Folia Oeconomica Stetinensia
DOI: 10.2478/v10031-012-0022-9

THE IMPACT OF POLISH-GERMAN TRADE FLOWS ON CO_2 EMISSIONS

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Received 25 July 2012, Accepted 12 November 2012

Abstract

This study analyses the embodied carbon in the trade flows between Poland and Germany. The calculations are based on data from Eurostat and OECD for 2008. The study uses input–output analysis, which allows the assignment of responsibility to individual flows for generating specific amounts of emissions in the economy. It demonstrates that Polish exports to Germany contain significantly more embodied carbon than do imports from Germany, despite the fact that the value of imports is higher. Moreover, it is found that Polish-German trade flows were responsible for more CO_2 emissions that Lithuania and Latvia emitted together in 2008.

Keywords: Input-output, CO2 emissions, EU climate policy, embodied carbon.

JEL classification: C67, F18, F64.

Introduction

In December 2008 the EU adopted a new climate and energy policy for Europe. The policy consists of a package of binding measures designed to reach the EU's target of a 20% reduction in emissions by 2020. The cornerstone of the package is a reformed and more centralized and harmonized EU Emissions Trading System (ETS) for the post-2012 period, building on the 2003 Emissions Trading Directive[1]. The new system will be based on more stringent rules, to give incentives to the current EU reduction target. This will increase the costs of industrial operations which need to acquire emission allowances in auctions. As a result, it will push up the prices of industrial goods and energy, which will indirectly charge the entire economies of the EU Member States. Additionally, costs of greenhouse gases (GHG) reduction measures in non-ETS sectors need to be taken into account. Böhringer and Rutherford et al.[2] have estimated that the policy pursued by the EU's emissions reductions will reduce welfare in EU Member States by about 0.5–2.0%.

Current EU climate policy solutions force the economies of the Member States to bear only the costs of emissions that are produced within their borders. Therefore, in the context of GHG emissions generated outside of Member States and linked to their economic activity, there is some controversy about the moral and cost responsibility. In the EU this problem has two dimensions. The first concerns carbon leakage, which occurs with the growth of greenhouse gas emissions in countries with no emission-reduction commitments, due to reductive measures taken by other countries. This issue is often discussed in the literature of climate change economics[3]. A second dimension is still unrecognized and is associated with exchanging the costs of climate emission reductions between the EU member states by trade-exchange channels.

This issue of the exchange of the costs of climate policy efforts through the internal EU trade relations might be examined using the concept of embodied emissions, which could be calculated by two different methods: the emissions embodied in bilateral trade (EEBT) and Multi-Regional Input-Output Analysis (MRIOA). The EEBT method determines the emissions occurring in one region in order to produce the total exports to another region, but it cannot determine the total emissions required to produce a given product, since imports are usually required to produce the exports. For instance, to calculate the emissions embodied in the production of a car in region A, one must first determine the production levels and emissions occurring in region A. Production in region A requires imports from regions B and C. The resulting production and emissions in regions B and C also require imports from other regions, and so on. This process continues indefinitely through the global production system. This type of analysis is then performed using Multi-Regional Input-Output Analysis[4].

In recent years, the amount of research on embodied emissions has been systematically increasing. The review of Wiedmann[5] covers over 50 papers on this topic written in 2007–2009. Since that time, many new articles have been published. A significant number of them focus on the emissions embodied in trade flows. The vast majority of published works concerns Asia[6]. So far, the literature lacks studies focused on the emissions embodied in internal EU trade. There are only few publications that are to some extent relevant. One of these is the report of the WWF[7] which presents the consumption-based emission of the EU countries in 2004. Bordigoni, Hita et al.[8] have produced a comprehensive analysis of energy consumption, carbon emission, and bilateral trade flows in 59 sectors for all the EU countries in 2005. The results include CO_2 balance sheets defining the responsibility of individual EU member states for emissions emerging in two groups of counties: EU and non-EU. The study showed that a large fraction of the emissions embodied in the imports of individual EU countries was physically emitted in other EU Member States. This confirms that the costs of emissions are exchanged through EU internal trade flows. However, none of the reviewed studies refers to this problem directly. This issue is of particular interest for trade relations between the EU-15 and the New Member States (NMS). This is because of evident differences in economic and energy backgrounds, which affect the implementation of climate policies in these countries.

Taking into account the above, the aim of this study is to determine the CO_2 emissions from fuel combustion that arise as a result of the trade between Germany and Poland, which are here taken as the main representatives of the EU15 and the NMS, respectively. Emissions of CO_2 from fuel combustion constitute about 75% of all EU GHG emissions, and CO_2 is considered the most cost-generating gas within the EU climate regime. Thus, understanding the driving forces of CO_2 emission transfers is essential in formulating effective and fair EU climate change mitigation policy, and in fulfilling applicable targets.

1. Methods

If trade-adjusted emission inventories (leading to a trade balance) are to be compared, Kanemoto, Lenzen et al.[9] suggest an EEBT approach, due to its close links with monetary trade balance. Thus, this method is a natural choice, considering the aim and scope of this paper.

The EEBT methodology is based on the input-output (I-O) analysis developed by Leontief[10]. Since its main assumptions have been described in detail, among others, by Miller and Blair[11], only the main formulas are presented here.

The economy can be divided into n interrelated industries, whose total output is expressed by:

$$x = Ax + y \tag{1}$$

The vector x represents the total output in each sector; A is a matrix whose elements a_{ij} indicate the demand of sector i per unit of production in sector j. Then Ax is a vector of total intermediate consumption. The elements of the vector y indicate the size of the final demand on the production in each sector. All scales adopted in the calculations are expressed in terms of value. In order to calculate x, the following transformations have to be performed:

$$\begin{gathered} x - Ax = y \\ (I - A)x = y \\ x = (I - A)^{-1}y \end{gathered} \tag{2}$$

In the sequence of Equation (2), I is the identity matrix, i.e., the matrix whose elements on the main diagonal are ones, while the rest are zero. The matrix $(I - A)^{-1}$ is "Leontief's Inverse matrix" and is fundamental for the input-output analysis. The values of this matrix describe the influence of the exogenous change of the final demand on the total production. It allows the tracking of the mutual interactions between the elements of the production system, including an analysis of flows between the sectors.

Based on Equation (1), the vector of total production of country r, denoted by x^r, can be described with the formula:

$$x^r = A^{rr}x^r + y^r \tag{3}$$

where y^r is the vector of the final demand on domestic production, A^{rr} is a matrix whose elements a_{ij}^{rr} are the amount of input from sector i in r per dollar's worth of output of sector j in r. Thus, $A^{rr}x^r$ expresses the total intermediate demand in country r for domestic production.

The final demand in Equation (3) can be expressed as:

$$y^r = c^r + e^r \tag{4}$$

where c^r is the vector of the final consumption of domestic production, and e^r is the vector of export. The output equation can therefore be rewritten as:

$$x^r = A^{rr}x^r + c^r + e^r \tag{5}$$

and according to Equation (2):

$$x^r = (I - A^{rr})^{-1} (c^r + e^r) \tag{6}$$

In order to evaluate the total CO_2 emissions created during the production processes in country *r*, the total production vector has to be multiplied by the relevant CO_2 emission factors:

$$f^r_{CO_2} = F^r_{CO_2} x^r = F^r_{CO_2} (I - A^{rr})^{-1} (c^r + e^r) \tag{7}$$

where $F^r_{CO_2}$ is the vector of total CO_2 emission in country *r*, and $F^r_{CO_2}$ is a diagonal matrix whose elements indicate the amount of CO_2 emission per dollar of total output of each sector in country *r*.

The assumption of linearity accompanying the input-output approach allows the decomposition of Equation (7) and the evaluation of the effect of each component of final demand individually. However, because this study focuses on identifying the emission effect caused by export, only this aspect has been considered further.

The vector of the total CO_2 emissions generated in country *r* to meet the total external demand, denoted $f^{sx}_{CO_2}$, can be expressed as:

$$f^{sx}_{CO_2} = f^r_{CO_2} \left(I - A^{rr}\right)^{-1} e^r \tag{8}$$

Because the export vector e^r is the sum of trade flows from country *r* to country *s*:

$$e^r = \sum_s e^{rs} \tag{9}$$

further break down of the Equation (8) is possible to capture the emissions embodied in trade flows to a single country according in the relation:

$$f^{rs}_{CO_2} = f^r_{CO_2} \left(I - A^{rr}\right)^{-1} e^{rs} \tag{10}$$

where $f^{rs}_{CO_2}$ is the vector the emission embodied in exports from country *r* to country *s*.

Equation (10) captures the total emission effect of exports from country *r* to country *s,* which can be further broken down into two effects: the direct emission effect and the indirect emission effect. The former, denoted in Equation (11) by $fd^{rs}_{CO_2}$, refers to emissions which occur in exporting sectors during the manufacturing of products to be sold abroad.

$$fd^{rs}_{CO_2} = f^r_{CO_2} e^{rs} \tag{11}$$

The indirect effect consists of all other emissions generated in the domestic supply chain to provide the exporting sectors with intermediate materials for the manufacture of goods to be sold abroad. These emissions, denoted here by $fi^{rs}_{CO_2}$, could be calculated simply by subtracting the direct emissions from the total emissions emerging due to country's *r* export activity to country *s*, according to Equation (12):

$$fi^{rs}_{CO_2} = f^{rs}_{CO_2} - fd^{rs}_{CO_2} \tag{12}$$

All the datasets used in the study are the latest available and concern 2008, except for A^{rr}, the matrix of domestic coefficients, which is based on 2005 data. This implies the assumption of unchanged technology between 2005 and 2008, which is acceptable[12]. There are three main types of data used in the study: CO_2 emissions data, trade exchange values, and input-output tables. The input-output tables and the trade exchange values come from OECD's STAN database. Sectors in this database are organized according the International Standard Industrial Classification Revision 3 (ISIC Rev. 3) and cover all economic activities, including services. The data on CO_2 emissions was provided by Eurostat as a part of the Air Emissions Accounts by activity in NACE rev. 1 classification for industries and households, which differs significantly from the standard IPCC inventory. It was necessary to calculate the sectoral CO_2 intensity factors, which were obtained by three steps. First, adjustments between the datasets of Eurostat and OECD were performed. Next, the sectoral gross outputs in current prices in national currencies were converted to USD values. For the Polish Zloty (PLN) and for the Euro (EUR), we used OECD's average USD exchange rates for 2008. Finally, the CO_2 emissions values were divided by gross output and expressed in tonnes of CO_2 per 1000 USD (equivalently, kilograms per dollar). Calculations were made for trade in goods from the four main sectors: agriculture; mining and quarrying; manufacturing; electricity, gas, and water supply, divided into 21 subcategories based on ISIC Rev. 3. Although the calculations do not include the transboundary exchange of services, typically service-related sectors were taken into account during estimation of the indirect emissions as a result of exports.

2. Results and discussion

The results shows that in 2008, every US dollar of Polish exports to Germany caused in average emissions of 0.3 kg of CO_2 from fuel combustion facilities located in Poland. The emission intensity of German exports to Poland was estimated at 0.16 kg of CO_2 per US dollar, half of the Polish value. In 2008, the turnover from trade between Poland and Germany amounted to 95.5 billion USD. The manufacturing of the traded goods resulted in about 21 Mt of CO_2 emissions from fuel combustion in these countries alone. Thus is more than the amount of CO_2 emitted by Latvia and Lithuania together in that time (20.3 Mt of CO_2).

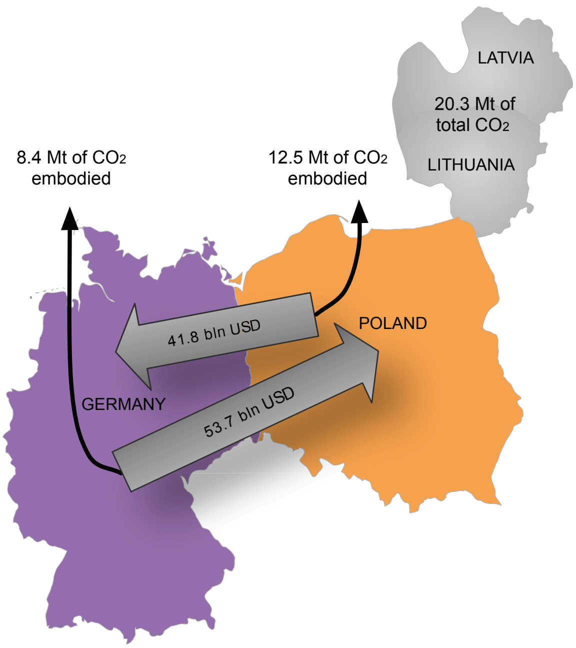

Fig. 1. The value of Polish-German trade flows (in 2008 USD) with their CO_2 emission impact in 2008

Source: own study.

Figure 1 shows the value of trade flows between the two countries and the carbon impact that each flow leaves in the exporting country. There is a clear disproportion between the figures characterizing Poland and Germany in this respect. Although Poland exported about 20% less than Germany in terms of value, it emitted about one third more CO_2. The emissions in Poland as a result of the trade with Germany constitute an important part of the Polish carbon footprint, and represent 4% of the total CO_2 emissions from fuel combustion in the country (Figure 3). As regards the direct and indirect emission effect of trade in Poland, direct emissions slightly exceeded indirect emissions. In the case of Germany, the emissions caused by exports to Poland are definitely less important for the whole emission picture of that country. Another difference that can be characterized is the smaller significance of indirect emissions in Germany. This could be the result of less carbon intensive power generation and better energy-efficiency patterns in Germany, as this sector usually has a great impact on the level of indirect emissions.

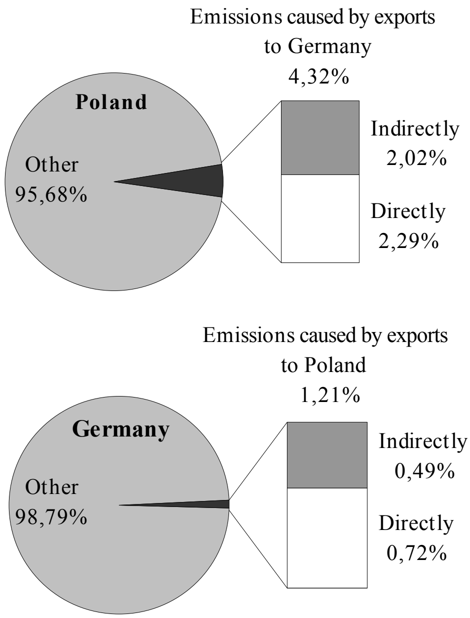

Fig. 2. The CO_2 emission impact of trade between Poland and Germany as a percentage of total CO_2 emissions in these countries

Source: own study.

Figures 3 and 4 are intended to clarify the cumulative data on emissions caused by the trade flows through their sectoral disaggregation. The largest emissions in Poland arise from exports of the basic metals sector. However, this is not reflected in the value of exporting goods of this sector, which is in the sixth place in this regard. This indicates that production of basic metals in Poland in terms of the whole manufacturing cycle is very carbon-intensive. It is evident that the sector producing motor vehicles and trailers leads among sectors exporting to Germany. Surprisingly, the emissions due to exports of this sector are practically negligible. This may result from the fact that assembly in this sector mainly involves putting together components that have often been imported. This would not seem to involve large emissions on Polish territory. Other important sectors in terms of emissions generated by their export activity are those producing chemical and chemical products, non-metallic mineral products, and coke and petroleum products. However, last of these played an important role in the Polish export portfolio. The other sector had rather limited positive impacts on the trade balance with Germany.

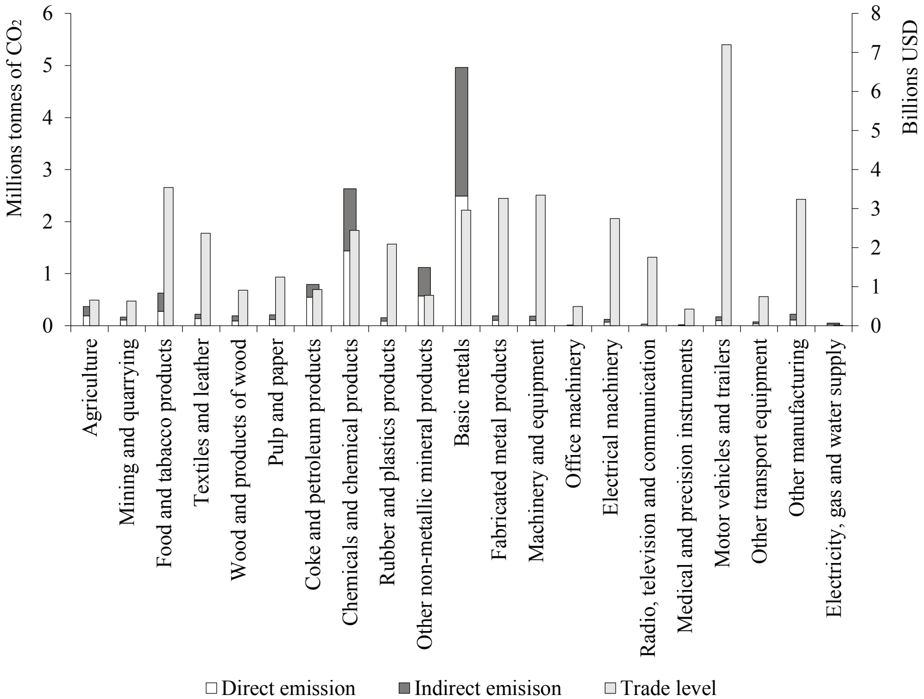

Fig. 3. The CO_2 emissions embodied in trade from Poland to Germany in 2008

Source: own study.

The emissions emerging in Germany as a result of production for export to Poland are clearly lower than in the Polish case. We have calculated that, as in Poland, most emissions caused by trade with Germany are generated in the production chain of basic metals and chemicals. However, the third emission-generating export flows are these from the electricity, gas, and water supply sector, which on the Polish side had negligible impact. These emissions are associated with electricity transfer to Poland, which practically did not exist in the other direction. It is worth noting that this sector is of very little value in comparison to other sectors exporting to Poland. Nevertheless, the direct emission impact of this sector is bigger than the carbon-intensive production of chemicals, the export value of which is about 14 times higher. Another noticeable difference between German and Polish emissions embodied in export is the lower level of emissions in the agriculture, food and tobacco products sectors in Germany, compared to Poland. This is probably due to the generally higher energy efficiency in German economic entities operating of these sectors.

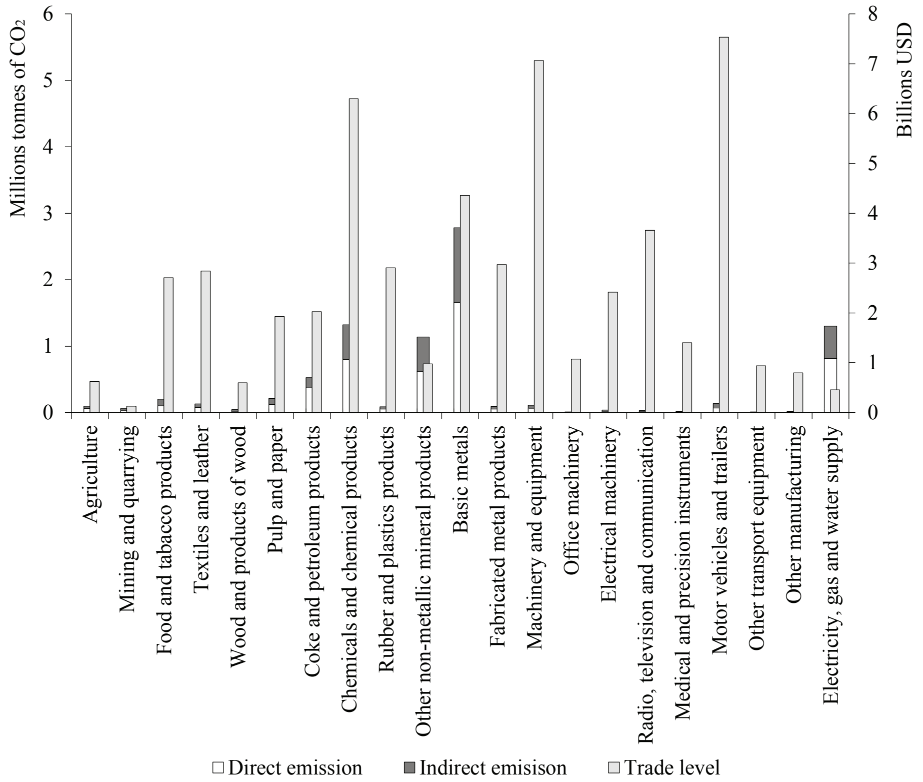

Fig. 4. The CO_2 emissions embodied in trade from Germany to Poland in 2008

Source: own study.

Regarding the overall structure of emissions caused by the export flows of the two countries, there are also some differences in terms of their sources. In Germany, we can observe (especially in the basic metals, chemical, and non-metallic sectors) a small excess of direct emissions. In Poland, the ratio of indirect and direct emissions is more equal. This should be linked with the higher carbon-intensity of the Polish electricity sector, which is usually an important factor influencing indirect emissions.

Conclusions

The bilateral of Poland trade with Germany contributes to approximately 21 Mt of CO_2 being emitted on both sides of the border. Although the value of German exports to Poland exceeded by about 30% the value of Polish exports to Germany, the Polish export flows contribute to a larger amount of emissions. These results indicate the much worse performance of the Polish economy in terms of emission standards. Thus, not considering the impact of foreign suppliers, goods produced in Germany have less emission baggage than goods produced in Poland. We can therefore conclude that the substitution of Polish goods by German goods positively influences the reduction of emissions in EU. Regarding the question of whether the costs of emissions are indeed transferred between the two countries, we can conclude that this phenomenon does occur, though in such a way that neither of the countries takes advantage of the other. If this situation continues to hold, Poland will indeed bear the higher costs associated with emissions due to exports. However, Germany, which exports more to Poland, will allow Poland to save great amounts on CO_2 emissions. There is also a lack of evidence that the structure of bilateral trade promotes the exchange of products of energy-intensive sectors for goods produced in traditionally low energy-intensive sectors. Both countries trade with each other with a similar intensity in, for example, the products of the basic metal and chemical sectors.

Some of the conclusions presented above require further examinations in order to be empirically supported. Certainly a deeper comparative analysis of the examined carbon flows would be helpful. This could, for example, lead to the separation of the individual drivers of emissions in these countries.

Notes

1 Skjćrseth, Wettestad (2010).

2 Böhringer, Rutherford et al. (2009)

3 Bernard, Vielle (2009); Kuik, Hofkes (2010); *Contribution of Working Group III*… (2007); Peters, Hertwich (2008).

4 Peters (2008).

5 Wiedmann (2009).

6 Dong et al. (2010); Guo et al. (2010); Lin, Sun (2010); Liu et al. (2010); Su et al. (2010); Yunfeng, Laike (2010).

7 Bang et al. (2008).

8 Bordigoni, Hita et al. (2012).

9 Kanemoto, Lenzen et al. (2011).

10 Leontief (1941).

11 Miller, Blair (2009).

12 Dietzenbacher, Hoen (2006).

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