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International trade undermines national emission reduction targets: New evidence from air pollution

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ABSTRACT

Many developed countries in Annex B of the Kyoto Protocol have been able to report decreasing emissions, and some have officially fulfilled their CO_2 reduction commitments. This is in part because current reporting and regulatory regimes allow these countries to displace emissions intensive production offshore. Using a new highly detailed account of emissions embodied in international trade we investigate this phenomenon of emissions leakage. We independently confirm previous findings that adjusting for trade, developed countries emissions have increased, not decreased. We find that the sectors successfully holding or lowering their domestic emissions are often the same as those increasing their imports of embodied CO_2. We also find that the fastest growing flow paths of embodied CO_2 largely originate outside the Kyoto Annex B signatory nations. Finally, we find that historically the same phenomenon of emissions displacement has already occurred for air pollution, with the result that despite aggressive legislation in major emitters total global air pollution emissions have increased. If regulatory policies do not account for embodied imports, global emissions are likely to rise even if developed countries emitters enforce strong national emissions targets.

1. Introduction

The shifting of CO_2 emissions from developed to developing countries is a substantial and growing problem. CO_2 leakage was not formally addressed in the initial Kyoto Protocol discussions as it was anticipated to be a minor issue or one to be addressed later (Intergovernmental Panel on Climate Change, 1995). However estimates now indicate that it is not minor, and that up to 30% of global emissions are linked to production for export (Aichele and Felbermayr, 2012; Andrew et al., 2013; Caldeira and Davis, 2011; Chen and Chen, 2011; Hertwich and Peters, 2009; Nakano et al., 2009; Peters and Hertwich, 2008b; Peters et al., 2011a, 2011b). A consumption-based inventory of the UK found that growing consumption in the country was supplied by emissions-intensive imports, not new domestic production. Consequently the UK's total carbon footprint increased 12% between 1992 and 2004, not decreased by 5% as its territorial emissions inventory showed (BBC News, 2008; Wiedmann et al., 2008, 2010). A recent UK study recommended that consumption-based inventories be constructed as a complement to current territorial emissions inventories (Barrett et al., 2013). In China, estimates show that in 2005 nearly 30% of emissions were linked to production for export (Feng et al., 2013; Weber et al., 2008). Since export production has played a major role in its emissions growth (Minx et al., 2011), China has argued that responsibility for emissions should lie not just with the producer but also with the final consumers of goods (BBC News, 2009; Information Office of the State Council of China, 2011; Leggett, 2011). For nearly all large economies the discrepancy between their territorial emissions and their actual carbon footprint is growing.

This study uses a new set of high-resolution global multi-region input–output (MRIO) tables (Lenzen et al., 2012a, 2013b) to investigate flows of embodied CO_2 and air pollution over time. The Eora tables provide high sector detail, cover 187 countries, and offer a true, not interpolated or proxy-estimated, timeseries from 1970 to 2011.

Here we present several findings. First, we are able to independently confirm previous findings that adjusting for trade, developed countries emissions have increased, not decreased. Independent confirmation of this result is important given the prominence of consumption-based accounting in setting national and international GHG reduction targets. Our inventories also consider non-CO_2 GHGs, and we confirm the burden-shifting effect is similar, or stronger, for these gasses. Second, we find that the sectors successfully holding or lowering their domestic emissions are the often the same as those increasing their imports of embodied CO_2. This suggests that it is not cleaner production or

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consumption patterns that are reducing domestic emissions, but simply burden-shifting of the same emissions-intensive activities. Third, we find that 72% of the 200 fastest-growing flows of embodied CO_2 originate outside the Kyoto Annex B signatory nations. These fastest growing flows transport embodied emissions from developing countries both to developed and other developing countries. Finally, we find that historically the same phenomenon of emissions displacement has already occurred for air pollution. The result has been that despite aggressive legislation of SO_2, NO_x and PM_{10} in major emitters, total global air pollution emissions have increased.

2. Materials and methods

All results are based on the Eora environmentally extended multi-region input-output (MRIO) table (Lenzen et al., 2012a, 2013b) and are available online at http://worldmrio.com. Input–output tables have long been used to re-attribute pollution from production to final consumers (Kanemoto et al., 2012; Lenzen et al., 2004; Leontief and Ford, 1971; Peters, 2008; Wiedmann, 2009), including for calculating carbon footprints. Eora is one of a new generation of such systems robust enough for policy use (a survey of current systems is provided by Tukker and Dietzenbacher, 2013 and Wiedmann et al., 2011). Eora advances the state of the art by covering all UNFCCC countries – not just regions or a subset of countries – and provides a consistent, accurately modeled time series from 1970 to 2011, significantly improved detail, non-CO_2 emissions, and confidence estimates for all results. While it has been shown that increasing the resolution of embodied CO_2 models does not alter the basic results (Davis and Caldeira, 2010; Peters et al., 2012), accurate models with complete country coverage are required for policy applications.

The MRIO table can be used to estimate consumption-based inventories of CO_2 and other greenhouse gas emissions. Eora covers 15,909 sectors across 187 countries with IO tables modeled for each year and thus offers substantially more breadth, detail, and accuracy than has yet been achieved. The Eora MRIO also incorporates data on trade in services. However these data are often less detailed and thus the MRIO model has higher uncertainty about embodied emissions transfers due to trade in services. Another limitation of the model used in this study is poorer data availability in 1970–1989. The MRIO in those years is built using the 1990 MRIO table as an initial template then using the constrained optimization method described in (Lenzen et al., 2012a) with UNSNA MA and OC data as constraints.

The Leontief demand-pull model used to construct consumption-based inventories is a workhorse model that has been well described since its introduction (Leontief, 1986; Leontief and Ford, 1970). For a detailed explanation of how this model is implemented with the Eora MRIO the reader is referred to previously published descriptions (Lenzen et al., 2012b, 2013a). Briefly, the method proceeds as follows. Territorial environmental emissions F can be decomposed into consumption-based environmental emissions and embodied environmental emissions in export and import for country S using an MRIO table following Kanemoto et al. (2012):

$$\underbrace{F_j^s}_{\text{production}} \quad \sum_r f_i^r \left[\underbrace{\sum_{it} L_{ij}^{rt} y_j^{ts}}_{\text{consumption}} - \overbrace{\underbrace{\sum_{it \neq s} L_{ij}^{rt} y_j^{ts}}_{\text{imports}} + \underbrace{\sum_{it \neq s} L_{ij}^{rs} y_j^{ss}}_{\text{exports}}}^{\text{net trade balance}} \right]$$

$$= \sum_r f_i^r \left[\sum_i L_{ij}^{rs} y_j^{ss} + \sum_{it \neq s} L_{ij}^{rs} y_j^{st} \right] = \sum_r f_i^r \sum_{it} L_{ij}^{rs} y_j^{st}$$

where f is emissions intensity, r is the emitter country, L is the Leontief inverse, y is final demand, and i and j are the sectors of origin and destination. "Consumption" covers consumption-based emissions and "imports" means the embodied emissions in imports, where t is the supplying (most recent seller) region and s is the destination country (region). "Exports" covers embodied emissions in exports where s is the last selling and t is the destination region.

Rather than relying on just one emissions data source Eora provides an timeseries of GHG gas and air pollutant emissions built on multiple data sources including: GHG data from the Emission Database for Global Atmospheric Research (EDGAR), the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory, Eurostat, energy data, linked to CO_2 emissions, from the IEA/OECD, the Energy Information Administration (EIA), the United Nations Statistics Division (UNSD), and Eurostat. All results presented here for CO_2 are exclusive of emissions from land use, land-use change and forestry (LULUCF). It should be noted that Guan et al. (2012) found that official Chinese CO_2 emissions estimates may be unreliable; however to our knowledge no better alternative currently exists. Data on ozone depleting substances (ODS) emissions were sourced from the United Nations Environment Program. The full set of data sources is documented in SI S1.

3. Results and discussion

3.1. Embodied emissions undermine Kyoto targets

Using the Eora MRIO we confirm earlier findings that much of the apparent success in decreasing domestic emissions has been more than offset by an increase in embodied emissions in imports. For the USA, Japan, most EU nations, and the EU-27 as a whole, the amount of CO_2 burden shifting to developing countries exceeds the size of their Kyoto-specified emissions reduction. While territorial emissions in these countries have decreased, their total carbon footprint has increased.

According to the territorial emissions inventory developed (Kyoto Annex B listed) countries reduced emissions by 1.59 Gt and developing countries increased emissions by 13.7 Gt during the period 1990–2011. However, after assigning emissions responsibility to consumers we find that developing countries transfer 2.95 Gt of CO_2 to developed countries thorough international trade in 2011. Under a consumer responsibility principle developed countries have not recorded a decrease from 1990 levels but rather an increase.

The Kyoto Protocol Annex B signatories agreed to reduce emissions a total of 0.76 Gt (5.2%) from 1990 levels. The EU as a group has nearly succeeded in meeting its target (due both to intentional action and to economic recession) and Russia and the former Soviet states have reduced emissions even beyond their Kyoto targets. However despite these successful reductions, in 2011 1.67 Gt of CO_2 was embodied in net imports to developed countries. In many countries the magnitude of emissions transfers is on par with that of the original reduction target (Fig. 1). The United Kingdom and Poland are perhaps the most striking cases for how outsourcing emissions-intensive production has helped countries meet their targets. Both countries report reductions that exceed their Kyoto targets, however once emissions embodied in their imports are included, they no longer achieve these targets. Similar outsourcing can be observed also for countries that either have failed to meet their targets, such as the USA and Japan, or that have met their Kyoto targets even including emissions embodied in imports, such as Russia. Remarkably, in all cases, changes in emissions embodied in imports are comparable to, or larger than, changes in domestic emissions.

Non-CO_2 GHG emissions comprise 18% of total developed countries' GHG emissions yet comparatively little analysis has been presented on embodied flows of these gasses. An early study by Subak (1995) estimated international flows of CH_4, and Nijdam et al.