A Structural Decomposition Analysis of the Pollution Terms of Trade

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Abstract

The Antweiler Pollution Terms of Trade Index (PTTI) defined as the ratio of the pollution content per monetary unit of exports over the pollution content per monetary unit of imports, is a measure of environmental gains or losses that a country sustains from international trade. Its values and changes over time can be used to investigate the impact of trade and policy regimes on such gains and losses. We argue that the measurement of PTTI in monetary values distorts the picture of the true pollution content of trade. We suggest a procedure of structural decomposition analysis (SDA) of changes in the PTTI that addresses this issue. Such a method measures the impact of changes in prices of traded commodities, real changes in the trade mix and volume, and technology changes, on PTTI values. A case study for the Netherlands is provided using annual changes in the index for the 2007-2010 period, considering the pollution content of traded commodities in terms of greenhouse CO_2 equivalent. Results confirm the significant role of prices and the misleading role they can play if ignored.

Keywords: Greenhouse emissions, Pollution content, Pollution terms of trade, Structural decomposition analysis.

JEL: Q50, Q55, Q56

Introduction

Trade liberalization coupled with environmental concerns, environmental treaties, and country specific regulations, motivate theoretical and empirical approaches to the understanding and measurement of international trade impacts on the environment. Measuring the pollution generated by exportable and importable commodities of a country or group of countries, and changes of these measurements in the course of time is thus important. Indices based on such information are equally substantial. They summarize this information and facilitate its use. The need to test related theoretical views and to quantify countries' positions in the matrix of international trade-and- environmental pollution, lends weight to empirical approaches. Pollution generated by export and import commodities change over time due to different trade regimes or due to technological change. It is thus important to measure not only the pollution generated by tradeable goods but also its' changes over time. Indices based on such measurements are equally substantial. They summarize this information and facilitate its use.

Such indices consider one or more pollutants at a time. They may reflect absolute measurements such as the pollution content of exports, imports, and their difference or they may reflect relative magnitudes such as the ratio of the pollution contents of exports and imports. Different indices are expected to capture different aspects of the relation between trade and environment, with their values depending on different variables. Index value changes reflect the impact of changes in these variables. Knowledge of these effects provides information on both, the patterns of index changes and the significance of the specific forces that drives them. This should be useful in interpreting environmental impacts due to trade, and evaluate different trade policy results on environmental pollution and its international distribution.

In this study we focus on the Pollution Terms of Trade Index and its changes. A method of structural decomposition analysis of such changes and the role of volume and mix of trade, technological changes, and changes in prices of traded commodities is suggested. We show that the levels and changes of these prices may significantly alter the measurement of the true pollution content of trade that the index intends to capture. The proposed SDA method is applied on data for the Netherlands. Compatible trade and environmental data are used and obtained from the Input Output and Environmental Accounts of the Dutch economy.

Related Literature

The concept and index of the pollution terms of trade (PTT) was introduced by Antweiler (1996) in order to measure a country's environmental gains and losses caused by international trade. Another measure suggested by Muradian et al.,(2002) was the use of the balance of emissions embodied in trade, i.e. the difference between pollution embodied in exports and in imports. The latter found several applications in the literature and without doubt provided valuable information on the overall pollution effect of international trade activities. Nevertheless, the measure is affected by the size of the international trade balance and its short term changes. As in the case with the international terms of trade, there is also a need for an equivalent index with respect to pollution, which is unaffected by the size of trade balance. Such an index would also capture a long term view. The Antweiler PTTI satisfies the aforementioned criteria as a measure of relative trade weighted pollution intensity. It is defined as the ratio of pollution embodied per monetary unit of exports over the pollution embodied per monetary unit of imports, where pollution refers to any particular pollutant.

Previous efforts to construct a pollution terms of trade index were based on pollution abatement costs (Kalt 1988, Robinson 1988). The idea was inspired by Walter (1983) who suggested the use of the abatement-cost content of trade but did not produce a theoretically justified measure. Moreover, as Antweiler (1996) maintains these efforts did not lead to the construction of indices appropriate for international comparisons. Based on Antweiler's Pollution Terms of Trade Index (PTTI), a country "gains" from trade in environmental terms when the exported goods have a lower pollution content per monetary unit, than the corresponding content of imports. In such a case the value of the index is lower than one. If a country engages in "environmental dumping" it aims at a reduction of the PTTI.

Consider n traded commodities (i=1,2,…,n) for a country trading with κ other countries (j=1,2,…,κ), Θ pollutants (θ=1, 2…, Θ) produced in the production processes of the n outputs, and $\psi_{\theta ij}$ is the content of θ per unit of produced i in country j, then the PTTI of a certain country and period t can be written using summations rather than matrix forms, as:

$$(PTTI)_t = \frac{\left(\sum_{i=1}^{n} X_{it}\right)^{-1} \sum_{\theta=1}^{\Theta}\sum_{i=1}^{n} \omega_\theta \psi_{\theta it} \mathrm{X}_{it}}{\left(\sum_{i=1}^{n}\sum_{j=1}^{\kappa} \mathrm{M}_{ijt}\right)^{-1} \sum_{\theta=1}^{\Theta}\sum_{i=1}^{n}\sum_{j=1}^{\kappa} \omega_\theta \psi_{\theta ijt} \mathrm{M}_{ijt}} \qquad (1)$$

where X_i is the value of i exported from the country and M_{ij} is the value of i imported from country j. Moreover, ω_θ is a weight corresponding to the particular pollutant θ. Weights make comparable different pollutants possibly measured in different units, or assign a different degree of significance to each pollutant, or both. Based on their definition, coefficients $\psi_{\theta ij}$ represent different production technologies with respect to each pollutant θ in the production process of each output i, in each country j.

Antweiler (1996) also provided estimates for 164 countries which reflected two influential factors. One is the composition effect that depends on the mix and quantities of exported and imported commodities. The second is the technology effect that is related to the production process of each traded commodity in each country. Lack of detailed data in Antweiler's study led to the assumption that technologies for the same commodities are similar across trading countries, i.e. the pollution content of a traded commodity per unit is the same regardless of the country of production. As a result, when this common assumption is made, differences in PTTI values reflect only different composition effects.

More recently, Grether and Mathys (2013) implicated the PTTI in the discussion on the "true" factor content of trade and its environmental version, (i.e. the pollution content of trade). The concept of the factor content of trade proposed by Vanek (1968) and predictions based on that, face trouble when the assumption of similar production technologies is lifted and international trade in production inputs is present. Trefler and Zhu (2010) proposed an algorithm giving Vanek consistent predictions. They took under consideration that models satisfying Vanek predictions are more than the Heckscher-Ohlin consistent models. They also adopted as correct Vanek-relevant definition of the factor content of trade, the one suggested by Deardoff (1985). The algorithm uses Input-Output (IO) table data on trading countries to capture the factor content of trade.

A similar logic is extended in Grether and Mathys (2013) where internationally traded inputs, internationally traded inputs of other inputs, etc., together now with their pollution contents are embodied in exportable and importable commodities produced by national sectors. Technology coefficients and multipliers are used to capture direct and indirect effects induced by final demand on outputs and their pollution content. Moreover, the authors express the pollution content of trade in terms of value added. This is based on Johnson and Noguera (2012) where the value added content of trade is measured to avoid the problem of double counting in the value of trade when there is increased world-wide production sharing.

As a result, Grether and Matys (2013) propose the use of a new PTTI in place of the Antweiler PTTI. The new index uses international Input-Output tables' data, technology coefficients and multipliers in order to capture direct and indirect final demand driven effects and impacts of trade and value added[1]. The Grether and Mathys index reflects the impact of four different effects (between-country trade, technology relating to pollutant production, intermediate trade, and value added) as opposed to the two effects of Antweiler index. We maintain skepticism for this approach. Of course, one can chose to establish and investigate the concept of the pollution content of trade, with the inclusion in the latter of indirect trade effects. This however does not remedy any structural default in the initial Antweiler PTTI. There are certain facts that generate our skepticism.

Even though inputs are used in the production of inputs and become "embodied" in them directly or indirectly, for all practical and theoretical purposes the pollution embodied in a

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[1] The authors considered SO_2 emissions for 62 developing and developed countries over the 1990-2000 period. Their study involved a significant amount of thorough data work. They account for different technologies of production in similar sectors of the different countries resulting in different emission intensities. They use input output tables for the countries of the study where in final demand, international trade of every country is broken down to bilateral trade with all other countries separately. It seems however, that as a result there are some compatibility issues between sector definitions in different data sources. Moreover, since bilateral trade data for all countries and per sectoral output are not available, the authors are forced to make restrictive analogy assumptions and obtain approximations of the true values. This way they estimate their pollution terms of trade index for each country, taking under consideration its trade with each other country separately, and the different production technologies as well.

commodity is only the pollution generated in its production process and not the pollution generated in the production of the commodity's inputs, inputs of inputs, etc. Extending the concept of the true factor content of trade to the case of embodied pollution, is an arbitrary choice not well justified. There are no theoretical arguments, frameworks, conclusions which are better explained, altered, or collapsed with it. The case of Vanek's concept and the predictions altered in such situations are not paralleled here. Environmental dumping for example, relates only to the pollution content of exports or imports generated where production is and according to prevailing technologies in each producing country. This, regardless of the traded commodities usage (i.e. for intermediate or final consumption) and regardless of the pollution content of their own traded inputs and inputs of inputs. Empirical investigation of environmental dumping and other hypotheses and explanations of their rejection or confirmation should not ignore this fact.

The inclusion of the subject of the value added content of trade in the discussion and calculation of the PTTI, is also of limited importance. The fact remains that pollution is embodied in actual commodities produced and not in magnitudes such as value added. Sectoral value added magnitudes and changes can be used to understand better patterns of production and trade which affect the trade mix used in the PTTI. In the end, it is the volume of exports, imports and their pollution content, i.e. pollution embodied at the production level of exported and imported commodities, that should be used to quantify environmental benefits and losses due to international trade.

A problem with the PTTI lies in our view elsewhere. Regardless of the technology assumption, total values of exports and imports, i.e. the denominators of both the nominator and denominator in (1) are expressed in monetary values. This biases the results when intercountry or intertemporal comparisons are made. Differences in the trade mix over countries or time, combined with differences in prices of different traded commodities, do not allow comparisons of PTTI values using the true pollution contents of exports and imports. If this problem could be resolved the PTTI estimates would have served their purpose satisfactorily. This is much easier said than done. Resorting to actual commodities instead of their monetary values, would have made their aggregation impossible. Hence the denominators of the nominator and denominator in (1) would be impossible to estimate, while the nominators would still be calculated as pollution contents. If however information on price changes and indices is available, changes in the PTTI values can be estimated without the impact of prices and their changes. These changes would reflect changes in the true pollution content of exports and imports and they would provide therefore changes in the true environmental gains and losses.

Changes in the true pollution contents of exports and imports and the PTTI index are not less important than the values of the index at its levels. Even without the distorting effect of prices, estimated values of PTTI at a given time may not necessarily reflect environmental dumping or specialization towards production processes that generate more or less pollution, due to relevant policies of taxation, incentives, etc. They may simply reflect existing comparative advantages and technologies regardless of such policies. It is interesting and useful to examine also the changes in the Antweiler PTTI values over time as policies, and institutional or legal frameworks change. It is of interest therefore to examine and attribute changes in the PTTI values to components, which supports a better understanding of the conditions that led to these changes. It is the purpose of this study to suggest a structural decomposition analysis of changes in the values of the Antweiler index in (1).

The issue of index changes not reflecting the changes in actual pollution content of exports and imports (because both are measured in monetary values), can be resolved using appropriate data. The recent availability of such data allows for the construction of price indices for traded commodities and the separate calculation of impacts caused by actual traded quantities and prices, on changes of the PTTI in (1).

The method of structural decomposition analysis (SDA) of PTTI changes, suggested here, resembles the SDA processes for other economic variables found in the literature on Input-Output analysis. The proposed method estimates the role and significance of: (a) changes in prices of exported and imported commodities, (b) real changes in the mix and magnitude of traded quantities that have pollution content, and (c) changes in production technologies of the different traded commodities[2].

Data on the value of domestic production by economic sector, imports and exports classified similarly by the same foreign or domestic sectors, are now available in current and previous year prices. This allows for the construction of price indices necessary to calculate the price effects on changes of the Antweiler PTTI. The data are found in Input-Output tables of recent years, published by Eurostat. They can be combined with compatible (i.e. of similar sectoral classification) Eurostat's data on environmental accounts, i.e. amount of pollutants associated with each producing sector, to calculate the amount of pollution content per unit of production, imports and exports. As a case study, the suggested structural decomposition analysis is applied on the year to year changes of the PTTI, using data on the Netherlands for the period 2007-2010. Input-Output data for this period were available in the needed forms and were combined with the Dutch

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[2] It should be noted that if someone makes the theoretical choice and has appropriate data, they can apply our SDA method using different factors than the above as causes of PTTI changes or a different concept of PTTI. The procedure can be used for example to break down changes in PTTI into impacts of the five factors selected by Grether and Mathys (2013), even though their study uses these factors for component analysis (FCA).

environmental accounts for the same four years. The Antweiler PTTI is calculated and its changes analyzed using the SDA method with respect to the three greenhouse gas pollutants, expressed and treated as one pollutant in terms of greenhouse equivalent. Different or more pollutants can be considered also as in (1).

Data and Methodology

The available set of Input Output Tables for the economy of the Netherlands published by Eurostat was utilized. That set includes the Use and Make Matrices and the "Symmetric" Input-Output Tables ("siot") which are of the traditional sector by sector Leontief form. Unlike most of the European siot matrices which are of the commodity by commodity Leontief form, the sector by sector form makes the Dutch siot tables most suitable for use in combination with the environmental accounts which provide pollution data on a sectoral basis, (even though under certain assumptions such siot matrices can be constructed separately for other countries too). It was desired to have all exports and imports as sectoral outputs therefore, rather than commodities regardless of producing sector, because of the pollution data.

All Dutch tables are given in current and previous year prices which in the case of siot allows for the construction of price indices for each sector by sector and final demand transaction. This can be done also for the overall sectoral outputs, exports, and imports by corresponding foreign sectoral output. Every change in values can be broken down to changes due to actual quantities and prices. Moreover, the siot tables are given for the 2007-2010 period broken down in two detailed matrices one of which refers to transactions with domestically produced outputs and another one with imported outputs. The sum of the two matrices is the original (siot) matrix. As with the latter, the two matrices are given for the 2007-2010 period in both, current and previous year prices.

Information provided by the Central Bureau of Statistics of the Netherlands and Eurostat on greenhouse gasses (carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O) were also utilized. We used in particular the data on greenhouse CO_2 gas equivalent which was treated as one pollutant. The latter is a weighted sum of the three greenhouse gasses. The Antweiler PTTI with respect to greenhouse CO_2 gas equivalents is considered for our SDA, in its initial form and under altered assumptions. The environmental accounts provide information on emissions of the greenhouse gas equivalents and other pollutants on a sector by sector basis for a series of years including the 2007-2010 period. Sectors are defined in a similar way as in the IO Tables according to NACE 2. The tables classify the economy into sixty five domestic, producing, endogenous (i.e. non final demand) sectors, two of which however have no economic activity and there are no imports of corresponding foreign sectors. Some of the NACE 2 sectors of the environmental accounts are in a more disaggregated and others in a more aggregated form than the sectors in the IO Tables.

To achieve exact correspondence, we aggregated and classified all economic sectors into thirty-nine and calculated their total domestic output and exports, together with imports of corresponding foreign outputs. This was done using the Leontief form (siot) tables in both, current and previous year prices. For each of the four years t and all sectors i the greenhouse gas equivalent per unit of output ψ_{it} (in ton. per mil. euros) was estimated using the sectoral outputs in current prices. Multiplying each coefficient by the corresponding sectoral exports we have the pollution content of these sectoral exports and their sum gives us the pollution content of all exports.

As in Antweiler (1996), lack of detailed or accurate data corresponding to equivalent outputs for all trading countries and their bilateral trade with the Netherlands led to the assumption that for the same sectoral outputs, similar technologies of production with respect to greenhouse emissions prevail in both, the Dutch sectors and in the other trading countries. That means that for output i the same ψ_{it} prevail in all countries. As in the case of exports, using these coefficients we can find the pollution content of each imported i and the pollution content of total imports. If different pollution coefficients ψ_{it} prevail and data are available, nothing changes in the suggested method of SDA.

Using the assumption on imports, superscript cp and pp to denote values of exports and imports in current and previous year prices respectively (ψ_{it}'s are always here in current prices), we define the Antweiler PTTI for year t in current prices as:

$$(PTTI)_t^{cp} = \frac{\left(\sum_{i=1}^{n} X_{it}^{cp}\right)^{-1} \sum_{i=1}^{n} \psi_{it} X_{it}^{cp}}{\left(\sum_{i=1}^{n}\sum_{j=1}^{\kappa} \mathrm{M}_{ijt}^{cp}\right)^{-1} \sum_{i=1}^{n}\sum_{j=1}^{k} \psi_{it} M_{ijt}^{cp}} \qquad (2)$$

We define similarly the index for year t, measured in previous year (t-1) prices as:

$$(PTTI)_t^{pp} = \frac{\left(\sum_{i=1}^{n} X_{it}^{pp}\right)^{-1} \sum_{i=1}^{n} \psi_{it} X_{it}^{pp}}{\left(\sum_{i=1}^{n}\sum_{j=1}^{\kappa} \mathrm{M}_{ijt}^{pp}\right)^{-1} \sum_{i=1}^{n}\sum_{j=1}^{k} \psi_{it} M_{ijt}^{pp}} \qquad (3)$$

Finally, we can define the index for year t in current prices (or previous year prices) that would have prevailed under the technology of the previous year (t-1), using the star symbol * as:

$$(PTTI)_{t*}^{cp(pp)} = \frac{\left(\sum_{i=1}^{n} X_{it}^{cp(pp)}\right)^{-1} \sum_{i=1}^{n} \psi_{i(t-1)} X_{it}^{cp(pp)}}{\left(\sum_{i=1}^{n}\sum_{j=1}^{\kappa} \mathrm{M}_{ijt}^{cp(pp)}\right)^{-1} \sum_{i=1}^{n}\sum_{j=1}^{k} \psi_{i(t-1)} M_{ijt}^{cp(pp)}} \qquad (4)$$

Based on the above definitions and concepts, the total change of the defined and measured Antweiler PTTI between two periods t-1 and t, is given by $(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}$ (5). We can use now the concepts and definitions adopted thus far. The change in (5) can be broken down initially into two parts: A part is caused solely by changes in prices of traded commodities, given by $(PTTI)_t^{cp} - (PTTI)_t^{pp}$ (6). Another part is caused by changes in both, the real volume and mix of trade, and technology with respect to pollutant emissions (ψ's). It equals $(PTTI)_t^{pp} - (PTTI)_{t-1}^{cp}$ (7). The change in (5) can be broken down also in the following two parts: One is the change in real volume and mix of trade, which is equal to $(PTTI)_{t*}^{pp} - (PTTI)_{t-1}^{cp}$ (8). The other is the change in both, technology (ψ's) and prices, given by $(PTTI)_t^{cp} - (PTTI)_{t*}^{pp}$ (9). The part of change in (5) due to changes in technology only, is given by the difference $(PTTI)_t^{pp} - (PTTI)_{t*}^{pp}$ (10). As expected, using the concepts, (10) should be derived also as the difference (9) minus (6), or the total change in (5) minus the sum of (6) plus (8). Other equations resulting from the concepts exist and can be used to confirm the formulas measuring the role of one or two of the three factors examined, in causing the total change (for example the change due to real volume and mix of trade in (8) equals the total change in (5) minus the change due to changes in technology and prices (9)).

What is of essence here, is the fact that the total change of the Antweiler PTTI between t-1 and t, as expressed in (5) can be divided into three parts: The difference in (6) caused by changes in prices, the difference in (8) caused by changes in the real volume and mix of trade, and the difference in (10) caused by changes in technology with regards to pollution content per unit of exported and imported commodities. This type of SDA can be conducted for any length of period instead from year to year. However, trade data in previous year prices should be expressed then in prices of any other original period.

Expressions (5), (6), (8), and (10) give us the value of change in the Antweiler index and its decomposition into the three parts. If for every year t we divide the results of all these expressions by $(PTTI)_{t-1}^{cp}$ we obtain the percentage change of the index and the part of this percentage change attributed to prices, the real volume and mix of trade, and technology. As expected the sum of the three parts equals the percentage change of the index. Moreover, dividing every difference in (6), (8), and (10) by (5), we obtain the percentage share of the change in index, that can be attributed to prices, real volume and mix of trade, and technology. The sum of the last three percentages equals of course unity.

Results

Using the mentioned data and variables for the Netherlands for the years 2007-2010 and the interim year to year periods as a case study of the proposed SDA for the Antweiler PTTI in (1) which was estimated for each year. The magnitudes in (2), (3) and (4) were also estimated.

Subsequently we estimated the change in PTTI as is (5) and the changes in (6), (8), and (10). The results for all changes are given below in Table 1.

Table 1: Changes in the Antweiler PTTI and the impacts of the three factors

Year	$(PTTI)^{cp}$	$(PTTI)^{pp}$	Total change	Price effect	Trade effect	Technology effect
			$(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}$	$(PTTI)_t^{cp} - (PTTI)_t^{pp}$	$(PTTI)_{t*}^{pp} - (PTTI)_{t-1}^{cp}$	$(PTTI)_t^{pp} - (PTTI)_{t*}^{pp}$
2010	1.218	1.222	-0.171	-0.004	-0.172	0.005
2009	1.389	1.259	0.163	0.130	0.036	-0.002
2008	1.226	1.252	-0.016	-0.026	0.012	-0.001
2007	1.241					

The results are quite interesting because despite the short overall period covered, we can see cases of relatively small and large changes in the observed PTTIs and a diverse behavior in the role of the factors influencing their changes. Moreover, as one would expect, the change in the PTTIs caused by changes in technology are small in absolute magnitude for year to year periods. However, these changes still provide interesting information on the SDA of the index.

During the first period 2007-2008 the Antweiler PTTI undergoes an insignificant change of negative sign. This is due to the price effect, with the sum of the two other effects having a positive sign. The results serve to show that although the measured index declines, if we had measured the content of pollution per actual quantity unit of traded commodities the result would have been of the opposite sign. If we are interested in actual pollution content therefore and the consequences of trade and environmental policy such as environmental taxes, dumping, etc. it is the change in the sum of technology effect and the real volume and trade effect that we should be looking at, with the distinction between the two effects being done to evaluate the role of technology change and possibly for other purposes related to technology.

During the second period the index presents a much larger and rather significant change. A look however at the results for the period shows that this impression is largely created by changes in prices of the traded commodities. The sum of the other two effects is very small. Unlike the observed magnitude of change in PTTI, if the change in actual pollution content of trade was taken under consideration only, the pollution terms of trade would present a much smaller change. In the third period 2009-2010 the measured Antweiler PTTI displays a reduction in which the role of prices change played now a minimal role. The real trade effect seems to be the most important factor for the outcome this time and the reduction of the index reflects to a large extent changes in the actual pollution content of trade. This is always given by the sum of the two non-price effects as in (7).

The significance of each factor for the changes of the index appears clearer in the two tables that follow. In both tables the three first columns are the same as in Table 1, referring to the values of the index in current and previous year prices for each year.

Table 2: Percentage change of the Antweiler PTTI, and its' parts of the three factors.

Year	$(PTTI)^{cp}$	$(PTTI)^{pp}$	Total % change	Price effect	Trade effect	Technology effect
			$\frac{(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}}{(PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_t^{cp} - (PTTI)_t^{pp}}{(PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_{t*}^{pp} - (PTTI)_{t-1}^{cp}}{(PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_t^{pp} - (PTTI)_{t*}^{pp}}{(PTTI)_{t-1}^{cp}}$
2010	1.218	1.222	-0.123	-0.003	-0.124	0.004
2009	1.389	1.259	0.133	0.106	0.029	-0.002
2008	1.226	1.252	-0.013	-0.021	0.010	-0.001
2007	1.241					

The fourth column of Table 2 provides the three sequential percentage changes of the index for the covered period. This column is also the sum of the three last columns that follow. These columns present separately the parts of the total percentage change in PTTI, attributed to the three effects. The impact of the three factors in terms of the relative changes in PTTI they cause, becomes clear. The small percentage change of -1.3% between the first two years is mostly due to the price effect, which caused a -2.1% change in the index and determined also the sign of its change. The sum of the two other effects causes an almost 1% positive change in the index. The relatively large percentage increase of the index (13.3%) during the next one year period, is attributed again to the role of prices which caused a 10.6% percent change in the index. The change in actual pollution content of trade due to real volume and trade mix changes and technology changes as well, is very small in relative terms. Another possibility and completely different situation appears during the third one year period. The -12.3% change of the index can be attributed now almost solely to the two non-price effects which cause a 12% change in the value of the Antweiler PTTI.

Table 3 that follows is perhaps more informative and shows the relative importance of each factor in terms of its relative share of effect in the total change of the Antweiler PTTI, regardless of what its' absolute or percentage change is in the specific period.

Table 3: Percentage change and percentage shares of the total Antweiler PTTI change.

Year	$(PTTI)^{cp}$	$(PTTI)^{pp}$	Total % change	Price effect	Trade effect	Technology effect
			$\frac{(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}}{(PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_t^{cp} - (PTTI)_t^{pp}}{(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_{t*}^{pp} - (PTTI)_{t-1}^{cp}}{(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}}$	$\frac{(PTTI)_t^{pp} - (PTTI)_{t*}^{pp}}{(PTTI)_t^{cp} - (PTTI)_{t-1}^{cp}}$
2010	1.218	1.222	-0.123	-0.026	-1.005	-0.030
2009	1.389	1.259	0.133	0.798	0.220	-0.017
2008	1.226	1.252	-0.013	1.696	-0.785	0.089
2007	1.241					

The first three columns are the same as in the previous tables while the fourth is the same as in Table 2 showing the percentage change of the index. The three columns that follow show the size of each effect as a share of the change in index, i.e. the relative shares, which as expected sum up to unity. It should be noted that their signs are not always the same as their corresponding estimates in the other tables above. A positive sign for an effect now implies that the sign and direction of the effect's influence on the index is the same as the direction of overall change of the index.

During the first one-year period the price effect is 169.6% of the total change in the index showing again the significance of the price changes which imposed the negative sign of the index's change. The two non-price effects showing the impact of changes in the true pollution content of trade have a negative share of 69.6% of the total change in the PTTI indication. Their total effect is in the opposite direction than the one that prevailed over the index. It is interesting that when shares of impacts are considered which diminish -to some extent only- the influence of the small size of the periods examined on the measured technology effect, the latter becomes clearer. For this particular one year period, almost 9% of the total PTTI change is caused by technology changes which considered separately from the other non-price effect, cause a change of the index towards its actual direction of change.

During the second period a large share of almost 80% of the change in the index, can be attributed to changes in prices of the traded commodities. This adds to a positive 22% share of the real trade effect. A small negative share corresponds to the technology effect showing now that this effects tends to move the index towards the opposite to its prevailing direction. Here the price changes are seen again as expected from previous results, as the major factor driving the change in the index value with the two non-price effect playing a relatively smaller role. A different situation arose as known in the third period and appears here. The share of real trade effect tells the whole story with the share of price effect being very small. Both effects reinforce each other and they are positive since they both contribute to the prevailing reduction of the index. A negative share of 3% belongs to the technology effect showing that its size is a small share of the total change in index and moved the index towards the opposite than the prevailing direction.

Final remarks

We discussed the issue of the Antweiler Pollution Terms of Trade Index (PTTI) and its values arguing that its' intertemporal changes can better reflect the impact of regulation, taxation, or incentives on the relative pollution content of trade per unit of traded commodities. Moreover we proposed a method of structural decomposition analysis (SDA) of changes in the index. The method measures the impact of changes in prices of traded commodities, the impact of changes in the actual volume of trade, and the impact of changes in technology of production in terms of pollutant generation per unit of production. Measuring the impact of prices is of particular importance because the volume of imports and exports in the PTTI is measured in values and changes in its magnitude can be largely influenced by price changes. The impact of changes in the real volume of trade and technology of production are what we should consider as changes in the index due to actual changes in the pollution content of trade.

If instead of a SDA of changes in the index one wishes to conduct component analysis, in order to measure the effect of the three factors (i.e. price, real volume of trade, and production technology) on the estimated PTTI value for one or more years, this is still theoretically possible but we consider it significantly more data demanding. We used emissions of the CO_2 greenhouse equivalent in our study for the Netherlands, but another or more pollutants can also be used in applying the proposed SDA method. In addition, lack of data forced us to assume that technology of production of each specific traded commodity has been similar in the producing countries. This restrictive assumption found also in the literature, can be lifted if data are available without any changes in the logic and basics of the SDA method. Trying to lift the assumption in our empirical analysis using intercountry IO tables and other data and methods found in the literature, resulted in the necessity to make various assumptions for the missing data (as in this literature) which we consider also restrictive. More importantly, the lack of certain data in these datasets hindered our ability to account for effects of price changes that we consider very important.

The Antweiler PTTI and its changes can be used to test theories and assumptions on the international distribution of pollution generation through trade. Appropriate use of the index should be based on its' definition and the subject of research. On the other hand, previous empirical results using the index, may seem "paradoxical" because there is no separate consideration of prices and not because the initial PTTI's definition is irrelevant to the tested theories.

We showed using the Dutch IO and environmental accounts how changes in prices can reverse, minimize, and substantially magnify the value of measured PTTI changes. Hence, subtracting the effect of price changes can considerably change the conclusion of a hypothesis testing. What matters for practical purposes is that the changes in the actual pollution content of trade to be considered when the redistribution of environment-polluting activities is examined.

As is the case with most forms of SDA in the literature, even though the proposed method distinguishes and measures the impact of the three factors as desired, it doesn't capture the so called synergy effects. The three impacts are not independent. Isolating the change in one factor by keeping others constant overlooks the fact that the observed change of one is also the result of changes in the others. The method however offers a reasonable account of the different effects separately, while the synergy effects are not ignored but absorbed by the three estimated impacts. Their separate estimate is left to future research work.

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