Ecological Economics 146 (2018) 574–587

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Exploring the Characteristics of CO_2 Emissions Embodied in International Trade and the Fair Share of Responsibility

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ARTICLE INFO

Keywords:
Embodied emission
GHG accounting
Producer responsibility
Consumer responsibility
Shared responsibility
Input-output analysis

ABSTRACT

This paper explores the characteristics of embodied CO_2 emissions from the perspective of carbon inflows, carbon outflows, and the net effects, at both an aggregate and bilateral scale. We identify several important relationships in bilateral carbon flows, including China–EU, China–USA, Russia–EU, and China–Japan, which make China and Russia the largest carbon exporters and the EU and the USA the largest carbon importers. A further investigation of the sectors contributing to carbon flows shows that exports from the mineral, chemicals, metals, oil, transport, and other manufacturing sectors are the main cause of carbon outflows, while the intermediate inputs of the electricity and transport sectors are the primary cause of carbon outflows due to export production. Moreover, we propose an intensity-based shared responsibility strategy and find that China should take the most responsibility because it is responsible for nearly 32% of all embodied emissions, due to its less efficient and high carbon-intensive technologies. The USA and the EU follow China, with shares of 13.2% and 11.3%, respectively, owing to their heavy consumption. As a result, China and the USA contribute 31.8% and 20.6%, respectively, of the total global emissions, outweighing the aggregated contribution from all other countries/regions.

1. Introduction

Ever since the adoption of United Nations Framework Convention on Climate Change (UNFCCC) in 1992, dramatic efforts have been made to reach an agreement on alleviation of climate change resulting from anthropogenic emissions of greenhouse gases (GHGs). In international negotiations, the trickiest part has always lain in the equity and justice concerns in allocating responsibilities for emissions' reduction.

Existing research on estimation of CO_2 emissions' responsibility per country/region has suggested either the production-based (Creutzig et al., 2015; Liu et al., 2012; Sugar et al., 2012) or the consumption-based accounting approaches (Barrett et al., 2013; Feng et al., 2014; Mi et al., 2016; Yang et al., 2014). With expansion of international trades, the geographic separation of production and consumption has been greatly strengthened, which will enlarge the disparity between estimations that adopt different strategies. Thus, Munksgaard and Pedersen (2001), demonstrated that there are notable distinctions arising from whether the producer or the consumer is responsible for the emitted CO_2; this is especially true for open economies like Denmark. Inspired by their work, many studies have examined the emissions embodied in international trade, in hoping to gain some implications for global climate policy. Peters and Hertwich (2008a) estimated the CO_2 emissions embodied in international trade among 87 countries in 2001, and provided data on the exported and imported emissions of major countries. Weber et al. (2008) took China as a study case and systematically analyzed the characteristics of its exported CO_2 emissions in sectoral and its trading partners' details. Davis and Caldeira (2010) calculated the trade-embodied emissions for major countries in 2004 and identified the top net import/export countries and the contributing sectors. Caro et al. (2017) estimated the total CO_2 emissions arising from consumption in 175 countries during 2008–2012, with a focus on the Mediterranean area. Sato (2013) provided a review of existing studies on embodied carbon in trade and evaluated some empirical understanding of the carbon flows.

The pros and cons for the two accounting methods have been

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https://doi.org/10.1016/j.ecolecon.2017.12.020
Received 16 May 2017; Received in revised form 11 December 2017; Accepted 11 December 2017

reviewed by Steininger et al. (2013) and Afionis et al. (2017), as to issues including equity and justice, emissions' coverage, technical complexity, mitigation effectiveness, and political acceptability. The debate on sharing responsibilities between importing and exporting countries became heated due to avoidance of the extremes that place the full burden of responsibility on either producers or consumers. Researchers have advocated specifying the weights between producers and consumers based on either value-added (Andrew and Forgie, 2008; Lenzen et al., 2007), income (Marques et al., 2012), beneficiary (Csutora and Mózner, 2014), or the equity principle of "common but differentiated responsibilities" (L. Liu et al., 2015). This paper, on the other hand, proposes an alternative intensity-based principle that builds on the comparison of carbon intensities in producing traded goods by importers or exporters. Before that, we explore the characteristics of emissions embodied in international trade in more detail, e.g., the bilateral CO_2 flows and the contributing sectors.

This paper is structured as follows. After a literature review of the CO_2 accounting principles in Section 2, a description of the intensity-based shared responsibility is given in Section 3. In Section 4, an empirical exploration of the CO_2 embodied in trade among major countries is presented in detail. In Section 5, the climate policy implications of the shared responsibility are discussed, with comparisons to other accounting approaches. Section 6 provides some discussions and Section 7 concludes.

2. Literature Review

Under the framework of UNFCCC, the production-based accounting (PBA) approach dominates in estimating the National Emissions Inventory (NEI) of each conference of parties (COP), with the boundary including all GHGs "taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (Dong et al., 2014). Hereafter, it exclusively refers to emissions generated at the point of production when talking about reduction targets (Afionis et al., 2017). The PBA approach has many merits, e.g., its simplicity in calculation and consistency with GDP accounting and current methodologies for compiling energy statistics, as well as the data availability (Peters, 2008).

However, climate policies based on the PBA principle, e.g., the Kyoto Protocol (KP), have not proven successful, since it provides the possibility for Annex-I countries to transfer their GHG-intensive industries to non-Annex-I countries, if domestically produced emissions alone are applied to the reduction (Peters, 2008). Thus, it promotes the relocation of industries to environmental unregulated regions (pollution haven hypothesis, PHH) (López et al., 2013) and enhances the so-called "carbon leakage" (Marques et al., 2012; Pedersen and De Haan, 2006; Peters and Hertwich, 2008a; Peters et al., 2011). For instance, Peters et al. (2007) and Wiedmann et al. (2007) have found that imports of products to Europe from emerging countries like China have increased steeply, and the considerable progress made by Europe in cutting emissions has been achieved partially by delocalizing Europe's domestic manufacturing overseas. Barrett et al. (2013) and Druckman et al. (2008) also argued that any achievements of the UK in reducing its domestic emissions are offset by the increase of emissions transferred from countries not covered by Annex-I of KP. Moreover, this process has led to an even greater increase of global emissions, since developing countries generally use more GHG-intensive technologies than do developed countries in producing the displaced goods. Consequently, the US government refused to ratify the KP claiming that it excluded high-emitting developing countries. From similar concerns, Canada, Japan, New Zealand, and Russia also withdrew from the second commitment of KP, partly blamed on the limited emission coverage of PBA (Afionis et al., 2017).

With the specialization of countries and the expansion of international trade, an even greater proportion of emissions is generated from the production of internationally traded goods and then leaked through exports (Barrett et al., 2013; Davis and Caldeira, 2010; Peters and Hertwich, 2008a; Peters et al., 2011). Therefore, the reasonableness and fairness of the PBA principle have been widely questioned (Ferng, 2003; Peters and Hertwich, 2008b), which has led to increased calls for a switch to other accounting methods (Peters, 2008; Springmann, 2012). Consumption-based accounting (CBA) was then proposed as the most prominent alternative and has attracted extensive attention from the scholastic community (Bows and Barrett, 2010; Steininger et al., 2013). As this metric accounts for emissions at the point of consumption, it avoids the carbon leakage problem. The CBA approach has since gained increasing popularity in estimating the consumption-based emissions (or carbon footprint) and assessing the emissions embodied in trade (Caro et al., 2017; Hertwich and Peters, 2009; H. Liu et al., 2015; Wood and Dey, 2009), as it has demonstrated advantages in improving both cost-effectiveness and justice (Steininger et al., 2013).

However, the CBA represents another extreme similar to the PBA. Given that both parties benefit from the international trade, the producers and consumers should share the responsibility, because exporting countries harvest the associated economic and home-country employment benefits, and importing countries gain from the price difference and avoid the local emissions' reduction if produced domestically instead (Andrew and Forgie, 2008). As to political acceptance, it would be difficult to reach an agreement that satisfies all parties when applying either PBA or CBA. Realizing that increasing geographic separation of production and consumption has, to a large extent, enlarged the disparity between estimations with PBA and CBA, the debate about how to share the responsibility of traded emissions between importing and exporting countries becomes more complicated (Bastianoni et al., 2004; Munksgaard and Pedersen, 2001).

The central problem with shared responsibility is to devise an indicator to quantify the sharing weights. Some researchers have started to discuss the shared responsibility as to specifying the weights between producers and consumers. Gallego and Lenzen (2005) suggested sharing emissions at each stage of the supply chain on a simple 50:50 basis. Similarly, Rodrigues et al. (2006) deduced that the arithmetic average of the upstream environmental pressure of final demand and the downstream environmental pressure of primary inputs satisfied all required conditions that shared responsibility should have. Ferng (2003) suggested a benefit principle that assigns the responsibility to the driving forces behind the emitting activities. Lenzen et al. (2007) used value added as an allocative proxy for responsibility shares within an NEI, and the value added proxy was then applied by Andrew and Forgie (2008) to account for the GHG emissions in New Zealand and by Lenzen (2007) to show how shared responsibility could be estimated for Australian sectors. These efforts were limited to the national GHG accounting and, thus, failed to solve the responsibility allocation between countries.

Moreover, Marques et al. (2012) proposed the principle of income-based environmental responsibility, where the responsibility is allocated to suppliers who gain the income from the product. Similarly, Csutora and Mózner (2014) argued that GHG emissions should be allocated to the country where the economic benefits accrue in terms of compensation of employees, profit remaining in the producing country, and government income. L. Liu et al. (2015), from an equity perspective, provided a principle that adopts horizontal allocation rules and vertical extending rules, and that brings level of development, emissions per capita, gains from trade, and historical emissions of a country into consideration. Rather than these sharing strategies, we propose a more straightforward approach to apportion emissions based on the sectoral difference of carbon intensity between importing countries and exporting countries, the so-called intensity-based shared responsibility principle.

3. Methodology and Data

This intensity-based shared responsibility principle, in essence,