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Methodological and Ideological Options

Measuring emissions avoided by international trade: Accounting for price differences

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ABSTRACT

Net Emissions Avoided by trade (NEA) are the difference between the pollution that would have been produced in a country if it had not exported any products and all the imports required to satisfy its domestic demand had been produced internally, and its actual emissions. The Domestic Technology Assumption (DTA) applied to an Input–Output model is the appropriate method to estimate the NEA. The usual implementation of the DTA involves that the country analyzed should produce a quantity of products equivalent to the monetary value of the imports required to satisfy its final demand (i.e. 'monetary DTA'). However, due to price differences, the same physical quantity of goods in different countries could have a different monetary value and the estimation of the NEA would be biased. We show that a 'physical DTA', focused on the pollution to produce domestically the imports measured in physical units, would be a better approach. We have applied both methodologies to analyze greenhouse gas emissions in Spain 1995–2007. Both methodologies show that Spain is avoiding emissions through trade. However, the NEA increases up to three times when applying the 'physical DTA', showing that results from the 'monetary DTA' are biased by price differences.

1. Introduction

In recent years, there has been an increasing interest in assessing the environmental consequences of international trade and their policy implications. One of the most relevant questions is the extent to which countries are taking advantage (or being damaged) from trade by importing (exporting) products from other regions and avoiding (suffering) the pollution related to the production of traded goods. By importing goods and services, one country could benefit from the consumption of such commodities and, at the same time, avoid the emissions generated away when producing those goods. On the contrary, exporting countries would support the environmental costs of producing those goods. This situation has been called 'environmental load displacement' or 'environmental cost shifting' (Muradian and Martínez-Alier, 2001) and it is closely connected to some controversial hypotheses such as the 'Environmental Kuznets Curve' (Arrow et al., 1995; Grossman and Krueger, 1991; Roca, 2003; Stern et al., 1996) or the 'pollution haven hypothesis' (Dietzenbacher and Mukhopadhyay, 2007).

The interest on trade and environmental pressures has also been especially strong in the field of climate change (Peters and Hertwich, 2008; Peters et al., 2011; Serrano and Dietzenbacher, 2010; Weidema et al., 2006). In this case, two outstanding debates rotate around the 'carbon leakage' (Wyckoff and Roop, 1994) and how to share the responsibility for greenhouse gas (GHG) emissions between producing and consuming countries (Gallego and Lenzen, 2005; Lenzen et al., 2007; Peters, 2008).

In this context, the estimation of the effects of trade in domestic emissions has a significant role and it becomes an important element to determine which countries are being environmentally benefitted (or harmed) from trade. This issue may be analyzed from two different approaches: by calculating the emissions avoided by trade or by computing the 'emission trade balance' (ETB). Although both concepts look very similar and, in some cases, they have been used in the literature indistinctly, they are conceptually distinct and, in fact, they answer different research questions as discussed later.

Undoubtedly, if one wants to assess what would have been the domestic emissions of a country if there was not international trade

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(neither exports nor imports) and all the domestic demand had been completely provided by domestic production,[1] the appropriate approach is to calculate the Net Emission Avoided by trade (NEA). By definition, NEA is the difference between the emissions that would take place in that country if it was closed to international trade (Emissions Without Trade, EWoT) and its actual emissions. If the NEA is positive, trade would be "beneficial" for the country by contributing to reduce its domestic emissions; otherwise, trade would be "harmful". In the case of global pollutants, such as GHG, it would be "beneficial" (or "harmful") in the sense that the country would appear as less (more) polluting, while in the case of local or regional pollution the benefits (or costs) would affect the environmental quality in the country analyzed.

The estimation of EWoT implies applying the so-called Domestic Technology Assumption (DTA) in the framework of an Environmentally Extend Input–Output (EE-IO) model. Although we maintain the name DTA, in this case it is not really an "assumption" but an implication of the research objective. So far, the practical implementation of the DTA has involved that the country analyzed should produce domestically (i.e. with its domestic technology)[2] a monetary value of products equivalent to the value of the imports required to satisfy its domestic final demand (i.e. 'monetary DTA').[3] However, the monetary value of goods depends on both the quantity and the price of traded goods. Consequently, due to price differences among countries, it could be the case that the same physical quantity of goods in different countries would have a different monetary value. In such a case, applying the 'monetary DTA' to estimate the emissions derived of producing imported goods using the domestic technology would result in different volumes of emissions for the same physical quantity of domestic and imported goods.

In order to overcome this shortcoming, in this paper we propose a new approach for calculating the EWoT and, consequently, the NEA based on the idea that the emissions avoided by imports should reflect the pollution to produce domestically the same quantity of imported goods but measured in physical terms. That is what we call the 'physical DTA'.

In this paper the 'physical DTA' is applied to the analysis of the NEA of GHG in Spain for the period 1995–2007 and we compare the results with those obtained from the standard 'monetary DTA'.

Although it is not the main focus of this paper, we consider necessary to revisit the issue of the conceptual difference between the NEA and ETB we discussed at the beginning of this section.[4] Both the NEA and ETB assess the effects of trade in domestic emissions, but from different approaches. Whereas the NEA allows estimating to what extent countries are taking advantage from trade by avoiding pollution in its territory, the ETB allows assessing the difference between the emissions embodied in the imports and in the exports.[5], [6]

As it has been extensively argued in the literature, the proper way to estimate emissions embodied in trade and ETB is to apply Environmentally Extended Multi-regional Input–Output (EE-MRIO) models. However, until the publication of MRIO databases such as GTAP, EXIOPOL, WIOD or EORA, many studies applied the DTA (Dietzenbacher and Tukker, 2013; Rueda-Cantuche, 2011; Wiedmann, 2009; Wiedmann et al., 2007). Consequently, the quantitative results of both concepts – the NEA and the ETB – were the same; this would be the reason why, on some occasions, both concepts could have been used interchangeably in the literature creating some confusion. Nevertheless, the proliferation of MRIO databases allows omitting the use of the DTA for calculating ETB. Then, the estimation of ETB and – in consequence – emissions from the 'consumer responsibility' perspective (i.e. carbon footprint) applying the DTA will be justified only in specific cases. For instance, when the analysis refers to a country or a region without individual data in MRIO databases or when the high level of disaggregation of national Input–Output (IO) tables justifies adopting this approach. In this sense, the methodological innovation for estimating the NEA presented in this paper would also be relevant when for any reason it was applied the DTA to estimate emissions from the 'consumer responsibility' perspective. In fact, in previous studies we applied the 'physical DTA' to estimate carbon footprints and ETB in Spain (Arto, 2009; Arto et al., 2010a,b, 2012).[7]

The structure of the paper is as follows. After this introduction, Section 2 explains in detail the methodology for calculating the NEA according to the 'monetary DTA' and to the 'physical DTA'. Section 3 describes the database used in the case study and reports the results. Finally, Section 4 presents the conclusions.

2. Methodology

2.1. Formalization of the 'Monetary-DTA' and 'Physical-DTA'

The starting point of our analysis is the IO table of a country as shown in Fig. 1. This figure describes the flows of goods and services between all the sectors and the use by final users: $\mathbf{Z^D}$ is the matrix of intermediate deliveries, $\mathbf{f^D}$ is the column vector of final demand for domestic commodities, $\mathbf{e}$ is the column vector of total exports, $\mathbf{x}$ is the column vector of total output, $\mathbf{Z^M}$ is the matrix of imported intermediate commodities, $\mathbf{f^M}$ is the column vector of final demand for imported commodities, $\mathbf{x^M}$ is the vector of total imports, and $\mathbf{w}'$ is the transpose of the vector of sectoral value added. Fig. 1 has been extended with the transpose of the vector of sectoral emissions ($\mathbf{g}'$). Matrices of input coefficients for domestic and imported intermediate commodities are given by $\mathbf{A^D} = \mathbf{Z^D}\hat{\mathbf{x}}^{-1}$ and $\mathbf{A^M} = \mathbf{Z^M}\hat{\mathbf{x}}^{-1}$, where $\hat{\mathbf{x}}^{-1}$ denotes the inverse of the diagonal matrix of the vector of total output.

We are interested on assessing to what extent trade contributes to reduce (or to increase) the emissions in the country analyzed; this is equivalent to estimating the NEA. The NEA is the difference between two elements: *i*) EWoT: the emissions that would have been generated if the country had not exported any commodity and all imports required to satisfy its domestic final demand had been produced in the country

	Intermediate use	Final uses		Total output
		Domestic	Exports	
Domestic	$\mathbf{Z^D}$	$\mathbf{f^D}$	$\mathbf{e}$	$\mathbf{x}$
Imports	$\mathbf{Z^M}$	$\mathbf{f^M}$	$\mathbf{0}$	$\mathbf{x^M}$
Value added	$\mathbf{w'}$			
Total inputs	$\mathbf{x'}$			
Emissions	$\mathbf{g'}$			

Fig. 1. Input–Output table.
Source: own elaboration.

[1] This is a hypothetical assumption that implies that any good imported could be produced domestically. In fact, there are imported goods which would be impossible produce domestically due to the absence of some inputs. This is the case, for instance, of crude oil for countries that have not this natural resource.

[2] From the perspective of an EE-IO model the technology of each sector is defined by its emission intensity and its input structure.

[3] Examples of the use of this method can be found in Ackerman et al. (2007), Dietzenbacher and Mukhopadhyay (2007), Peters et al. (2007), Lin and Sun (2010), Liu et al. (2010), Rueda-Cantuche (2011) or Zhang (2012).

[4] The difference between NAE and ETB is also relevant for the political debate on "carbon border tax adjustments" (see Mattoo et al., 2009).

[5] The ETB can also be obtained by the difference between emissions from the 'consumer' and 'producer' responsibilities. For a detailed discussion see Serrano and Dietzenbacher (2010).

[6] The NEA and ETB are not equal due to differences in technologies of countries. Imagine a country with positive NEA, as it is the case for the most part of rich countries. If this country imports commodities from other countries, whose average technologies were more polluting than its own technology, then the ETB would be higher than the NEA; in the opposite case it would be lower.

[7] Later, Tukker et al. (2013) applied a similar approach to study the emission trade balance for the European Union.