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# The evolution of global trade and impacts on countries' carbon trade imbalances

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ABSTRACT

We examine carbon trade imbalances among 172 countries over a 10-year period (2000–2010). A carbon trade imbalance refers to the extent to which the carbon emissions embodied in a country's exports exceeds the emissions embodied in its imports. Although past research has considered how such imbalances coincide with variances in wealth and/or trade patterns, none have considered how such imbalances arise in the context of an evolving network structure. In this paper, we consider trade networks and carbon trade imbalances as co-evolving phenomena, and study these using an innovative combination of multi-regional input–output (MRIO) analysis with stochastic actor-oriented models (SAOMs). Our findings both challenge and support arguments made by ecological unequal exchange theory and the Gravity Model, and highlight the role emerging economies play in shaping network structure and the distribution of carbon trade balances overtime.



## 1. Introduction

The interconnectivity of international trade implies that activities and events in one part of the world have consequences, with winners and losers, around the globe. These consequences are numerous, and in this paper, we focus on the distribution of carbon dioxide associated with trade. Carbon dioxide ($CO_2$) is considered one of the main pollutants responsible for global climate change, with far reaching impacts for human and environmental systems (IPCC, 2014). As such, it is important to develop frameworks in which the allocation of responsibility of $CO_2$ can be understood in a global context. In this paper, we develop such a framework by reconfiguring $CO_2$ distributions in terms of how $CO_2$ becomes embodied in export and import flows. This is done through combining multi-regional input–output analysis (MRIO), an analytical technique used for studying the impacts of global trade on a number of environmental indicators,[1] with stochastic actor-oriented models (SAOMs), statistical models used for studying how networks and attributes of actors within these networks change overtime (Snijders et al., 2010). In combining MRIO with SAOMs, we are better equipped to test a number of intuitive concepts about the interdependencies of international trade and their impacts on carbon imbalances of countries. As of this writing, we are unaware of any other study that combines such approaches to explore the theoretical ideas that we present here regarding economic trade and carbon trade embodied in trade flows.

To better explain what we mean by carbon (CTI) trade imbalances (CTI), we offer Fig. 1 below:

Fig. 1 shows $CO_2$ produced within a country via manufacturing and consumption activities (referred to as *production-based* $CO_2$, and sometimes referred to as territorial $CO_2$), $CO_2$ embodied in the goods a country imports (referred to as $CO_2$ *embodied in imports*), and finally, the $CO_2$ embodied in the goods and services a country exports (referred to as $CO_2$ *embodied in exports*). 'Embodied emissions' refers to all upstream or lifecycle emissions that are related to the production of a certain product. Together, these forms of $CO_2$ comprise a country's $CO_2$ trade imbalance (CTI), such that a CTI of a given country represents: (i) the $CO_2$ emissions in country A that occur during the production of good and services *exported* to the rest of the world, compared to, (ii) the $CO_2$ emissions in other countries that occur during the production of goods

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[1] This method has been applied to global environmental issues such as land use (e.g. Yu et al., 2014), water consumption (e.g. Feng et al., 2012), biodiversity (e.g. Lenzen et al., 2012), and $CO_2$ emissions (e.g. Davis et al., 2011; Kagawa et al., 2015; Steinberger et al., 2012).

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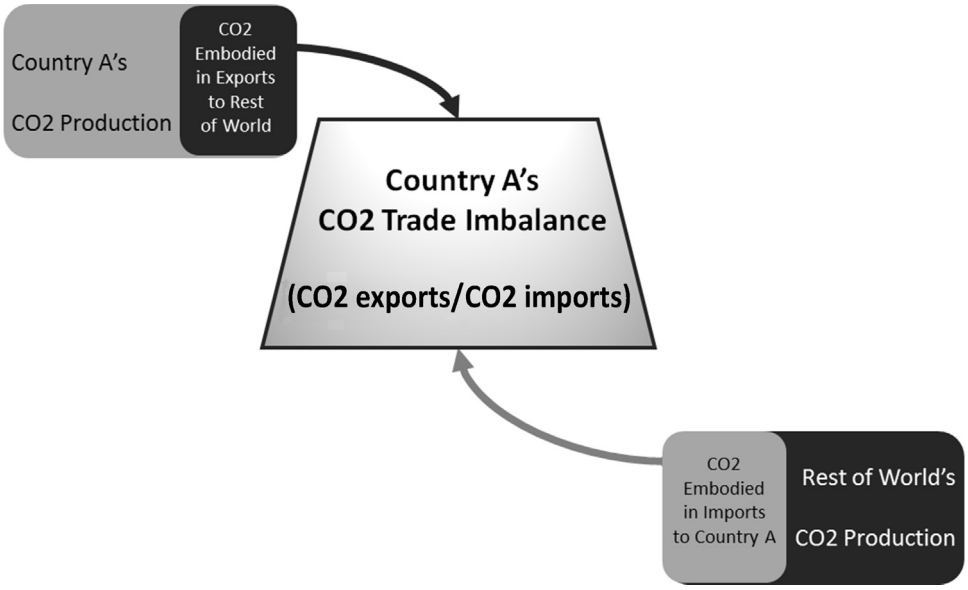


**Fig. 1.** Calculating a country's carbon trade imbalance.

and services *imported* by country A, such that CTI = $CO_2$ exports/$CO_2$ imports.[2] As such, a country's CTI is either a positive number, meaning the country is a net exporter of embodied $CO_2$ (i.e. has a carbon export surplus) or negative, meaning the country is a net importer embodied $CO_2$ (i.e. has a carbon export deficit). And these numbers represent the "imbalance" of $CO_2$ embodied in a country's trade.

### 1.1. Ecological unequal exchange

Research suggests that less-developed countries tend to be net exporters of carbon, while wealthy, developed countries tend to be net importers of carbon (Davis and Caldeira, 2010; Davis et al., 2011; Hertwich and Peters, 2009; Peters, 2008; Peters and Hertwich, 2008; Steinberger et al., 2012). An argument given for this disparity is that less-developed countries are caught in an 'ecologically unequal exchange' (EUE) pattern with wealthy, developed countries (Hornborg, 1998, 2011; Jorgenson, 2011, 2012; Moran et al., 2013; Rice, 2007).[3] Here, wealthy, developed countries are seen as dictating the terms of trade with poorer, less-developed ones, sending financial investment and/or high value added goods in exchange for lower value added goods and natural resources produced in, or extracted from these countries. Consequently, the populations in these less-developed nations tend to experience higher amounts of environmental costs. Environmental regulations in these countries tend to be less stringent than in developed ones (e.g. Copeland and Taylor, 2004), discouraging local agents from investing in cleaner, more efficient technologies, while simultaneously encouraging wealthier nations to externalize pollution-intensive manufacturing to these less-regulated regions (e.g. Roberts and Parks, 2007). In addition, as the residents in less-developed countries are, on the whole, poorer than those found in more developed countries, this lack of wealth often translates into a loss of an economic 'buffer' that would potentially mitigate the harmful health impacts associated with pollution-intensive economic activities (e.g. Prell et al., 2015).

Taken together, the negative environmental impacts associated with unequal trade to wealthier countries leads to our first hypothesis:

**H1.** Countries with wealthier trading partners tend to become or remain being net exporters of carbon overtime.

This past research (and our current hypothesis) portray CTIs as an outcome of international trade patterns and/or economic development, yet other research suggests processes that give rise to these unequal exchanges, and thus, suggest a means by which to perceive CTIs and trade patterns as co-evolving. The next section summarizes this research.

### 1.2. Trade tie formation and carbon trade imbalances

A common perspective found in the trade literature is that of 'comparative advantage' (Porter, 1990; Ricardo, 1821). According to this perspective, economic agents in a given country strive to produce goods at lower costs within their home countries in order to be competitve globally, and this in turn enables economic agents to increase their sales worldwide, subsequently leading to increases in their number of global trade partners. In relation to CTIs, firms striving for a competitive advantage in the production of carbon-intensive goods are more likely to be net exporters of carbon (i.e. maintain a positive CTI), and such carbon imbalances tend to occur in less-developed countries, where production costs are lower and environmental laws more permissive (Dick, 2010; Leonard, 1985; Roberts and Parks, 2007). By maintaining this competitive advantage for carbon-intensive products, a country is thus more likely to expand their reach into the global market, which leads to our second hypothesis:

**H2.** Countries that are net exporters of carbon (i.e. have a positive CTI) will tend to increase their number of export ties overtime.

Ecological unequal exchange theory expands ideas pertaining to comparative advantage by considering between-country economic and environmental disparities. Here, acquiring a 'comparative advantage' in pollution-intensive goods is a strategy

[2] Embodied, embedded or virtual refers to all direct and indirect emissions or resources consumed throughout the entire (global) production (also commodity or supply) chain.

[3] In the case of carbon, when carbon-intensive manufacturing is offshored, this process is referred to as 'carbon leakage' or the 'pollution haven thesis' (IPCC, 2014). More broadly, however, when developing countries experience environmental harm associated with producing/extracting goods for consumption in the wealthy, developed world, this process is referred to as ecological unequal exchange (Hornborg, 1998, 2011).