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# The pollution terms of trade and its five components[☆]

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ABSTRACT

Based on two extensions, this paper proposes a re-appraisal of the concept of the pollution terms of trade (PTT) introduced by Antweiler (1996). First, detailed data allows capturing the effect of differences in emission intensities across countries and over time. Second, relying on Johnson and Noguera (2012), the revised PTT index controls for trade in intermediate goods and is based on value-added rather than gross output figures. Applied to a database for $SO_2$ emission intensities for 62 developed and developing countries over the 1990–2000 period, it turns out that the first extension has a larger empirical importance than the second one. The global pattern is one in which the major rich economies exhibit a PTT index below one (higher pollution intensity in imports than in exports). Trade imbalances tend to exacerbate this asymmetry, allowing rich economies to further offshore their pollution through trade.



## 1. Introduction

By disconnecting production from consumption sources, international trade leads to a worldwide distribution of polluting emissions which does not reflect final demand. A common suspicion is that rich countries, with higher environmental standards, tend to offshore their pollution to poor countries, according to a “pollution-haven” effect (e.g. Levinson and Taylor, 2008). These concerns, along with a growing pressure to curb down global emissions, have led to a flurry of studies analyzing the emission-content of trade (e.g. Wiedmann, 2009). However, it is fair to say that most of these studies have been national or regional in scope, limited to one year, and that available evidence at the world-wide level is still scant. This lack of world-wide evidence is linked with important data requirements and limitations. First, input–output matrices are needed in order to capture the additional emissions generated by the derived demand for inputs (e.g. Levinson, 2010). Second, data on imported input requirements by trade partner are necessary to attribute intermediate imports to their final destination (Johnson and Noguera, 2012). Third, reliable trade and production data must be made available and compatible at a reasonable degree of disaggregation to identify the influence of the most polluting sectors. Fourth, country (and year)-specific emission coefficients are necessary to control for the fact that the emission content of a given amount of output varies across countries and over time, because of differences in both technologies and input–output relationships. Taking the best out of available data for a specific pollutant, which is sulfur dioxide ($SO_2$), the first objective of this paper is to provide evidence of the pollution content of trade at the world-wide level, illustrating in particular the importance of capturing differences in (total) emission coefficients between countries and years and taking properly into account trade in intermediate goods.

$SO_2$ is a particularly useful pollutant to investigate because it is primarily anthropogenic, primarily industry-driven (rather than generated by transportation or household activity), and primarily a local (rather than a trans-boundary or global) pollutant.[1] In previous work Grether et al. (2009) have decomposed world-wide $SO_2$ manufacturing emissions over 1990–2000 into the well-known scale, technique and composition effects. It has been shown that despite the considerable increase of manufacturing activity by 10% (scale effect) total emissions have fallen by roughly 10% thanks to the adoption of cleaner techniques (technique effect) and a small shift towards cleaner industries. When

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[1] We would like to thank an anonymous referee for pointing out these characteristics.

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using output as the scale measure, there is however an important shift towards "dirty" countries. These results confirm the importance of analyzing in more detail the $SO_2$ pollution content of trade.

The second objective of this paper is to propose a reconsideration of the concept of the pollution terms of trade (PTT) introduced more than fifteen years ago by Antweiler (1996). Most of the recent literature has produced results in terms of environmental trade balances, normally captured by the difference between import-embodied and export-embodied emissions, or balance of emissions embodied in trade (BEET) according to Muradian et al. (2002). As noted by Straumann (2003), this measure is sensitive to trade imbalances, which may disappear or be reversed over time. By simply taking the ratio between the average pollution content per dollar of exports and the average pollution content per dollar of imports, the PTT index abstracts from this source of bias and appears more appropriate as a long run structural indicator. The original application reported by Antweiler (1996), based on a large range of pollutants ($CO_2$, $SO_2$, $NO_2$, lead, particulate matter, volatile organic compounds), came to the rather paradoxical conclusion that rich countries tended to exhibit a larger PTT index than poor ones. As already discussed by Antweiler himself, a possible reason for this result could come from data limitation. Indeed, he had to rely on US input–output adjusted emission intensities, and apply them universally, as if there were no technological differences across countries. Relying on his own words the original PTT was only capturing the "trade-composition" part of the PTT variation, not the "technological" part.

Since then, although the calculation of input–output based embodied emissions has been burgeoning, there has been, to our knowledge, no systematic attempt to reconsider the issue of PTT estimates at the world-wide level. This is all the more regrettable that recent contributions point towards the importance of trade in intermediate goods in shaping the factor content or the value-added content of trade (e.g. Johnson and Noguera, 2012 and Trefler and Zhu, 2010). In the presence of intermediate trade, the relationship between demand and polluting emissions becomes more complex. This is so because imports may correspond to inputs which are used to produce other goods which are further exported to another destination country. This affects the measurement of import or export-embodied emissions (and thus also PTT calculations) in a non-trivial way. The new methodology developed recently makes it possible to control for these effects, by uncovering the implicit trade flows that relate the original producer (and the corresponding emissions) to the final consumer (in the destination country that does manage to offshore pollution).

This paper proposes to revisit PTT calculations by exploiting newly available data and recent methodological advances in the analysis of intermediate trade. The approach is directly borrowed from Antweiler (1996), the basic difference being that we include time and country variations into the analysis, as well as trade in intermediate goods, which allows for an original decomposition of the PTT index into five components: a between-sector, a between-country, a technique, an intermediate trade and a value added effect. The first effect corresponds to the "trade-composition" index measured by Antweiler (1996), the second (third) effect captures the influence of different emission intensities across countries (over time), the fourth effect reflects the impact of using implicit (i.e. final demand driven) rather than reported trade flows, and the fifth the impact of considering value added rather than output trade flows. Regarding empirics, the sample period is 1990–2000 with a good coverage (63 developed and developing economies), and a particular care given to capturing technological heterogeneity. Trade- and country-specific input–output tables are taken from the Trade Production and Protection database of the World Bank (Nicita and Olarreaga, 2007), while country- and time-specific polluting manufacturing emission intensities come from the recent database elaborated by Grether et al. (2009). We also impose the consistency between trade and input–output data, control for reexports and apply the proportionality assumption to spread intermediate input requirements across trade partners (see Johnson and Noguera, 2012). As it turns out, the new empirical evidence reverses the paradoxical pattern observed by Antweiler (1996), and confirms the importance of including the newly computed correction terms.

The next section reviews the empirical evidence regarding pollution content of trade calculations. Section 3 outlines the theoretical derivation of the PTT index when trade in intermediate goods is taken into account and makes the link between the environmental trade balance, the trade ratio, and the PTT index. Section 4 shortly describes the data, Section 5 reports and discusses the main results and the last section concludes.

## 2. Literature review

Serious concern has been raised that in an era of globalization and differences in environmental stringency, trade liberalization will lead to a delocalization of polluting industries to countries with lower standards, i.e. the so called "pollution havens" (see Copeland and Taylor, 2004).[2] The possibility of delocalizing economic activities implies that international evidence is called for. Yet most evidence is from the US (Ederington et al., 2005; Levinson and Taylor, 2008; Levinson, 2010). The seminal paper by Antweiler et al. (2001) investigated the effect of trade on $SO_2$ concentrations using data from a large international sample of measurement installations. With increased trade liberalization they find that the concentration-decreasing technique effect is more than over-compensating the concentration-increasing scale and composition effects. Using the same framework but $SO_2$ emission data (instead of concentration data) Cole and Elliott (2003) could only partly confirm that trade is good for the environment. This discrepancy illustrates the challenges faced by studies investigating the causal link between trade and the environment in terms of estimation techniques and data needs, especially when it comes to proxies for environmental regulation and pollution measures. So far, studies working with a panel of countries had to rely on global measures of environmental quality (e.g. total country-emissions) and had to use proxies to identify scale, composition and technique effects (e.g. GDP, GDP/capita, etc.).

Several other arguments have been put forward to explain why it might be difficult to identify the pollution haven effect empirically. Ederington and Minier (2003) argue that environmental regulation might act as a secondary trade barrier and Frankel and Rose (2005) take specifically into account the endogeneity of trade and estimate the effect of trade on a country's environment for a given level of GDP for a sample of 40 countries. They find that trade has a beneficial effect on $SO_2$ concentration levels. Further Ederington et al. (2005) argue that for most industries, pollution abatement costs are a small component of total costs, and that those industries with the largest pollution abatement costs also happen to be the least geographically mobile. Finally it has been put forward, that the "factor endowment effect"; i.e. the fact that dirty industries are relatively capital intensive and would be attracted by capital abundant countries, would go in opposite direction of the pollution haven effect, as capital abundant countries also turn out to adopt stricter environmental regulations. Grether et al. (2012) have disentangled the two effects for a large number of pollutants and almost fifty countries. They find significant pollution haven and factor endowment effects going in the expected direction for trade between low and high income countries. On a global scale however, because the bulk of trade is intra-regional with a high share between high income countries, these effects are small relative to other determinants of the worldwide pollution content of imports (here computed without taking input–output linkages into account).

Another strand of the literature has put the emphasis on the link between emissions and sectoral economic activity, using detailed environmental data but restricting itself to reporting emissions embodied in trade flows. Following Muradian et al. (2002) several papers have computed the balance of emissions embodied in trade (BEET). The

[2] We restrict here our discussion to the analysis of trade flows. A large number of studies investigated also the effect of differences in environmental regulation on FDI flows. See for example Eskeland and Harrison (2003) or Javorcik and Wei (2004).