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Identifying emission hotspots for low carbon technology transfers

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ABSTRACT

Data on consumption-based CO_2 emissions has become increasingly available over the past years. These data raise the awareness of the link between final goods and the environmental pollution caused by upstream production processes. Consumers of final products learn where in the world CO_2 was emitted along the upstream production chain. For producers of final products these data provide benchmarks for total CO_2 emitted in upstream production processes. These are used together with an extended version of the inverse important coefficient methodology to identify 'emission hotspots'. 'Emission hotspots' are defined as countries/industries where a bulk of the upstream emissions occur and where a change in technology brings about the largest decrease in upstream emissions. This knowledge provides a basis for well-targeted technology transfers to clean up the upstream production chain, thus reducing the emission footprint of final goods production. The highest impact overall in a significant number global value chains analyzed here would be replacing upstream use of coal electricity by low carbon electricity. These results support the call of the 'Powering Past Coal Alliance' at the COP23 of ending the use of coal power sooner rather than later.

1. Introduction: emissions and technology diffusion

Achieving the <1.5 °C warming target is only feasible if carbon emissions peak before 2020 (Figueres et al., 2017). This means that we cannot wait for new breakthrough technologies that significantly alter the production structure of emission intensive industries such as electricity, iron and steel, or transport. An accelerated diffusion of existing low-carbon technologies is vital for achieving a plateauing followed by a decrease of carbon emissions within the next few years.

An important tool in the Paris agreement to achieve a global diffusion of clean technologies is the UNFCCC Technology Mechanism (CTCN, 2013; Krause, 2015; UNFCCC, 2015, 2011). This mechanism supports the transfer of technologies from developed to developing countries (Shimada and Kennedy, 2015). Such transfers are facilitated by the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). However, it is not yet used widely enough to build networks between the recipient and source countries to facilitate technology transfer to a significant extent (Coninck and Sagar, 2015, p. 7). In short: suitable technologies exist, but they need to be increasingly diffused around the world (Piccard, 2016; UN, 2016). This is also supported by the IEA "Bridge Strategy" which aims at employing as much of already existing low-carbon technology as possible as long as new technologies are not yet available. The question remains: how can the technology diffusion process be advanced?

An indirect way to support the diffusion of these technologies from a European perspective are (European) support policies that aid a cost reduction of low carbon technologies (Wiebe, 2016): First, via R&D support and, second, via an increased deployment in Europe and associated learning effects. With decreasing costs, the deployment of low carbon technologies becomes economically viable in more and more countries and thus diffused to these countries. Nonetheless, this indirect mechanism, via European-induced cost decreases, needs to be complemented by other actions to accelerate the diffusion.

Enhancing environmentally friendly behavior across related economic agents has been thoroughly researched; a prominent focus has been the effect of informing households about their energy consumption vis-à-vis social norms (Allcott, 2011) and identifying competitiveness as a significant component of green supply chain management (Kushwaha and Sharma, 2016; Luthra et al., 2016). This benchmarking gives incentives to improve their own actions compared to those of their peers. To this end, a final-product-based emission accounting scheme is used to inform

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Abbreviations: CO_2, carbon dioxide; FD, final demand; LCA, Life cycle analysis; MRIO, multi-regional input-output; VA, value added.

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industries about the emissions embodied in their final products (emission footprints). These are predicated upon industry averages, and can effectively give benchmarks against which establishments in that industry can compare their performance. Such benchmarking can increase pressure on firms to produce more cleanly, and, hence, be an effective means to overcome psychological barriers to climate change action (Stoknes, 2015, 2014; Wackernagel and Rees, 1998). In addition to this 'reputation-led' behavior, 'innovation-led' and 'imitation-led' contributions to green supply chain management have been identified (Testa and Iraldo, 2010). While they cannot find any evidence for 'cost-led' contributions, earlier research argues that the pressure to cut costs have already led to very resource efficient manufacturing processes in the 1990s (Orsato and Wells, 2007).

As little as half a decade ago, very few assessments of embodied carbon existed due to a lack of measurement concepts and tools (Lee, 2012). The measurement of embodied carbon includes not only the direct environmental impact at the final production stage or during the consumption phase, but it also includes all upstream production processes, the environmental footprint. Two main ways to calculate this environmental footprint exist nowadays: bottom-up life-cycle assessment (LCA) at the product-level and top-down environmentally extended multi-regional input-output analysis (EE MRIO) at the industry level. Of course, various blends of these two extremes have also been used (Cooper, 2003; Suh and Huppes, 2005; Tukker et al., 2009). LCA is more detailed (product-specific) and requires extensive data when a range of products, and not just one or two, are considered. EE MRIO is less-detailed, but valuable in assessing a large set of industries simultaneously, especially across various countries (see for example (Tukker and Dietzenbacher, 2013)) for an overview of existing datasets (Andrew and Peters, 2013; Dietzenbacher et al., 2013; Lenzen et al., 2013; Timmer et al., 2014; Tukker et al., 2013; Wiebe et al., 2012).

Initiatives have tackled the lack of data and analysis using the LCA approach for few selected industries. These industries are for example the car industry (Kushwaha and Sharma, 2016; Lee, 2011, 2012; Zhu et al., 2011a, 2011b) and more recently also the clothing industry, e.g. (Mair et al., 2016; Parisi et al., 2015; Resta et al., 2016; Roos et al., 2016; Wang et al., 2015; Zamani et al., 2017). However, LCA studies are very labor and data intensive and can, unfortunately, not be applied to every industry in every country in the world.

The focus in this paper is on final-product-based CO_2 emissions calculated using the MRIO approach. The advantage is that the data are available not only for selected industries, or even only selected products within industries, but for all product groups/industries and countries represented in the MRIO database. These data on environmental footprints help to bridge dissonance and psychological distance for producers from a great variety of industries as they become aware of where CO_2 was emitted along the supply chain that produces the goods they require (Stoknes, 2014; Wackernagel and Rees, 1998). This is because consumers/producers feel more responsible for reducing the upstream emissions of 'their' final product as opposed to emissions that cannot be readily traced to their behavior. The idea is that such knowledge can be extended to develop a better-targeted low-carbon energy technology transfers from CO_2-consuming to CO_2-producing countries. The emission hotspot analysis identifies industries/countries producing with high emission intensities and that are at the same time supplying a significant amount of the upstream product. Reducing the emissions in these hotspots using existing technologies is usually easier and more cost-efficient than further reducing the domestic emission intensity in countries/industries with already low emission intensity, possibly due to strict environmental policies. Naturally, this can also be applied at the country level, i.e. using consumption-based emission accounts for countries to identify where in the world the general investments into technology, e.g. by development cooperation programs, are necessary to reduce the country's footprints outside its own borders. Other studies using structural decomposition analysis in the context of MRIOs (Lenzen, 2016) have found that changing the economic structure and technologies in global exporters, such as China, has a significant effect on the emissions embodied in trade (Pan et al., 2017) and that clean technology transfers have the potential to counteract the emission cost of increasing international sourcing (Hoekstra et al., 2016).

The paper is structured as follows: At first, the data and calculation of final-product-based CO_2 emissions are introduced. Second, the methodology to identify upstream emission hotspots is developed, before discussing options for technology transfer.

2. Data: consumption-based and final-product-based emissions

The UNFCCC currently uses a territorial production-based accounting system when assessing emissions. That is, the UNFCCC allocates CO_2 and other greenhouse gases (GHGs) to the country in which they are emitted. Using data from the IEA's energy balances (IEA, 2015b) and the MRIO EXIOBASE (version 3.4 for 2011, see Appendix for details on why this data was chosen), Fig. 1 plots where in the world final demand for motor vehicles occurs, where most of the value is added to the motor vehicles and where the CO_2 is emitted along global value chains.

While North American and European countries account for about 50% of global motor vehicle demand and value added, only 27% of CO_2 associated with motor vehicle production is emitted in these regions. Germany (part of "Europe" in Fig. 1) and Japan (part of "other Asia" in Fig. 1) each yields 4 percentage points more in product value share than their world demand share (11% VA compared to 7% FD and 10% compared to 6% respectively). This suggests their relatively high involvement in the production chain. Still, their shares as an originator of CO_2 emissions are much lower (4% and 6% respectively), underlining very low polluting in the course of their vehicle-related production activities. This is due either to their engagement in cleaner links of the production chain, or to the use of cleaner production technologies than those used by other countries, or some combination of both. Due to the high industry aggregation in input-output systems, these two effects cannot be easily disentangled. The motor vehicle industry for example includes both final products (cars) as well as the production of important components of cars (engines). The USA comprises a 20% share in global final demand for motor vehicles, while its share in value added is only 16%, leaving the USA being more of a consumer than a producer. But as in Japan and Germany, its share of CO_2 emissions related to motor vehicle production is comparably small (11%).

In China and India, the opposite is true: their shares in CO_2 emitted along global production chains for motor vehicles are disproportionately high compared to demand and value added shares. China owns a 37% share of all CO_2 emissions, but its shares of final demand and value added are less than half of that. This suggests that China participates in more pollution-intensive stages of the motor-vehicle production supply chain, or that its industries pollute more than their counterparts in other countries. The same holds true for India, which also has a share of related CO_2 emissions that is higher than its world shares of demand and value added for motor vehicles, albeit by a factor of three.

The evidence is naturally slightly different for each industry, but the basic picture remains across them all. That is, North-American, European and OECD Asia-Pacific countries are relatively important consumers and contribute relatively high shares of value within