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ABSTRACT

In a world where climate goals are global but action remains firmly in the hands of states, reliable methods are needed to ensure that emissions reductions on a national level are not offset by carbon leakage. Appropriate indicators are needed to help policy makers set accurate targets for the carbon balance of their foreign trade and monitor the development of trade in a meaningful way. This paper proposes a new displacement indicator – the technology adjusted balance of emissions embodied in trade – that improves on existing ideas by separating out the effects of scale and composition of trade from the effects of different technologies and energy systems. The new indicator is calculated for Swedish and UK trade from 1995 to 2009, a period when both countries have reported decreasing territorial emissions together with sustained economic growth. One key finding is that, for both countries, outsourcing of emissions is less serious than what conventional analysis of emissions embodied in trade suggests. For Sweden, the technology adjusted balance of emissions embodied in trade is positive throughout the studied period, implying that its exports reduce emissions abroad more than what is generated by its imports. However, we also find that both countries have changed the composition of their imports and exports during this period: imports have become more carbon intensive and, exports less so, compared to the world economy at large.

1. Introduction

Over the last few decades several industrialized countries, among them the UK and Sweden, have reported substantial reductions in territorial carbon emissions in combination with sustained economic growth. This has been interpreted as a successful decoupling of economic growth from carbon emissions (Andersson and Lövin, 2015; Evans, 2015; Aden, 2016).

Many studies, however, (Barrett et al., 2013; Davis et al., 2010; Peters et al., 2011; Li and Hewitt, 2008; Peters and Hertwich, 2008; Wiedmann et al., 2010) have shown that industrialized countries, including the UK and Sweden, are large net importers of carbon emissions embodied in traded goods. It has been suggested that the observed reductions of territorial emissions are largely the result of displacement rather than examples of real decoupling (Davis et al., 2010; Aichele and Felbermayr, 2015; Peters et al., 2012; Baiocchi and Minx, 2010).

To determine to what extent emissions reductions are due to actual decoupling and to what extent they result from displacement we need a reliable method for analyzing carbon transfers in international trade flows. In this paper, we argue that established methods fail to distinguish properly between different drivers of imbalances in flows of embodied emissions and are therefore potentially misleading. We

propose a new method that is better suited to the task. We calculate the indicator for two representative countries to shed new light on the decoupling versus displacement controversy.

The issue is important for many reasons. If countries can meet their emissions targets by outsourcing carbon intensive production this may seriously undermine the efficiency of global climate policy. Conversely, widespread suspicion that national climate mitigation efforts are offset by carbon leakage may undermine the legitimacy of ambitious climate policies.

Spotting carbon leakage has been one motivation behind the development of consumption based carbon accounting methods in recent years (Davis et al., 2010). But the fact that a country is a net importer of emissions embodied in trade is not by itself evidence of emissions displacement.

Emissions displacement means that a country's foreign trade contributes to

i reduced domestic emissions and
ii increased emissions abroad

compared to a no-trade scenario with the same domestic and foreign consumption.

If a country's domestic production, and hence its export, is dominated by light (i.e. low carbon intensity) industry while heavy (i.e. high carbon intensity) industrial goods are imported, this will cause a net increase in direct emissions abroad and a net decrease in domestic emissions, compared to a no trade scenario with the same consumption pattern, and it can therefore be characterized as emissions displacement.

Net embodied imports or exports can also result from general differences in the carbon intensity of production between trading partners that do not contribute to increased emissions abroad. If a country has a more carbon-efficient production or energy system than its trading partners, even an exchange of exactly identical bundles of goods will result in a deficit in emissions embodied in trade (Jakob and Marschinski, 2013).

Kander et al. (2015) show that this latter case holds even if the more carbon-efficient country specializes in more energy intensive goods than what it imports. The exchange thereby results in a net reduction of the trading partner's as well as total global emissions. Clearly, it would be misleading to characterize this type of international exchange as emissions displacement.

To correctly identify emissions displacement, we must separate the effects of scale and composition of exports versus imports from the effects of general differences in carbon intensity between trading partners. Structural decomposition analysis provides a useful tool for this purpose (Copeland and Taylor, 1994; Xu et al., 2011; Xu and Dietzenbacher, 2014; Zhang, 2012; Pan et al., 2008). Jakob and Marschinski (2013) identify four determinants of the flow of embodied emissions in international trade: (i) trade balance; (ii) trade specialization; (iii) average energy intensity of production in the entire economy, compared to that of trading partners; and (iv) average carbon intensity of energy in the entire economy, compared to that of trading partners.

We will argue, however, that decomposing the balance of emissions embodied in trade in this way is not sufficient to solve the problem. This has to do with the definition of trade specialization. On the export side, specialization is defined as the ratio between the carbon intensity of exports and the carbon intensity of the domestic economy at large. On the import side, it is the ratio between the carbon intensity of the imported goods and the carbon intensity of the world economy minus the importing country.

This definition of trade specialization corresponds to standard usage in international trade theory, and would be unproblematic in the present context if the relative differences in carbon intensity between sectors were the same for all countries, and if export constituted the same share of each country's economy. But clearly this is not always the case. As a result, exchange of identical goods between two countries may technically be considered as trade specialization, given that the carbon intensity of the traded goods, relative to the rest of the exporting country's economy, differs. But clearly such exchange does not contribute to increased emissions in any of the two countries, and hence does not amount to emissions displacement.

For example, Sweden has a very carbon efficient energy system compared to the world average. But 10 per cent of domestic emissions and 20 per cent of emissions embodied in Swedish exports are not energy related but result from industrial processes, particularly in the steel and cement industries. In the steel industry, the major source of carbon emissions is the use of coke as a reduction agent in the production of pig iron from iron ore. The same reduction process is standard in steel industries all over the world, but due to Sweden's low carbon energy system, process related emissions make up a much larger share of total carbon emissions in the Swedish steel industry. As a result, even if the absolute carbon intensity in the Swedish steel industry is lower than the world average, its relative carbon intensity compared to the Swedish economy at large is substantially higher than the corresponding relative carbon intensity of the average steel industry compared to the world economy.

An exchange of identical steel products between Sweden and the world market will therefore be considered as Swedish trade specialization in carbon intensive goods on the export side and less carbon intensive goods on the import side. But such exchange of identical goods will not, of course, affect carbon emissions neither in Sweden nor outside. Trade specialization in this sense, therefore, is not a reliable indicator of carbon displacement.

To avoid this problem, and cancel out noise stemming from general differences in carbon efficiency between countries, we propose an analysis where relative carbon intensities of exports and imports are standardized by using the world average carbon intensity for each sector (cf. Kander et al., 2015; Domingos et al., 2016; Kander et al., 2016), and both imports and exports are compared with the carbon intensity of the world economy. In this way, any imbalances in trade related emissions can be attributed to either scale or composition of exports and imports.

This can provide policy makers with options for setting targets for the carbon balance of their foreign trade, and to be able to monitor the development of trade related emissions transfers in a meaningful way.

The technology adjustment suggested here could be seen as a correlate to factor adjustments that have been proposed in international trade theory in order to align theoretical predictions on factor content of trade with empirical observations in the presence of differences in factor productivity between countries (Choi and Krishna, 2004; Davis and Weinstein, 2001; Jakob and Marschinski, 2013; Maskus and Shuichiro, 2009; Reimer, 2006; Trefler and Zhu, 2010).

In our context, the "factor content" – carbon emissions – is an external cost and the idea is not primarily to test trade theoretical hypotheses. The adjustment suggested here serves instead to align national carbon accounting with effects on global emissions, in order to provide better feedback for policy makers.

To test the method, we apply it to Sweden and the UK. The reason for focusing on these two countries is that they have been put forward in the debate as examples of countries that have successfully decoupled economic growth from carbon emissions, providing evidence that a transition to a low carbon economy can be achieved without large economic sacrifice. For example, the Swedish government has claimed that the Swedish case "provides strong evidence that decoupling GDP growth from CO_2 emissions is possible" (Andersson and Lövin, 2015).

Sweden and the UK are similar in many respects, but there are also important differences in energy mix, production technologies and export composition, suggesting that a comparison between them may both shed light on the general decoupling/displacement controversy and generate relevant insights into how these differences affect displacement effects.

Table 1 shows that, regarding carbon intensity of energy and energy intensity, the UK is very similar to the average European Union country, whereas Sweden has a much more energy intensive economy, more similar to the world average than to other European countries. At the same time the carbon intensity of the Swedish energy mix is less than half of that of the UK, the EU or the world average.

Trade also makes up a very large share of the Swedish economy, compared to the UK, the EU or the world at large, and since a large proportion of Swedish export is in energy heavy basic industrial products such as steel and forestry, differences in carbon intensity of energy could have a great impact on the carbon balance in trade.

2. Methods

2.1. Environmentally extended input-output framework

The study is conducted within the framework of environmentally extended input-output analysis. Data on trade flows and carbon emissions intensities in different production sectors and countries were retrieved from the World Input Output Database, WIOD (Timmer et al., 2015; Dietzenbacher et al., 2013), which contains detailed information

Table 1
Summary of trade, energy, and carbon statistics for the UK, Sweden, EU and World.

Time	Trade (% of GDP)	CO_2 intensity (kg per kg of oil equivalent energy use)	Energy intensity (MJ/ $2011 PPP GDP)	Electricity from oil, gas and coal sources (% of total)	Electricity from hydroelectric sources (% of total)	Electricity from nuclear sources (% of total)
Sweden						
1995	70	1.10	7.69	5	46	47
2000	82	1.04	6.10	3	54	39
2005	85	1.00	5,81	2	46	46
2009	83	0.95	5.01	3	48	38
United Kingdom						
1995	51	2.49	5.48	71	1	27
2000	52	2.43	4.82	74	1	23
2005	52	2.44	4.19	74	1	21
2009	55	2.41	3.67	74	1	19
European Union						
1995	56	2.40	5.40	54	12	32
2000	69	2.31	4.81	54	12	31
2005	70	2.25	4.60	55	10	30
2009	68	2.17	4.13	53	11	28
World						
1995	44	2.48	7.18	62	19	18
2000	51	2.46	6.49	64	17	17
2005	56	2.51	6.19	66	16	15
2009	52	2.55	5.78	67	16	13

Data Source: The World Bank (2017).

on 41 countries (collectively covering ~95% of global GDP) divided into 35 sectors, including 27 EU and 13 other major economies, plus an aggregated "rest of world" region.

WIOD is one of several MRIO databases available to input–output researchers. Other databases include the EORA, GTAP-MRIO, OECD-Tiva and Exiobase. We choose to use WIOD as it offers a complete set of global input-output tables and environmental satellite accounts at homogenous sectoral classification, which is critical for our analysis in order to estimate the world average technology over a long term.

Each of these databases has its own set of strengths and weaknesses. For example, the full EORA has a much higher sector resolution and extends further in time, but the sector partitioning is not homogenous, and therefore does not support comparisons with world average. The homogenous version of EORA, on the other hand, contains only 26 sectors. Exiobase also has higher sector resolution than WIOD, but has been published only for one year. There is a more recent release of WIOD, which covers the period 2000–2014, but as yet it does not contain environmental accounts that are needed for our purpose. The 2013 release of WIOD, which we have used, strikes a balance between sector resolution, homogeneity and time extension, which makes it suitable for the current purpose.

Emissions in traded goods are traced through the value chain, from producer to final consumer, using IO analysis developed by (Leontief, 1936). The standard IO model can be expressed as:

$$x = Ax + f \tag{1}$$

Where x is the vector of total output, A is the matrix of technical coefficients, f is the final consumption vector. Solving the above equation for x gives:

$$x = (I - A)^{-1}f = Lf \tag{2}$$

where $(I - A)^{-1}$ is known as the Leontief inverse or the total requirement matrix. Its elements capture direct and indirect effects from a unit change in final demand.

Emissions embodied in trade are obtained by pre-multiplying the above equation with the carbon intensity vector, as follows:

$$C = \hat{e}Lf \tag{3}$$

In more detail:

$$\begin{bmatrix} c_{11} & \cdots & c_{1j} \\ \vdots & \ddots & \vdots \\ c_{i1} & \cdots & c_{ij} \end{bmatrix} = \begin{bmatrix} e_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e_i \end{bmatrix} \times \begin{bmatrix} l_{11} & \cdots & l_{1j} \\ \vdots & \ddots & \vdots \\ l_{i1} & \cdots & l_{ij} \end{bmatrix} \times \begin{bmatrix} f_{11} & \cdots & f_{1j} \\ \vdots & \ddots & \vdots \\ f_{i1} & \cdots & f_{ij} \end{bmatrix} \tag{4}$$

Where e is the vector of direct carbon intensities (CO_2 emissions per unit of output) for each sector and the ˆ operator denotes diagonalization. The pollution matrix C represents emissions associated with the production of goods and services in country i to satisfy final demand in country j. Diagonal elements (i.e., $i=j$) of the C matrix represents domestic pollution (d) due to domestic consumption $p_i^d = p_{ii}$.

Emissions embodied in exports, CEX_i, and imports CM_i, of country i can be calculated as follows:

$$CEX_i = \sum_{j \neq i}^{n} c_{ij} \tag{5}$$

$$CM_i = \sum_{j \neq i}^{n} c_{ji} \tag{6}$$

In the standard model, a country's balance of emissions embodied in trade, BEET, is calculated as the difference between the carbon missions embodied in its exports, e_i^{ex} and in e_i^m its imports

$$BEET_i = CEX_i - CM_i \tag{7}$$

Emissions embodied in exports are all direct emissions that have occurred within the country's borders as the result of production of goods that are finally consumed somewhere else. Likewise, emissions embodied in import are all direct emissions that have occurred outside the country's borders as the result of production of goods that are finally consumed in the country.

2.2. Adjusting for technology differences

As we argue in the introduction, the standard concept of BEET is not suitable for analyses of emissions displacement and carbon leakage. We therefore propose an alternative indicator, where irrelevant effects of general differences in energy systems and production technologies between countries have been cancelled out, to illuminate what is really interesting: specialization in heavy or light imports and exports and monetary balance of trade. We call this a technology-adjusted balance of emissions embodied in trade (TBEET).

The basic idea of TBEET is to standardize the relative carbon intensities for similar or identical products on the import and the export side by using the average carbon intensity on the world market for each sector. This will avoid spurious effects on the balance from similar goods being imported and exported. Admittedly, also a SRIO (single-region IO table), with domestic technology assumption for imports and exports, would in principle have achieved the same goal, but the additional benefit of using world average technology is that the cardinal ranking of export and import groups in terms of carbon intensity will be correct on the world scale, and also the construct will be additive. It will also be scale invariant, i.e. it will not matter if we study the sum of nations within EU or the EU as one unit of analysis, the results will be the same.

Let subscript s denote sector s and let $o_{i,s}$ be the total output of sector s in i. The carbon intensity $e_{i,s}$ is defined as

$$p_{i,s} = \frac{c_{i,s}}{o_{i,s}} \tag{8}$$

The world average carbon intensity p_i^{WA} can be defined as

$$p_s^{WA} = \frac{\sum_i^n c_{i,s}}{\sum_i^n o_{i,s}} \tag{9}$$

The technology-adjusted emissions embodied in exports, which we will label CEX_i^{WA}, are defined as the emissions that i's exports *would have* caused if the same products had been produced with world average technology:

$$CEX_i^{WA} = \sum_{j \neq i}^n c_{ij}^{WA} \tag{10}$$

Similarly

$$CM_i^{WA} = \sum_{j \neq i}^n c_{ji}^{WA} \tag{11}$$

c_{ij}^{WA} is calculated in the same way as c_{ij}, except that country specific carbon intensities p_i are replaced by world average (WA) carbon intensities e_i^{WA}, this gives $C^{WA} = \hat{e^{WA}}Lf$.

2.3. Decomposition

We use the additive form of the refined Laspeyres index method (RLIM) to calculate the contributions of scale and composition of exports and imports to a country's technology adjusted balance of emissions embodied in trade, TBEET. Although the additive refined Laspeyres index decomposition is not as commonly used as the logarithmic mean Divisia index method (LMDI), both methods have been widely used in decomposition studies and have the advantage of not leaving any unexplained residual term (Sun, 1998; Sun and Ang, 2000).

Jakob and Marschinski (2013) use a similar method to decompose the standard BEET, into four different drivers: (i) trade balance; (ii) trade specialization; (iii) average energy intensity of production in the entire economy, compared to that of trading partners; (iv) average carbon intensity of energy in the entire economy, compared to that of trading partners.

Since the effects of differences in energy intensity of production and carbon intensity of energy are cancelled out in our model, only the first two factors remain in our analysis. Moreover, trade specialization is given a slightly different definition in our analysis, and as we show in Section 3.2, the empirical results differ fundamentally from those of Jakob and Marschinski (2013). In their analysis, export specialization is defined as the ratio between the carbon intensity of a country's export and the average carbon intensity of its entire domestic economy:

$$sp_i = \frac{\left(\frac{CEX_i}{EX_i}\right)}{\left(\frac{C_i}{GDP_i}\right)} \tag{12}$$

If this ratio is positive, the country specializes in exporting products that are relatively carbon intensive compared to the rest of the domestic economy.

This definition of trade specialization corresponds to standard usage in international trade theory but, as we argued in the introduction, may provide misleading results when used as a tool for analyzing carbon displacement.

In our analysis, the carbon intensity of exports as well as imports is calculated on the assumption that it was produced with world average carbon intensities for each sector, and these intensities are then divided by the carbon intensity of the world economy at large:

$$sp_i^{WA} = \frac{\left(\frac{CEX_i^{WA}}{EX_i}\right)}{\left(\frac{C_w}{GDP_w}\right)} \tag{13}$$

If this ratio is positive, the country specializes in exporting products that are relatively carbon intensive compared to the world economy.

The final decomposition into two factors − specialization, ΔC_i^{sp}, and trade balance, ΔC_i^{TB} – can then be written as:

$$\Delta C_i^{sp} = \left(\frac{CEX_i^{WA}}{EX_i} - \frac{CM_i^{WA}}{M_i}\right)*M_i + \frac{1}{2}*\left(\frac{CEX_i^{WA}}{EX_i} - \frac{CM_i^{WA}}{M_i}\right)*(EX_i - M_i) \tag{14}$$

$$\Delta C_i^{TB} = \frac{CM_i^{WA}}{M_i}*(EX_i - M_i) + \frac{1}{2}*\left(\frac{CEX_i^{WA}}{EX_i} - \frac{CM_i^{WA}}{M_i}\right)*(EX_i - M_i) \tag{15}$$

For purposes of comparison with previous results, our analysis will also include a four-factor decomposition of the standard BEET for the UK and Sweden, using the same method as Jakob and Marschinski (2013), but applied to the WIOD data.

3. Results

3.1. Development of emissions for the UK and Sweden

Fig. 1 presents territorial, or production based (PBA), and consumption based (CBA) emissions for the UK and Sweden from 1995 to 2009. The balance of emissions embodied in trade (BEET) is equal to the difference between PBA and CBA. A negative BEET indicates net import of embodied emissions. As Fig. 1 shows this is the case for the UK as well as for Sweden.

Fig. 1 also outlines the development in the technology adjusted TBEET measure to illustrate how it differs from the traditional BEET measure.

For the UK, TBEET and BEET are both negative since 1998, but TBEET somewhat less so than BEET. This indicates a stable result with both methods, suggesting that Britain has specialized in importing more heavy goods and exporting more light products.

For Sweden, TBEET is positive in contrast to BEET that is negative throughout the whole period. But a worrying sign for policy makers is that the positive carbon balance of trade for Sweden is diminishing over time. What has happened after 2009 is not possible to say without more recent MRIO data, but a fair suspicion is that the negative trend for TBEET has continued, changing Sweden into a net displacer of carbon emissions through its international trade patterns.

For Sweden, the BEET corresponds to 25 to 40 per cent of total emissions. The magnitude of the TBEET is smaller, corresponding to less than 25 per cent throughout the period. For the UK, the BEET corresponds to 10 to 25 percent of total emissions, whereas the TBEET is smaller than the BEET for all years except 2009, and never exceeds 15 per cent of total emissions.
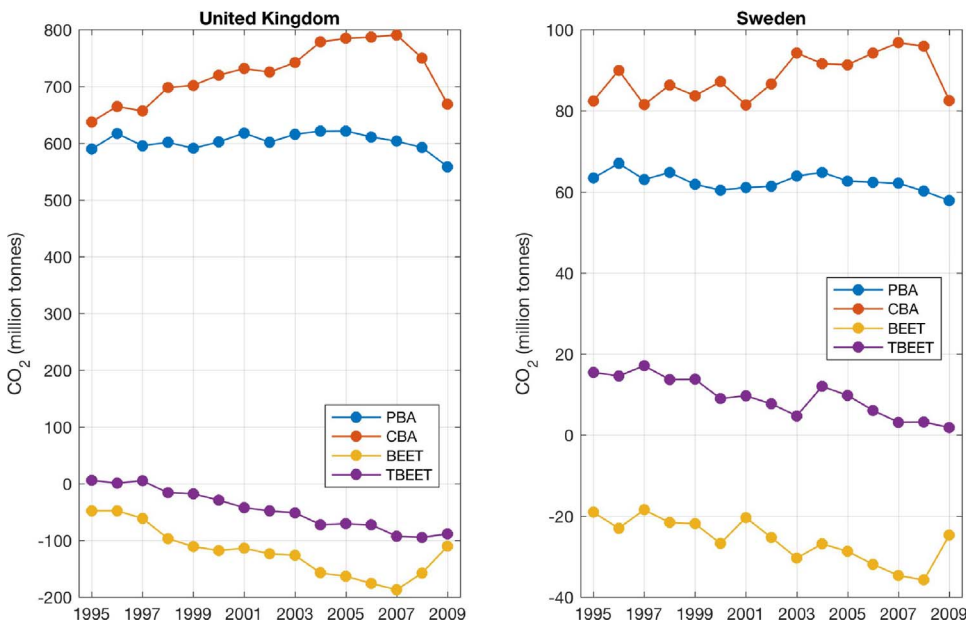
Fig 1. Swedish and UK emissions and emissions in trade, 1995–2009. Note: PBA = production based account, CBA = consumption based account, BEET = balance of emissions embodied in trade, TBEET = technology adjusted balance of emissions embodied in trade.

For both countries, the change in TBEET over the period exceeds the decrease in production-based emissions. This clearly shows that changes in TBEET can have significant impact on emission trends.

It also implies that Swedish and UK claims to have managed to decouple economic growth from carbon emissions growth must be toned down. It is common to distinguish between absolute and relative decoupling, the former signifying an absolute reduction of emissions together with GDP growth, the latter a slower growth rate in emissions than in GDP, leading do decreasing carbon intensity of the economy albeit no reduction of absolute emissions.

Based on official records of territorial carbon emissions, both the UK and Sweden claim to show absolute decoupling. If the territorial emissions trend is adjusted for changes in TBEET, however, this is not correct.

Fig. 2 shows the development of GDP, territorial emissions (PBA) and territorial emissions adjusted for displacement (PBA-TBEET) for the UK and Sweden, using 1995 as base year with index 100. As can be seen, both countries show relative decoupling, but none of them have decoupled economic growth from carbon emissions in the absolute sense.

3.2. Decomposition

For purposes of comparison, we first apply the four-factor decomposition analysis proposed by Jakob and Marschinski (2013) to the BEET of UK and Sweden. Fig. 3 shows the contribution of the four different factors to the BEET for the UK and Sweden.

According to Fig. 3 it appears that the negative BEET for Sweden is driven entirely by the low energy intensity of the economy (compared to its trading partners) and the low carbon intensity of energy. Trade balance and specialization work in the opposite direction. The positive contribution of trade specialization has increased over the period, so it appears that reduced domestic emissions have been achieved together with an increased specialization towards carbon intensive exports and less carbon intensive imports. We will soon show, however, that this image changes drastically with the TBEET indicator proposed in this paper.

For the UK, the analysis suggests that the bulk of the negative British BEET is driven by energy intensity of the economy (the UK being more energy efficient than its trading partners). Trade balance and trade specialization exhibit no clear pattern.

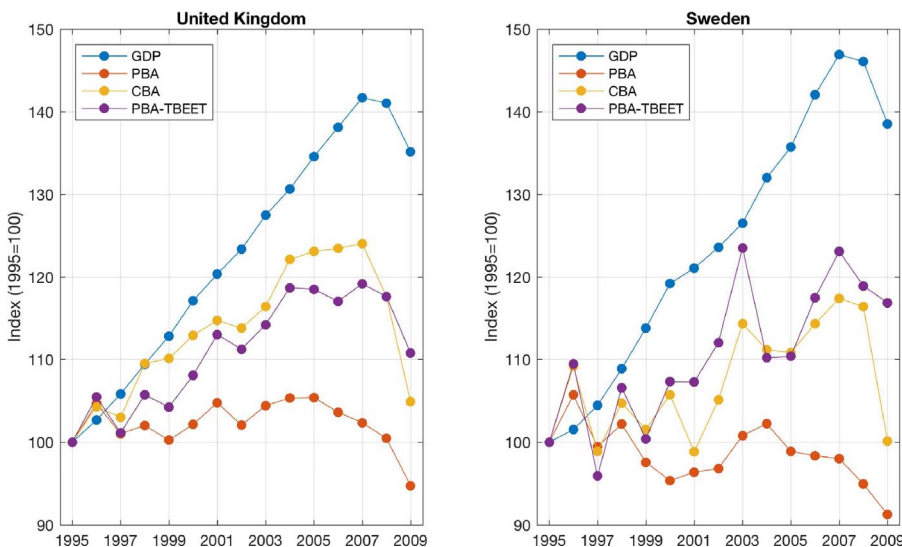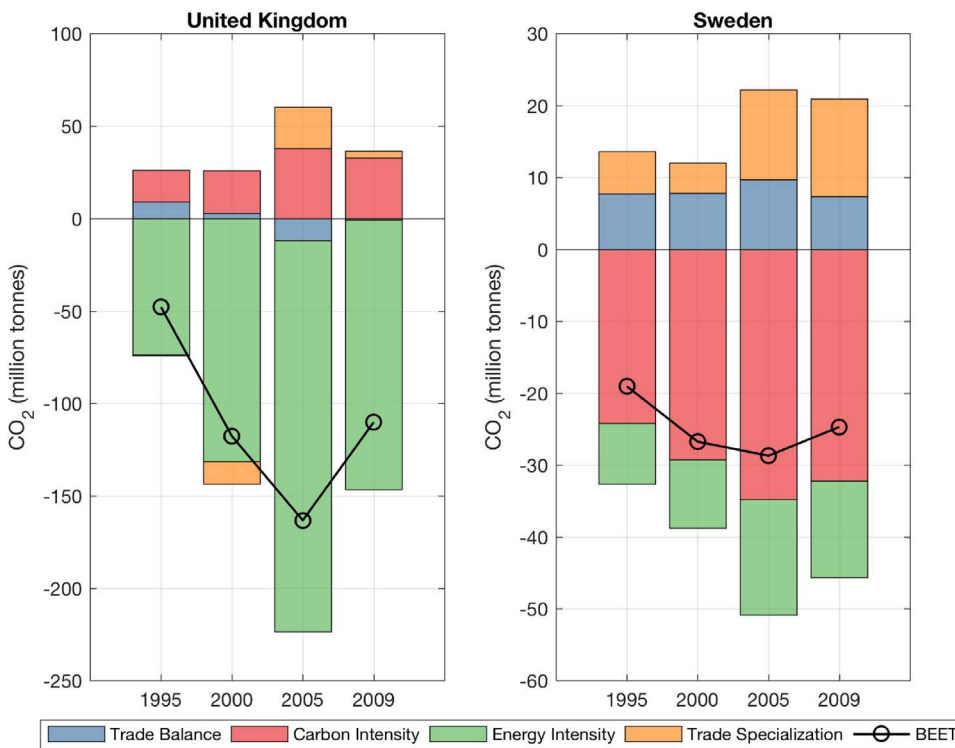Thus, a structural decomposition analysis of the UK and Swedish

Fig. 2. Indices of GDP, territorial emissions (PBA), consumption based (CBA) and territorial emissions adjusted for displacement (PBA-TBEET) for the UK, base year 1995 = 100.

Fig. 3. Decomposition of the BEET for the UK and Sweden into monetary trade balance, carbon intensity of energy, energy intensity of economy and trade specialization effects.

BEET does not support the displacement hypothesis for any of the countries.

However, as our further analysis will show, this result is largely an effect of the standard definition of specialization, where exchange of identical products can be diagnosed as trade specialization if the relative carbon intensity of similar sectors, compared to the average carbon intensity of the whole domestic economy, vary between countries.

In our further analysis, we have therefore standardized the relative carbon intensities of each sector in export and import, by calculating carbon intensity on the assumption that all traded goods were produced with world average carbon intensity for the relevant sector, and comparing with the carbon intensity of the global economy.

The resulting technology adjusted balance of emissions embodied in trade, TBEET, can then be decomposed into only two drivers: trade balance and specialization. The result for the UK and Sweden is given in Fig. 4.

For the UK, trade specialization has a clearly negative impact and is the main driver of the increasingly negative TBEET throughout the period. The negative impact from trade specialization is also increasing over time. The impact from trade balance is much weaker and varies over the period.

This indicates that the UK is indeed outsourcing carbon emissions by importing more carbon intensive goods than it exports, and that the outsourcing of emissions is growing steadily throughout the period.

This contrasts with the conclusions suggested by the previous four-factor decomposition of the standard BEET, where the impact from British trade specialization was more ambiguous.

The contrast is even sharper in the Swedish case. For Sweden, the impact of trade specialization appeared to be positive throughout the period in the decomposition of the standard BEET. When differences in technology are completely adjusted for, the impact of specialization shows to be negative, and increasingly so over the period. Only for the first few years it is still positive, indicating that since 2002 the Swedish trade has turned from specializing in export of heavy industrial (carbon intensive) goods to importing more carbon intensive products than it exports. However, the impact from monetary trade balance outweighs

the negative effect of trade specialization. The fact that Swedish TBEET remained slightly positive in 2009 is explained by a consistent positive monetary trade balance.

For both Sweden and the UK, the impact from trade specialization has thus become more and more negative over the period. This could be due to a shift in the export structure towards less energy heavy and carbon demanding products, or a shift in the import structure towards more energy heavy and carbon demanding products, or both.

Fig. 5 shows the development of the impact from trade specialization divided between imports and exports for the UK and Sweden. The analysis shows that for both countries the export structure has become less carbon intensive and the import structure more carbon intensive, although the trend is much more pronounced for the UK. This supports the conclusion that both countries have reduced domestic emissions, at least partly, by reorienting domestic production structure towards less carbon intensive goods and imports towards more carbon intensive goods.

4. Discussion

Our analysis shows that the proposed TBEET provides new and more reliable results regarding emissions displacement in international trade flows than standard balance of emissions embodied in trade.

One key observation is that, for both countries studied, outsourcing of emissions is less serious than what conventional analysis of emissions embodied in trade suggests. For Sweden, TBEET is even positive throughout the studied period, implying that there is no net displacement of carbon emissions. This means Swedish exports continue to contribute to avoiding more emissions abroad than what is caused by Swedish imports, even if this effect is declining and might switch sign in the near future (or perhaps already has, given that the most recent data are from 2009). This can be interpreted as Sweden supplying heavy products to the world that are elsewhere produced with worse carbon efficiency. For the UK, TBEET indicates some net displacement of carbon emissions, but to a lesser extent than what standard BEET analysis suggests.

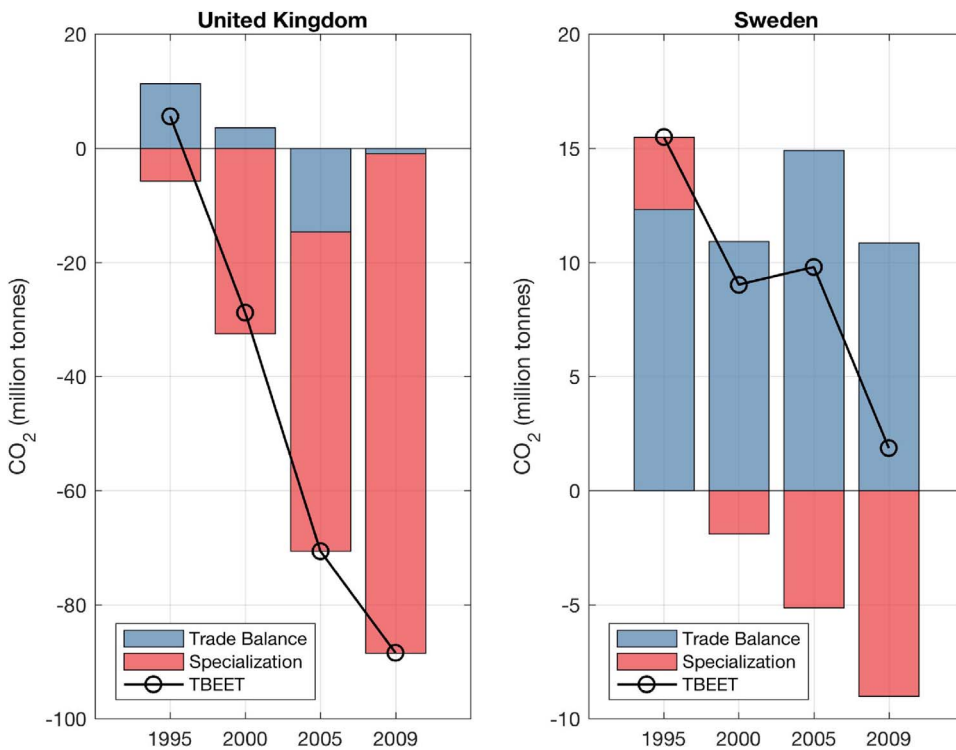Results in this study also reveal, however, that at least part of the

Fig. 4. Decomposition of the TBEET for the UK and Sweden into monetary trade balance effect and trade specialization effect.

observed reductions of territorial emissions in the UK and Sweden over the period 1995 to 2009 were offset by changes in the structure of foreign trade, which can be characterized as increased displacement. This is due to changes in the composition of imports as well as exports. The structure of imports is substantially more carbon intensive than exports for both countries at the end of the period, even when global technology differences of different commodity groups have been taken into account, and the gap is increasing.

Since our analysis covers only two nations, a limited time period and not all greenhouse gases, we cannot exclude the possibility of some real decoupling taking place in other developed economies, and certainly it does not prove that decoupling is impossible, but the analysis as such does not support the claim that absolute decoupling has taken place in the UK and Sweden in this period.

In our analysis, outsourcing of emissions can be attributed to either general trade imbalances or to the composition of export and import portfolios, or both. In the long run, however, trade imbalances also affect investment patterns: a country with a long-term trade surplus will over time invest more abroad than foreign investments within its borders. In current consumption based accounting no distinction is made between consumption and investments, so emissions related to foreign investments are accounted for as domestic consumption. This is an accounting principle that could be disputed. One possible area for future development of carbon accounting, which might contribute to a deeper understanding of how trade affects global emissions, would therefore be to develop models that separate between consumption and investments and take into account patterns of foreign investments.

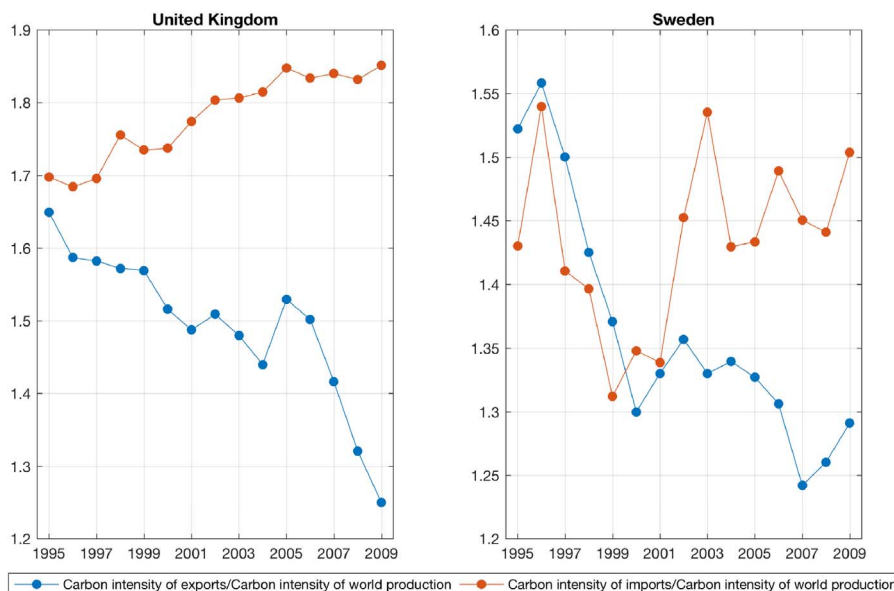It should be noted that displacement is not always bad for the global

Fig. 5. Impact from trade structure for the United Kingdom and Sweden.

climate. If countries with more carbon intensive energy and production technologies than the world average specialize in less heavy industrial exports and instead import those commodities, this will be good for the climate. The ideal is not that all countries should have carbon neutral foreign trade. Rather, from the perspective of globally climate efficient distribution of production, each country should specialize according to comparative carbon advantages (Antweiler et al., 2001; Atkinson et al., 2011; Su and Thomson, 2016). That is, countries that are better endowed with for example renewable energy resources should focus on producing and exporting energy demanding goods – and hence show a positive TBEET – whereas countries with less renewable energy resources should focus on producing less energy demanding goods – and may therefore show a negative TBEET.

It is worrying, however, that countries like Sweden, with good access to hydropower and wind, and energy efficient production, and the UK, with energy efficient production, appear to be increasingly displacing carbon intensive production to countries that are less well-endowed in these respects. Also, for any country, it is clearly the case that any gains in domestic carbon efficiency can be lost if there is a parallel change of structure in export and import that increases displacement.

We suggest that the method of analysis proposed in this paper could serve as a useful complement to other climate policy monitoring instruments, and provide decision makers with valuable information about the global efficiency of domestic climate mitigation efforts.

After the Paris agreement, nations are faced with the challenge of living up to mitigation commitments stated in their Nationally Determined Contributions (NDCs). To this date 161 countries have submitted NDCs or Intended NDC's (INDCs). Most developed countries have submitted absolute targets for domestic emissions reductions, but some large rapidly emerging economies – most notably China and India – have submitted targets that are relative to their GDP growth, thereby allowing for increased domestic emissions in absolute terms. This mix of absolute and relative targets is probably a necessity for the agreement to be politically viable, but it also means that decision makers in countries with absolute commitments must ensure that national efforts are not offset by structural outsourcing to countries with only relative commitments.

For countries with carbon efficient energy mix and energy intensive export industries, an effective policy for reducing global emissions needs to strike a fine balance between incentivizing carbon efficiency and preserving competitiveness in those heavy industries. For such countries, policies that result in a shift to lighter production will be identified as effective from a pure CBA as well as a pure PBA perspective. The TBEET analysis shows that the real effect on global emissions might well be negative.

To avoid such counterproductive effects, national policy instruments such as carbon taxes, cap-and-trade systems and border tax adjustments should be designed to take relative carbon efficiency – as compared to similar production in other countries – into account.

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