Policy from Supply Chain Analysis

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Abstract

In the absence of globally harmonized policy for climate mitigation, a minority of countries and regions have implemented regulations and measures with relatively limited scope. Most of these measures are based on emissions within the regulated territories, with little account for emissions associated with traded goods. Border carbon adjustments have been discussed as a means of protecting regulated industries, incidentally shifting production-emissions accounting measures to a consumption basis. The prospect of regulation of extraterritorial emissions leads to questions of equity that may run counter to the UNFCCC's goal of 'common but differentiated responsibilities'. We examine the supply chain emissions and accrual of value-added of two traded commodities, meat and clothing, and find that sharp contrasts between the characteristics of the two supply chains lead to quite different conclusions about the carbon policy options that are likely to be most effective. In addition, we see large disparities between the accumulation of value-added and emissions responsibilities.

Introduction

International trade is growing rapidly, faster than global GDP. Similarly, emissions embodied in international trade are growing faster than global emissions (Peters et al., 2011b). Trade overall is becoming much more significant as a result of lower trade barriers, lower transportation costs, and the resulting increased effectiveness of comparative advantage.

Global climate policy is highly fragmented, with a number of (mainly developed) countries implementing subnational, unilateral or multilateral policy (e.g., the EU-ETS, regional trading schemes in the USA and Canada, emissions trading and carbon taxes in a number of countries, and support for low-carbon technologies). These piecemeal policies have little to show so far for their efforts, and the majority of global emissions are not regulated at all. Border Carbon Adjustments (BCAs) have been suggested as one way to prevent carbon leakage (Peters, 2008) and protect 'vulnerable' domestic industries, but also to widen the scope of emissions covered by regulation (Helm et al., 2012). However, the consistency of BCAs with existing international trade agreements has not yet been tested (Fischer and Fox, 2012), and limited existing theoretical research indicates BCAs may only reduce carbon leakage marginally (Böhringer et al., 2012) or even have no effect on global emissions (Whalley, 2009; Jakob et al., 2013).

There are significant trade-offs in the application of regulation at different stages in the supply chain of any commodity. The goal is to reduce emissions most effectively, where effectiveness comprises economic efficiency as well as political feasibility and with consideration of administrative burden. The point of obligation, i.e. which agent is held responsible for emissions, may not be the same in each commodity's supply chain. In the EU-ETS, the 11,000 largest CO_2-emitting facilities were included in the scheme, covering 40% of CO_2 emissions. In New Zealand's ETS legislation agricultural emissions were initially scheduled to be included, but with the point of obligation at the processing companies rather than the tens of thousands of individual farmers, specifically to minimise administrative burden and cost.

Value-added captured by each country in the global supply chain represents economic benefit gained, and the sum of value-added in each country is the gross domestic product. However, as has been often stated (first by Kuznets, who created the index; Kuznets, 1934), GDP is not a perfect measure of societal wellbeing, and the damages caused by pollutants generated from economic activity are often not captured. This is the well-known problem of environmental externalities. The comparative study of value-added and pollutants has been well studied. The case of greenhouse gases is more complex, because the majority of these gases are well-mixed in the atmosphere, and therefore generate global effects rather than local. In addition, because of significant inertia in the climate system (and the economic and social systems (Peters et al., 2013)), effects are not only spatially distributed but temporally as well. Cost of greenhouse gas pollution is borne quite differently to that of local pollutants. Further, because of the seemingly inextricable link between development and energy consumption, issues of equity quickly arise, and it is unclear which agents should bear the cost of mitigation. It is therefore of significant interest to study the relationships between value-added gained from activity to global supply chains and potential responsibility for emissions of greenhouse gases. There are many other social, environmental, and economic issues of concern with the meat and clothing industries, but we do not discuss those here.

There is a considerable literature in analysis of emissions embodied in international trade (Munksgaard and Pedersen, 2001; Peters and Hertwich, 2008; Wiedmann, 2009; Davis and Caldeira, 2010). There is also a considerable literature in value added in trade (Koopman et al., 2010; Escaith and Inomata, 2011; Johnson and Noguera, 2012). These two strands have been connected previously in the 'shared responsibility' work of Lenzen (2007) and Andrew and Forgie (2008), where value-added as a fraction of output was used to allocate emissions to agents along the supply chain.

In this article we investigate the supply chains of two contrasting commodity groups – meat and clothing – for final consumption in three European countries – France, Norway, and the United Kingdom. Both commodities are significant in the basket of goods purchased by households in these countries, with meat ranging from 3%–4% and clothing from 5%–7% of total household expenditure (Eurostat, 2009). The two commodity groups contrast in several interesting aspects. First, the emissions sources in their supply chains are very different: agricultural emissions form the bulk of meat's supply chain emissions, while for clothing it is electricity, used by both textile and clothing manufacture. Because of this distinction, we must include non-CO_2 gases in our analysis. Second, under the General Agreement on Tariffs and Trade (GATT), countries are permitted to apply import tariffs to agricultural and fisheries commodities, so that European production of meat faces little competition from cheaper production in developing countries. In addition, Norway, not a member of the EU, retains the right to apply tariffs to agricultural imports from the EU, while France and the UK must treat other EU countries without discrimination. In all three countries, large government subsidies support the local meat industries. In contrast, the production of textiles and clothing in developing countries has long been protected under international rules of trade, with the Multifiber Arrangement (1974–1994), and then Agreement on Textiles and Clothing (1995–2004). China processes more than half the world's textile fibre (Liu, 2011), while ready-made garments form about 80% of Bangladesh's exports (BGMEA, 2013). Third, much of the final processing of meat imported into developed countries occurs in developed countries, while clothing is generally imported as ready-made garments. Fourth, compared with meat, consumption of clothing is much more linked to fashion and desirability rather than need, and this allows significantly higher margins, most of which are captured late in the supply chain, particularly at point of sale to households.

The next section of this article details the methods used in our analysis. This is followed by an exploration of results, and we then conclude with discussion of the results and ideas for future research.

Methods

We used a global model of the world economy (Peters et al., 2011a; Andrew and Peters, 2013) derived from version 8 of the Global Trade Analysis Project (GTAP) database, with the world divided into 129 countries and regions, each with 57 sectors, for the year 2007 (Narayanan et al., 2012). To analyse specific supply chains we used structural path analysis (SPA) (Defourny and Thorbecke, 1984; Peters and Hertwich, 2006). While uncertainty is difficult to quantify in such a model, previous sensitivity work has shown the results of such analysis to be robust (Peters et al., 2012).

We derived CO_2 emissions data from energy volumes in the GTAP database (in turn derived from IEA data) supplemented with flaring and cement emissions from CDIAC (Carbon Dioxide Information Analysis Center) (Boden et al., 2012), and non-CO_2 emissions from EDGAR (Emissions Database for Global Atmospheric Research) (European Commission, 2011) and UNFCCC submissions by Annex-I parties to the Kyoto Protocol (UNFCCC, 2012). Gases are normalised using the 100-year global warming potential. Data on value-added were taken directly from the GTAP economic database.

The modelling framework, based on the System of National Accounts (European Commission et al., 2009), accumulates production impacts (here GHG emissions and value added) along supply chains to the point of final consumption, by both households and governments on behalf of households.

While the retail and wholesale trade sectors are generally a significant component of total value-added, the analysis of this contribution to particular supply chains is not possible with the data available. The figures presented herein for value-added in the Home country should therefore be seen as lower bounds.

Results

When the supply chains are divided between developing and developed countries, there is a clear contrast between clothing and meat supply chains (Figure 1). Emissions in the clothing supply chain occur predominantly in developing countries (between 74% and 83%), while value-added accrues mostly in developed countries (58%–72%). For the meat supply chain, much higher proportions of both emissions (83%–93%) and value-added (93%–97%) occur in developed countries.

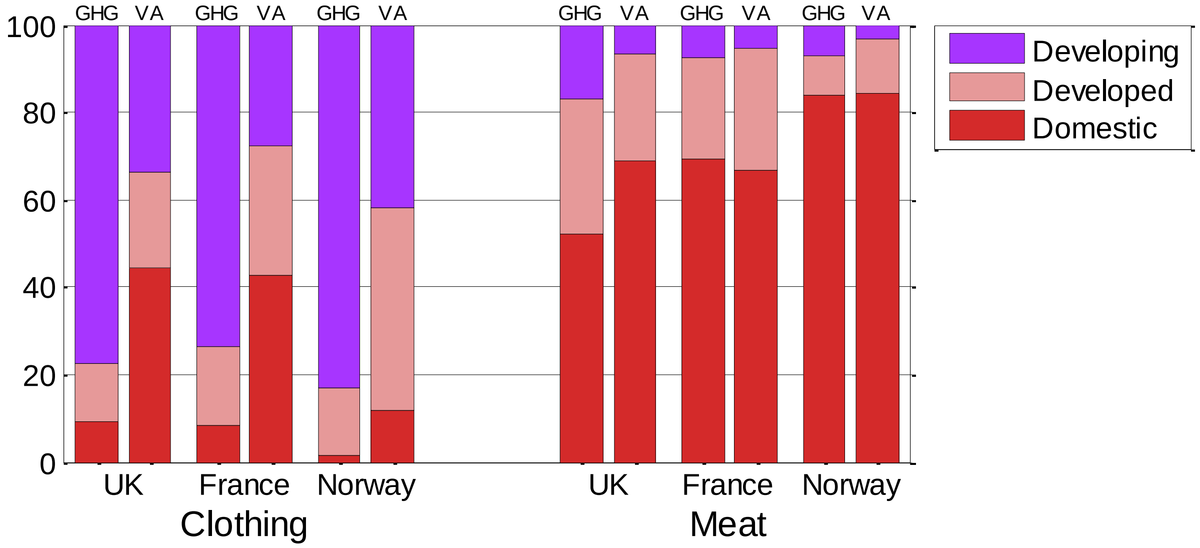

Figure 1: Percentage of greenhouse gas emissions and value-added occurring in developed and developing countries in the entire clothing and meat supply chains for UK, France, and Norway.

Clothing

Emissions in China are the largest contribution to total emissions in the clothing supply chain of each of the three Home countries, and almost half of those were in the Chinese electricity sector (Figure 2). For both the UK and France the second-highest contributions are domestic emissions, while domestic emissions in Norway's clothing supply chain are substantially smaller (1.6% of the total) because of both lesser production and lower electricity emissions intensity from Norway's hydropower resource. While about half of clothing purchased by final demand in the UK and France was domestically produced (51% and 54%, respectively), in Norway only one-sixth (16%) of final demand was supplied by domestic production.

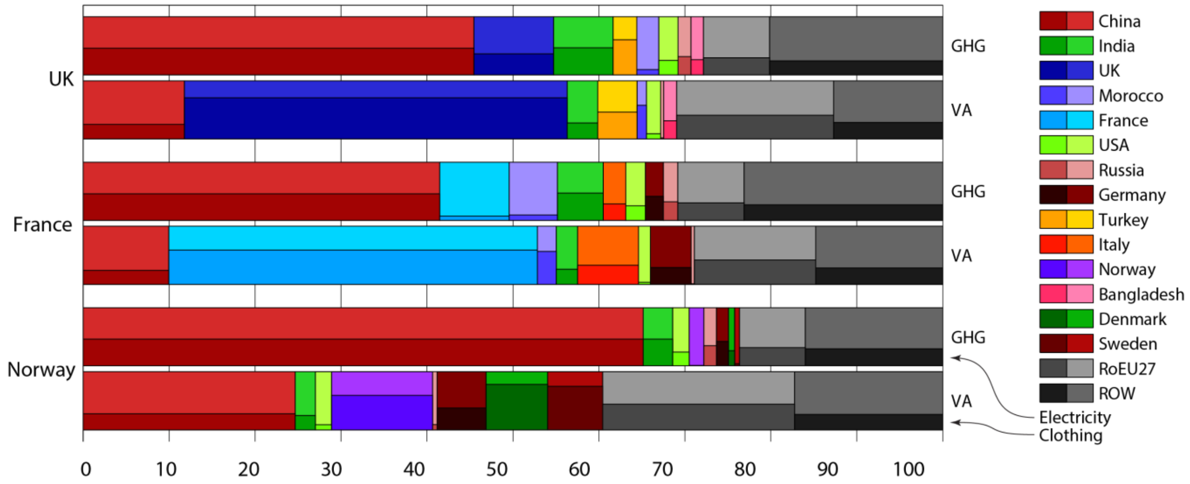

Figure 2: Contributions to total GHG emissions and value-added (VA) in the clothing supply chains of UK, France, and Norway. Out of the total contributions of each country, emissions from the electricity sector, and value-added in the clothing sector are highlighted.

About 70% of the textiles used by the Norwegian clothing sector were imported, 21% of which were from China. China's emissions also propagated through other supply chains, such as Norway's purchase of Danish clothing, which in part relies on imported Chinese textiles. Because of these imports in the supply chain, the value-added captured domestically is in each case less than the proportion of domestic supply from domestic production.

While China contributed most emissions to these supply chains, its share of value-added was much smaller, ranging from 10% in France's supply chain to 25% in Norway's. In the UK and France, by far the largest proportion of supply-chain value-added was captured in the domestic economies (45% and 43%, respectively), primarily in the wearing apparel sectors (71% and 59%).

The accumulated GHG/VA intensity is at least 18 times higher in China than in any of the three Home countries. That is, the return in value-added per unit of emissions is substantially lower in China than in the Home countries.

Figures 3, 4, and 5 show partial clothing supply chains derived using structural path analysis for the UK, France, and Norway, respectively, arranged according to contribution of greenhouse gases. The largest direct emission contributions are Chinese electricity (ELY) and rearing of sheep for wool production (WOL). The electricity sector can be seen to contribute at various places in the supply chains.

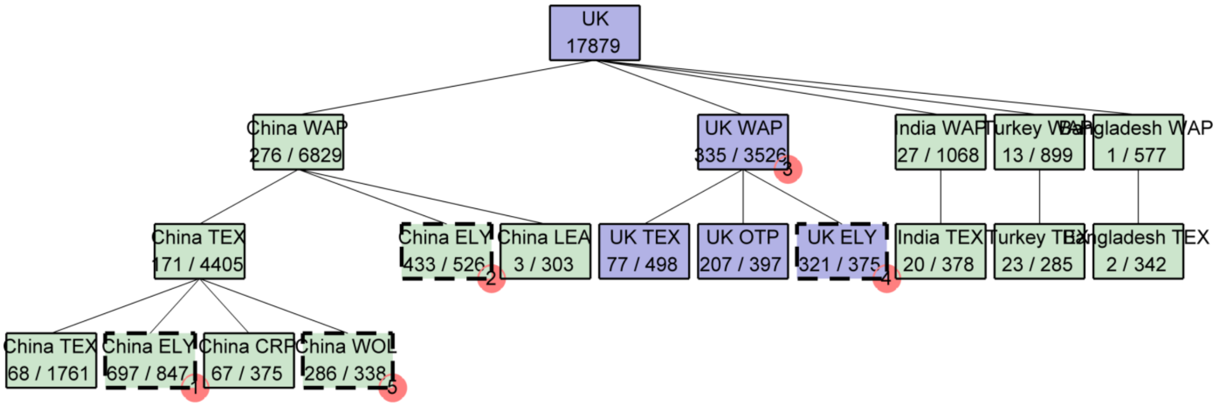

Figure 3: Partial supply chain of clothing purchased by households in the United Kingdom, with GHG emissions indicated as direct / total. The top-five direct contributions to total supply chain emissions are highlighted with red dots. Developed countries are purple, developing green. High emissions-intensity sectors are indicated with dashed boxes.

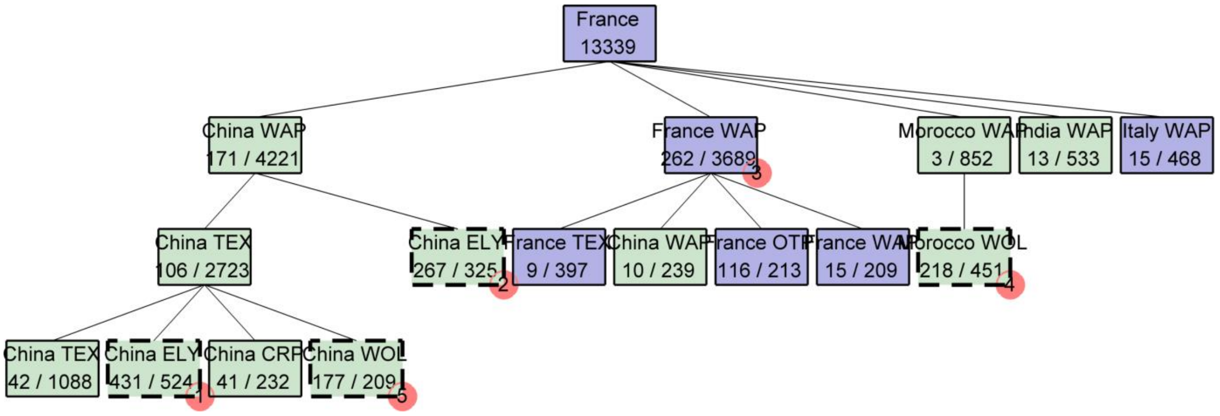

Figure 4: Partial supply chain of clothing purchased by households in France.

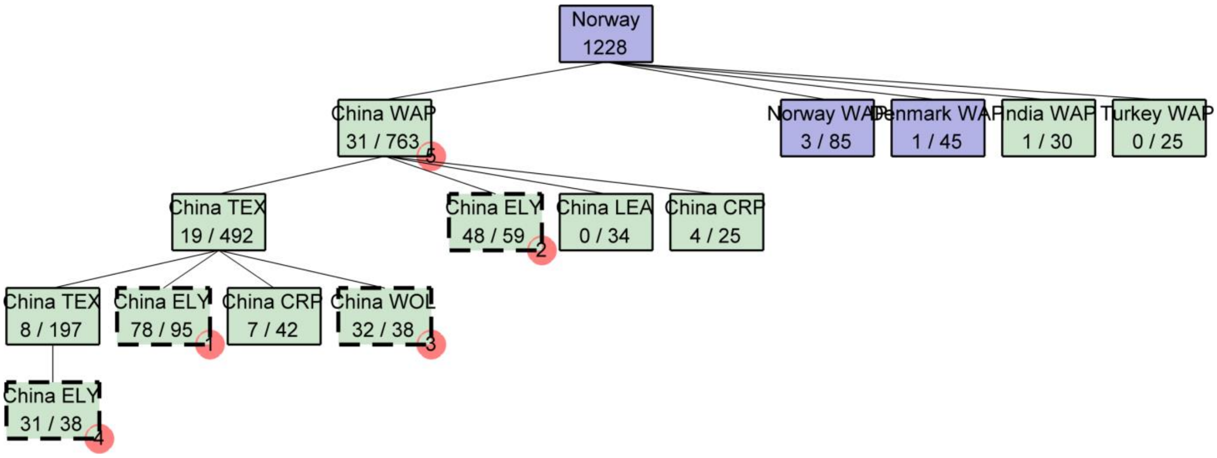

Figure 5: Partial supply chain of clothing purchased by households in Norway.

The largest sectoral contributor to emissions in the clothing supply chains of the three countries was electricity, with between 34% and 41% of total emissions, and Chinese electricity was the largest specific sector (19%–30%). While the direct emissions from the textile and clothing sectors were much lower, those two sectors act as funnels through which the supply flows, and emissions that pass through the textile sector were between 56% and 62% of total clothing emissions.

In the case of Norway, 30% of total emissions in the clothing supply chain occurred in the Chinese electricity sector. Further along the supply chain, the total emissions passing through the Chinese textiles sector were 48% of the total, while those passing through the Chinese clothing sector were

63% of the total supply-chain emissions for clothing sold in Norway to consumers. The French and British supply chains are less concentrated than that of Norway, and the emissions passing through the Chinese clothing sector in each case is 34% and 39%, respectively.

Table 1: Chinese emissions in the supply chains of the clothing sectors of UK, France, and Norway. Direct emissions are concentrated in the electricity sector, but higher proportions of emissions pass through the Chinese textile and clothing sectors

	direct as fraction of total			pass-through as fraction of total		
	UK	FRA	NOR	UK	FRA	NOR
CHN ELY	21%	19%	30%	23%	21%	32%
CHN TEX	2%	2%	3%	34%	31%	48%
CHN WAP	2%	1%	3%	39%	34%	63%

Between 25% and 29% of total emissions in these clothing supply chains were methane and nitrous oxide, much of which is currently unregulated even in countries with carbon regulation.

Meat

For the meat supply chains of these three countries, domestic production is a much higher proportion of total supply, and this is reflected in high domestic contributions to total emissions and value-added (Figure 6). While each of the Home countries had fairly similar levels of imported meat supply into the economy (ranging from 27% for Norway to 30% for the UK), there is a stark contrast in the amount of finished meat imported. France and Norway imported only 4% and 2%, respectively, of the meat that was sold directly to final demand (via the trade sectors), whereas in the UK the figure is over 21%. In particular, meat from Ireland and New Zealand is imported to the UK not only cut but packaged and labelled for the supermarket shelf. Despite this, the proportions of value-added captured by the UK and France are about the same (69% and 67%, respectively).

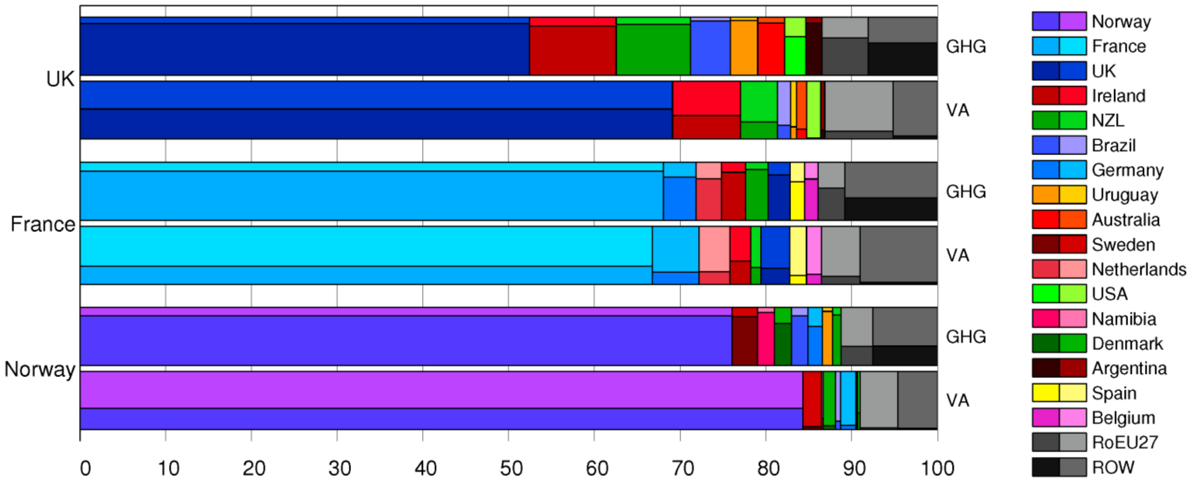

Figure 6: Contributions to total GHG emissions and value-added (VA) in the meat supply chains of UK, France, and Norway. Out of the total contributions of each country, emissions from the ruminant farming sector, and value-added in the meat processing sector are highlighted.

The largest foreign contributors to the UK's emissions supply chain are Ireland, New Zealand, and Brazil (but recall that deforestation emissions are not included in this analysis). While Ireland captures value-added in this supply chain in similar proportion to its emissions contribution, the same cannot be said for New Zealand or Brazil, which both capture less value-added than their emissions would suggest. In the case of New Zealand, the UK purchases about the same physical quantity of meat from Ireland and New Zealand, but meat from the latter is priced significantly lower than meat from Ireland, so that, despite having approximately the same emissions on a physical basis and a similar proportion of value-added in output, the emissions per dollar are much higher. The EU import quota system and other production and preference factors prevent supply and demand from leading to greater consumption of New Zealand meat in the UK.

Emissions from cattle farming form the largest proportion of total emissions for each of the countries shown in Figure 6. However, there appear to be differences between the countries that primarily raise livestock on pasture (e.g., UK, Ireland, New Zealand) and those that use higher proportions of feed concentrates (e.g., USA, Netherlands, Spain, Germany), although further sources would need to be consulted to confirm this interpretation.

There was generally a higher proportion of meat processing in domestic value-added than in value-added in foreign parts of the supply chains, probably because domestic meat processing facilities process not only most domestic animals, but also some imported meat.

Figures 7, 8, and 9 show partial meat supply chains for the UK, France, and Norway, respectively, arranged according to contribution of greenhouse gases. The largest direct emission contributions are rearing of ruminant livestock (CTL), but we also see contributions from the dairy farming sector (RMK), which sells old dairy cattle, and the cropping sector (OCR), which provides feed.

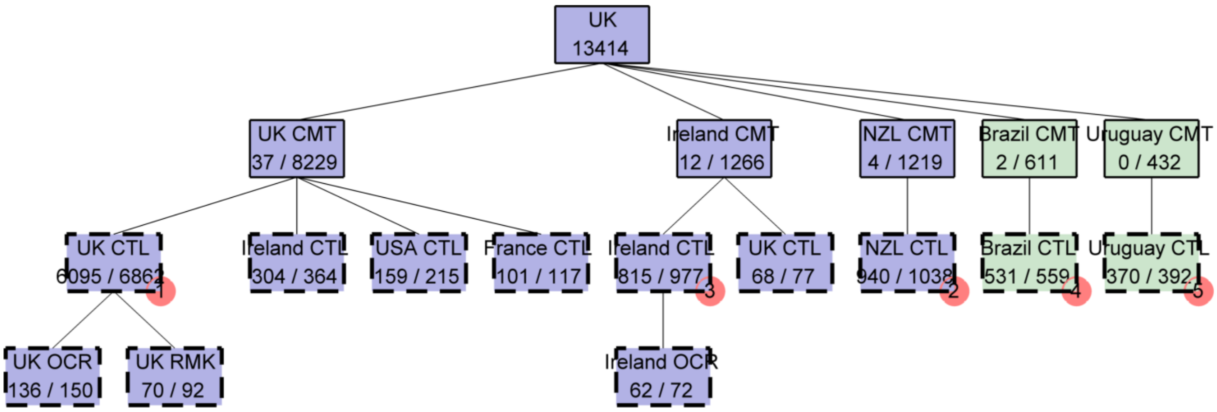

Figure 7: Partial supply chain of meat purchased by households in the United Kingdom.

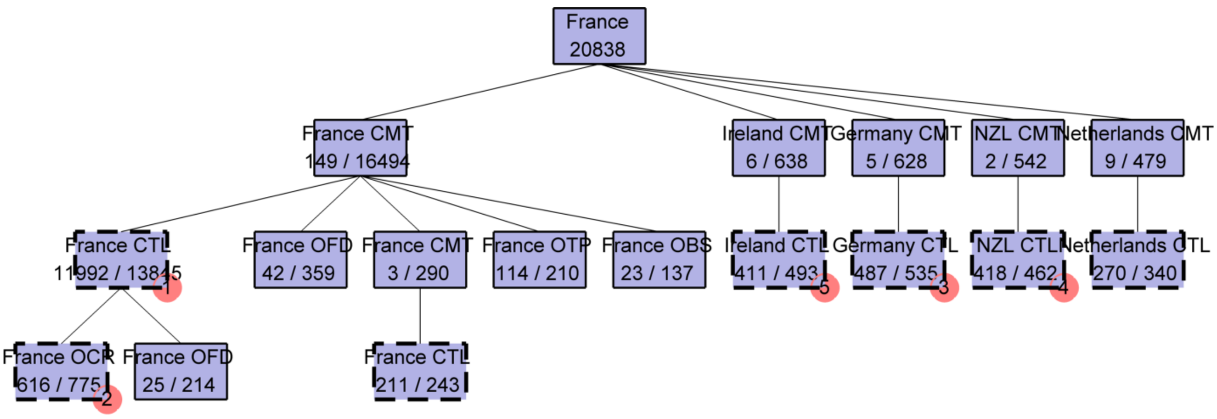

Figure 8: Partial supply chain of meat purchased by households in France.

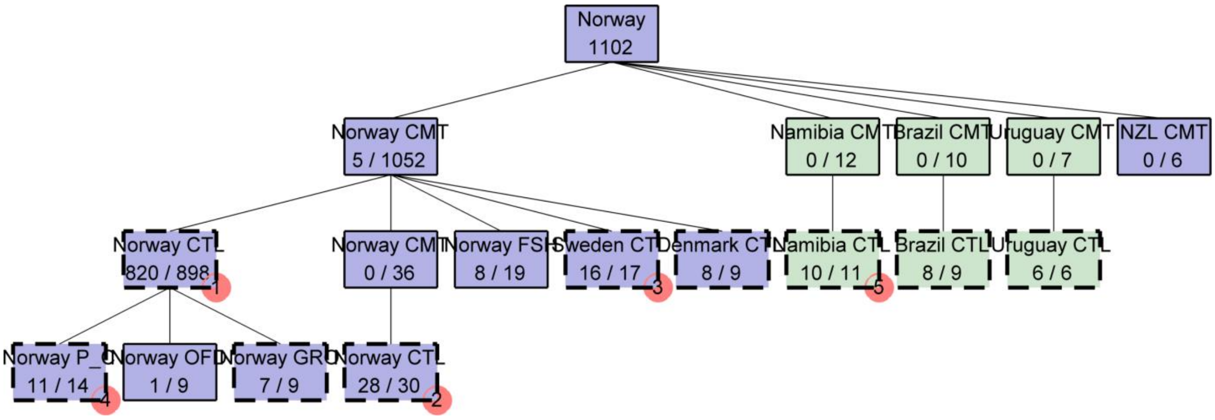

Figure 9: Partial supply chain of meat purchased by households in Norway.

For the meat industry, most emissions occur in the cattle farming sector, which has a very large number of participants (farmers), but most of those emissions pass through the meat processing sector, which has a significantly smaller number of participants. Most emissions (85%–90%) in the supply chains are methane and nitrous oxide, and, based on international negotiations so far, there is little prospect of these emission being regulated in the near future.

Discussion and Conclusions

The geographical contributions to total supply-chain emissions can vary substantially between different commodities and between consuming countries. With the two commodities selected for this study, meat and clothing, there are unsurprisingly strong contrasts not only in the amount imported, and hence imported emissions and proportion of total value-added captured domestically, but also in the countries from which the commodities are imported.

For meat, and among the countries included in our study, Norway presents the simplest case for maximising coverage of GHG emissions under carbon regulation, because of the very high proportion of consumption supplied by domestic production. But while this case might be simplest, there are still significant hurdles to jump before such regulation could be implemented, and non-CO_2 greenhouse gases, which contribute the majority of warming potential in the meat supply chain, seem unlikely to be regulated any time soon. Another perspective on the Norwegian situation is that, because of high import tariffs already in place, border carbon adjustments almost become unnecessary.

As for clothing, our analysis highlights that the largest contribution to supply-chain emissions are from the electricity sector, which is already the most likely in any country to be included in carbon regulation, although isn't yet in China, which produces more than half of all the world's textile fibres. Chinese electricity emissions enter the supply chain in various places, as Chinese textiles are used not only in Chinese clothing manufacture, but also exported for other countries to produce finished garments. If Chinese electricity generation were to be included in carbon regulation, then a good portion of clothing's supply-chain emissions would be covered by this regulation, not to mention the supply-chain emissions of many other commodities. Still, about 25% of clothing's supply-chain emissions are non-CO_2 gases, largely agricultural, and these are unlikely to be regulated any time soon.

Our analysis with greenhouse gas emissions and value-added only tells a part of the story of these supply chains. There are many other benefits and costs in the supply chains of both clothing and meat production, including water consumption, employment, and deforestation, and these additional indicators of global impacts could readily be included in analysis of global supply chains of commodities.

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