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Convergence in pollution terms of trade

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Abstract

By implementing the world input-output tables for 40-countries by 35-industries to account for intermediate trade, we constructed the pollution terms of trade (PTT) on the basis of CO_2 emissions between 1995 and 2009. We examine whether the PTTs have converged among the 40 countries in the past 15 years. The empirical evidence supports PTT convergence; PTT growth is negatively related to its initial level, and this empirical result is robust to various control variables.

Keywords: World input-output table; International trade; Pollution haven hypothesis; Pollution terms of trade

JEL Classification Codes: F18; O13; Q56.

1. Introduction

Environmentalists, economists and policymakers have paid substantial attention to the relationship between domestic economic activities and the environment and have instituted pollution abatement regulations where necessary (and where possible). In the globalised world, international trade complicates this problem; a large portion of domestic production is consumed abroad or used as input for production in foreign countries. A large portion of the environmental cost to a country arises because of consumption abroad. This cross-border shift in emissions caused by international trade can be measured in the pollution terms of trade (PTT) suggested by Antweiler (1996). The PTT is defined as the ratio of emissions per dollar of exports to emissions per dollar of imports. If the PTT is greater than 1, economic growth, along with balanced international trade, aggravates the level of emissions relative to the case in which there is no international trade.

What kind of dynamic paths would the PTT follow? Theoretical models have not reached common ground. The pollution haven hypothesis (PHH) asserts that production by dirty industries shifts towards developing countries where environmental regulations are either relatively lax or nonexistent. Given the less efficient pollution abatement technology at the initial stage, the PHH predicts that the dynamic path of developing countries' PTTs would worsen, meaning there would be an increase in the value of their

PTTs. Therefore, the PTTs diverge among trading countries. Conversely, the Green Solow model, a neoclassical growth model in which a representative agent optimally chooses a pollution abatement technology, suggests that emissions converge among trading countries (Brock and Taylor, 2010; Ordás Criado et al., 2011). The subtle issue of relating overall emissions directly to the PTT will be discussed in the following paragraphs.

Our study hinges on interrelated literatures regarding growth convergence, emission convergence, dynamic trade modelling and emissions associated with trade. The concept of convergence was first tested in the empirical growth literature (Baumol 1986; Barro, 1991; Barro and Sala-i-Martin, 1992). The growth convergence literature expanded exponentially and brought in many controversial issues for researchers to debate on. A long debate over econometric methodologies (Bernard and Durlaur, 1996) and sample selection led to the consensus that growth convergence holds true among developed countries but not among larger samples converging on the entire world; see the survey conducted by Islam (2003). Pollution emission convergence follows the arguments observed in the growth literature closely; emissions tend to converge among developed countries (Strazicich and List, 2003) but not globally (Nguyen Van, 2005). This comes as no surprise if we accept that a positive relationship in general holds true between production and emissions even though these are interrelated in a more complex manner;

see for example Brock and Taylor (2010) and Ordás Criado et al. (2011).

As criticised in the growth literature, theoretical models in these literatures should be based on open-economy models if the empirical objective is to compare growth rates among economies. Combining a classical trade model and a neoclassical growth model, many interesting results are obtained in dynamic Heckscher-Ohlin models (Bajona and Kehoe, 2010; Ben-David, 1993; Chen, 1992; Cuñat and Maffezzoli, 2004; Mountford, 1998; and Ventura, 1997). One notable feature is that convergence in growth may not be achieved because of factor endowments falling out of a diversification cone, meaning factor prices are not equalised across economies. An economy starting at a lower income level reaches a lower level of steady-state equilibrium than that reached by an economy starting at a higher income level or that which could be reached if trade were not liberalised (Cuñat and Maffezzoli, 2004).

In addition, PTT convergence may not hold true even in the case of sample countries among which emission convergence is achieved. First, emissions only measured for tradable products may differ greatly from pollution measured for the entire set of products. Second, the measurement of emissions per dollar used in the PTT may be linked in a complex way to emission levels or emissions per capita used in pollution convergence studies. Last, the PTT differs from the domestic pollution level because the PTT index is constructed as the ratio of the emissions for exports from the home country to that for imports from its trade partners; therefore, comparisons among countries are already built in.

Whether PTTs diverge or converge, therefore, is an open, empirical question. We empirically examine this issue by using pollution (CO_2) terms of trade for 40 countries between 1995 and 2009. In calculating PTTs, we closely follow the methodology of Grether and Mathys (2013) and address the issue of intermediate products in export production by implementing input-output tables at the national level for all 40 countries. The fundamental regression analysis executed herein concerns the relationship between the change in PTTs and the initial PTT levels. Empirical results provide strong evidence of PTT convergence. This finding is robust to the introduction of various control variables.

Some features of our analysis vis-à-vis what is currently available in the trade–environment literature should be highlighted. First, we focus on emissions embedded in international trade and not on emissions related to domestic production in its entirety (Cole and Elliot, 2003; Managi et al., 2009). Second, we choose the PTT for the measurement of emissions instead of the balance of emissions embodied in trade (BEET) because the PTT index has the advantage of abstracting from the scale effect and the trade imbalance effect[1]. Third, we focus on relatively longer-run dynamics by measuring the rate of PTT change in five-year terms as against investigating a static relationship between trade openness and pollution. Fourth, our analysis considers intermediate trade.

The structure of the rest of this paper is as follows. Section 2 delineates the basic construction of the PTT and relates it to other pollution concepts. The interrelated literatures on emissions, economic growth and international trade are also discussed. Section 3 reviews the methodology suggested by Trefler and Zhu (2010) and Grether and Mathys (2013) to account for intermediate inputs in the PTT. Section 4 describes the data and introduces the empirical model for testing PTT convergence. Section 5 presents the main empirical results, and finally, Section 6 offers concluding remarks.

2. Background

2.1 Pollution emission index concepts: (Nationwide) emission per capita, BEET and PTT

In this section, we introduce pollution emission concepts and explain their relationships with one another. In doing so, we provide the basic setup of theoretical models to refer to specific studies without invoking an equilibrium solution to the model.

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[1] The PTT is advocated in Antweiler (1996), whereas Muradian et al. (2002) advocate the BEET. The BEET is the net of pollution emissions embedded in international trade, i.e. pollution incurred in the home country for foreign demand subtracted by pollution incurred in foreign countries for the home country's demand. A positive (negative) signed BEET for a country indicates a carbon surplus (deficit) for international trade in that country.

Let's suppose that a world consists of N countries and S sectors. Q_{is} is the output of country i in sector s. For the sake of presentation, we suppress intermediate trade in this section[2]. Following dynamic Heckscher-Ohlin models of Bajona and Kehoe (2010) and Ventura (1997), the production in sector s utilises two factors of production, capital and labour, such that $Q_{is} = F_{is}(L_{is}, K_{is})$. At equilibrium, endowments of each factor must be equal to the sum of factors employed in each sector: $L_i = \sum L_{is}$ and $K_i = \sum K_{is}$. National income is the aggregate of production in all sectors such that $Y_i = \sum Q_{is}$. We follow Brock and Taylor (2010) to assume that emissions associated with production processes can be represented by the product of sector-specific pollution emission intensity D_{is} and production, i.e. $Z_{is} = D_{is} Q_{is}$. The amount of nationwide emissions, Z_i, per capita is then given by the following:

$$\frac{Z_i}{L_i} = \frac{\sum_s Z_{is}}{\sum_s L_{is}} = \frac{\sum_s D_{is} Q_{is}}{\sum_s L_{is}} .$$

(1)

The effects of international trade on emissions are classified into three separate mechanisms by Grossman and Krueger (1993), who distinguish three sources by which a change in trade can induce a change in the level of pollution: scale, composition and

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2 Intermediate trade is fully articulated in the next section and is fully incorporated in the extended model.

technique. The scale effect (the level of Q_{is}) increases emissions because of expanded production in the economy if international trade stimulates economic growth. The composition effect (the relative sizes of Q_{is} and Q_{ir}, $s \neq r$) affects the level of emissions through a change in the industry structure of the economy, which is because of the (partial) specialisation in industry induced by international trade. The technique effect (D_{is}) reduces emissions through the adoption of new production processes.

Suppressing the underlying utility functions, calculations of optimal behaviors and price vectors of final products and factors of production at equilibrium, the demand (in terms of value) in country *j* for products in sector *s* produced in country *i* is represented by C_{ijs}. Note that C_{ijs} represents an international trade flow when *i* and *j* are not equal. Then, country *i*'s trade balance is represented as follows: $\sum_{j \neq i} \sum_{s} C_{ijs} - \sum_{j \neq i} \sum_{s} C_{jis}$.

A common concern among environmentalists over trade liberalisation can be summarised by the PHH whereby the production of dirty industries shifts towards developing countries where environmental regulations are either relatively lax or nonexistent. Recent empirical studies examining the PHH can be classified into three approaches. One, suggested by the seminal work by Antweiler et al. (2001), regresses the emissions of national production on variables representing scale, technique and composition effects (Cole and Elliot, 2003; Managi et al., 2009). The second approach examines changes in the value of international trade with respect to environmental variables such as pollution abatement cost; see Levinson and Taylor (2008). The last approach directly measures the emissions embodied in international trade (Muradian et al., 2002; Ederington et al., 2004; Grether et al., 2009; Levinson, 2009; Douglas and Nishioka, 2012; Grether and Mathys, 2013; Xu and Dietzenbacher, 2014; Duan and Jiang, 2017).

The BEET for country *i* is defined as the emissions associated with the production of exports minus the emissions associated with the production of imports abroad, i.e.

$$\text{BEET} \equiv \sum_{j \neq i} \sum_{s} D_{is} C_{ijs} - \sum_{j \neq i} \sum_{s} D_{js} C_{jis} \; . \tag{2}$$

The BEET captures the (net) burden of pollution in international trade. If the BEET is positive, a country must bear extra (net) emissions for other countries' consumption.

The BEET becomes positive (therefore, detrimental to the home economy) if (the weighted average of) emission intensities for exports are greater than those for imports and/or if the trade balance is in surplus. Having the extra burden of emissions within domestic borders with a trade surplus cannot be avoided. This reality becomes clear when one imagines a country with some exports but no imports. To focus on the relative degree of intensity between exports and imports, emissions associated with trade flow in equation (2) are divided by trade values. Export emission intensity is

$\sum_{j\neq i}\sum_{s} D_{is}C_{ijs} \Big/ \sum_{j\neq i}\sum_{s} C_{ijs}$ and import emission intensity is $\sum_{j\neq i}\sum_{s} D_{js}C_{jis} \Big/ \sum_{j\neq i}\sum_{s} C_{jis}$. The PTT for country *i* is defined as the ratio of export emission intensity to import emissions intensity as follows:

$$\text{PTT} \equiv \frac{\text{export emission intensity}}{\text{import emission intensity}} = \frac{\sum_{s} v_s^i D_{is}}{\sum_{j\neq i}\sum_{s} w_{js}^i D_{js}}, \qquad (3)$$

where $v_s^i = \sum_{j\neq i} C_{ijs} \Big/ \sum_{j\neq i}\sum_{s} C_{ijs}$ is the share of sector *s* in country *i*'s total exports and $w_{js}^i = C_{jis} \Big/ \sum_{j\neq i}\sum_{s} C_{jis}$ is the share of sector *s* of country *j* in country *i*'s total imports.

As stated in Grether and Mathys (2013), the PTT has three advantages over the BEET. First, while the BEET takes a short-term perspective because it depends on trade imbalance to a large extent, the PTT takes a long-term perspective. Second, the PTT can abstract from any scale effects, calculating the ratio between the average pollution content per dollar of exports and that of imports. Third, it can be interpreted as a kind of international exchange rate of emissions.

2.2 Convergence and emissions

The concept of convergence originated in the economic growth literature. Initially, empirical examination of growth convergence was believed to lead to the selection of a growth model between a neoclassical, Solow-type growth model and a new growth model incorporating externalities and increasing returns. Later studies suggested that the convergence or divergence of growth can be obtained in both types of models. The key variable in that literature is the growth of income per capita (Y_i/L_i). Absolute convergence holds true in cross-section samples if the growth in income per capita is negatively related to the initial level of income per capita (Baumol 1986). Theoretically, absolute convergence requires the strong restriction that parameters, including time preference and savings rate, are equal across economies for all economies to reach the same steady state. Barro (1991) and Barro and Sala-i-Martin (1992) relax this restriction and consider conditional convergence by introducing conditional variables such as school enrolments and government consumption expenditures. According to the concept of conditional convergence, economies can reach different steady states, but upon controlling conditional variables, the income growth rate becomes negatively related to the initial income level.

Recent studies have made progress on the link between economic growth and emissions. Brock and Taylor (2010) and Ordás Criado et al. (2011) examine the Green Solow model, a neoclassical growth model, in which a representative agent optimally chooses a pollution abatement technology. Brock and Taylor (2010) provide strong empirical evidence that supports the convergence of CO_2 emissions per capita among 172 countries.

A natural consequence of the Green Solow model is the convergence of emissions per capita across countries, which has been examined by sophisticated econometric techniques over the past decade, frequently without theoretical basis (Aldy, 2006; Bulte et al., 2007; Ordás Criado and Grether, 2011). Ordás Criado et al. (2011) refine the Green Solow model by incorporating endogenously determined savings and abatement propensities and examine the relationship of pollution growth with the initial pollution levels and GDP per capita. They show that the pollution growth rate is positively related to the growth rate of GDP per capita and negatively related to the emission level. Countries initially exhibiting high levels of pollution have greater scope for adopting better (less polluting) extant technology, whereas countries that have already attained low levels of pollution must invest more in costly R&D to acquire new technology[3]. Consequently, countries with initially high pollution levels are expected to become less polluting with an increase in income per capita, whereas countries with initially low pollution levels are expected to become relatively more polluting.

One important criticism of both literatures is that theoretical models are all closed models. This criticism is reflected in growth models incorporating a classical two-factor,

[3] Relatedly, the environmental Kuznets curve (EKC) hypothesis asserts that emissions per capita increase with increasing income per capita in the early stages of economic development before decreasing with increasing income per capita during the later stages of economic development.

two-sector and two-country Heckscher-Ohlin model examined by Chen (1992), Ventura (1997), Mountford (1998), Cuñat and Maffezzoli (2004), Bajona and Kehoe (2010) and Chatterjee and Shukayev (2012). In these papers, international trade flows are endogenised, and trade flow, in general, is depicted as $C_{ijs} = C_{ijs}(P_1,\ldots P_S, r, w; K, L)$, where all arguments are (1 by N) vectors. Exports in sector *s* from country *j* to country *i* are determined by prices of all sectors ($P_1,\ldots P_S$), factor prices (*r, w*) and capital and labour endowments (*K, L*) in all countries. Prices of tradables are equalised internationally, and factor prices are also equalised if each country completely specialises in the case of free trade. However, factor prices are not equalised when factor endowments differ widely across economies.

Following the effective labour adjustment suggested by Trefler (1993), Ventura (1997) shows that a positive relationship between growth rate and the initial income level is possible when the elasticity of substitution between factor inputs is small, resulting in income divergence. Mountford (1998) examines the overlapping generation structure in a dynamic Heckscher-Ohlin model and shows that conditional convergence is obtained under free trade. However, Mountford (1998) presents the possibility that an initially higher-income country may end up with a lower steady-state equilibrium under free trade. Cuñat and Maffezzoli (2004) show the importance of similarity across economies at the initial stage. If the factor endowments of two economies are highly different, factor prices remain different even under free trade and each economy completely specialises. In this case, two economies reach different steady states under free trade but the same steady-state equilibrium under no trade. In sum, the most important implication obtained from dynamic Heckscher-Ohlin models is that convergence may not be obtained.

2.3 Relation between nationwide emissions and export intensity

It is important to show how emissions per capita in equation (1) are related to export intensity in the numerator of equation (3), which is as follows:

$$\sum_{j\neq i}\sum_{s} D_{is}C_{ijs} \Big/ \sum_{j\neq i}\sum_{s} C_{ijs} = \left(\frac{1}{\sum_{j\neq i}\sum_{s} C_{ijs} \Big/ L_i}\right)\left(\frac{\sum_{j\neq i}\sum_{s} D_{is}C_{ijs}}{\sum_{s} D_{is}Q_{is}}\right)\left(\frac{\sum_{s} D_{is}Q_{is}}{L_i}\right) \qquad (4)$$

The first term on the left-hand side of the equation is the reciprocal of exports per capita. The second term is the ratio of emissions in exports to emissions in overall production. The third term is emissions per capita in equation (1). To rephrase equation (4),

$$\text{export intensity} = \frac{1}{\text{exports per capita}} \times \frac{\text{emissions in exports}}{\text{emissions in production}} \times \text{emissions per capita}\ .$$

A change in emissions per capita can cause changes in the first two terms in unpredictable ways unless an underlying trade model is specificed. For example, once labour, L, (or capital, K) endowments change, the classical Rybczynski Theorem is invoked and the composition of production (the relative sizes of Q_{is} and $Q_{ir}, \quad s \neq r$) shifts towards labour- or capital-intensive sectors, resulting in changes in the first two terms. Thus, viewing this relationship between export intensity and pollution per capita in our framework, one gets the sense that the convergence of pollution per capita may not even assure export intensity convergence, leave alone the PTT.

To demonstrate how export intensity in equation (4) or PTT in equation (3) can differ from emission per capita, we compare the dynanmic behavires of emission per capita, export emission intensity, and PTT for China. Figure 1 shows time series of these variables along that of BEET for China as an illustrative example. Emission per capita for China had been relatively stable in the late 90s; however, China experiences a continuous increase in emission per capita after joining the WTO in 2001. On the other hand, export emission intensity has steadily declined for the entire sample between 1995 and 2009. The dynamic behavior of PTT is more complicated and shows some cyclical movement. We conclude again that observation of convergence in emission per caipta does not gurantee convergence in PTT and it is the matter of empirical issue.

{Place Figure 1 around here}

3. PTT with incorporation of intermediate imports

Another important issue in measuring emissions in the globalised world is the use of foreign inputs in export products. If one observes only the final goods, the impacts of emissions from intermediate goods are ignored. Explaining intermediate trade has been the classical problem in assessing the factor content of trade. Trefler and Zhu (2010) suggest an improved method of calculating the factor content of trade when intermediate trade is present. It requires a regional input-output model of the world economy where each region is a country[4]. Grether and Mathys (2013) apply the Trefler and Zhu (2010) factor content approach to emissions embedded in international trade. Instead of deducing the usage of labour or capital embedded in trade, Grether and Mathys (2013) calculate the emissions embedded in trade when intermediate products are present. Closely following the work of Trefler and Zhu (2010) and Grether and Mathys (2013), we show how we obtain the PTT, addressing imported intermediates.

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[4] Input-output analysis researchers have employed the multiregional input output (MRIO) model to assess environmental impacts with intermediate trade (the MRIO is well surveyed by Wiedmann et al., 2007, 2011; Wiedmann, 2011). The MRIO is applied to China (Pan et al., 2008; He and Fu, 2014), Japan–US (Ackerman et al., 2007), Norway (Peter et al., 2006), Spain (Serrano and Dietzenbacher, 2010), the United Kingdom (McGregor et al., 2008; Druckman, A. and Jackson, 2009) and multiple countries (Peter et al., 2011; Nakano et al., 2009; Douglas and Nishioka, 2012; Grether and Mathys, 2013). In all the above studies, CO_2 emissions embodied in trade are calculated; however, none of studies except that by He and Fu (2014) examined the PTT.

As in section 2, we consider a world that has N countries and S sectors. Q_i is an $S\times1$ vector of the gross output of country i. C_{ij} is an $S\times1$ vector of the final demand in country j for goods produced in country i. X_i is an $S\times1$ vector of the total exports from country i, where each component is X_{is} . M_{ij} ($i\neq j$) is an $S\times1$ vector of total imports of country j from country i, *and* B_{ij} is an $S\times S$ matrix of the input requirements of country j's sectors for intermediate inputs by country i's sectors. We define the world matrices for gross output Q and final demand C as follows:

$$Q = \begin{pmatrix} Q_1 & 0 & \cdots & 0 \\ 0 & Q_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & \ldots & Q_N \end{pmatrix}, \text{ (}NS\text{ by }N\text{)} \quad (5)$$

$$C = \begin{pmatrix} C_{11} & \ldots & C_{1N} \\ \vdots & \ddots & \vdots \\ C_{N1} & \ldots & C_{NN} \end{pmatrix}, \text{ (}NS\text{ by }N\text{)} \quad (6)$$

where the diagonal bloc (a column vector with S components) represents the final home country demand for its domestically produced goods and the off-diagonal elements represent the final demand in the foreign country for domestically produced goods.

Trade T can be defined as production minus intermediate demand BQ and final demand C, with the input requirement matrix B:

$$T = Q - [BQ+C] = Q\text{-}Q_D = \begin{pmatrix} X_1 & -M_{12} & \cdots & -M_{1N} \\ -M_{21} & X_2 & \cdots & -M_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ -M_{N1} & \cdots & \ldots & X_N \end{pmatrix}, \text{ (}NS\text{ by }N\text{)} \quad (7)$$

$$B = \begin{pmatrix} B_{11} & \dots & B_{1N} \\ \vdots & \ddots & \vdots \\ B_{N1} & \dots & B_{NN} \end{pmatrix}, (NS \text{ by } NS) \tag{8}$$

where diagonal blocs are input requirements of domestic intermediates and off-diagonal blocs represent input requirements of foreign intermediates. The matrix of implicit trade is given by the following:[5]

$$\tilde{T} = (I - B)^{-1}T. \tag{9}$$

Following Grether and Mathys (2013), we multiply a $1 \times NS$ vector of the direct emission intensities D' by $\tilde{T}$, where D' is constructed from each country's emission intensity such that $D = (D_1, \cdots D_N)$.[6] The matrix of trade-embodied emissions *E* is given by the following:

$$E = \begin{pmatrix} e_1^X & \dots & -e_{1N}^M \\ \vdots & \ddots & \vdots \\ -e_{N1}^M & \dots & e_N^X \end{pmatrix} = D'\tilde{T} = \begin{pmatrix} D'_1\tilde{X}_1 & \dots & -D'_1\widetilde{M}_{1N} \\ \vdots & \ddots & \vdots \\ -D'_N\widetilde{M}_{N1} & \dots & D'_N\tilde{X}_N \end{pmatrix}. \tag{10}$$

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5 $\tilde{T}$ can also be calculated by using $\tilde{T} = Q - \tilde{Q}_D$, where $\tilde{Q}_D = (1 - B)C$ is the implicit demand matrix (Johnson and Noguera, 2012).

6 Reversal of emission intensities among countries and years is uncommon in our dataset. In other words, it is rarely observed that an industry *k* in year *t* is dirty in country *i* and clean in country *j* in year *s*.

Now, we are left with redefining the PTT in equation (3). The PTT of country i is now redefined, fully incorporating intermediate imports as follows:

$$PTT_i = \frac{e_i^X}{U'\tilde{X}_i} \Big/ \frac{\sum_{j \neq i} e_{ji}^M}{\sum_{j \neq i} U'\tilde{M}_{ji}} \ , \tag{11}$$

where U' is an S×1 vector of 1s. PTT_i is the ratio of the pollution content in i's exports per dollar relative to the pollution content in i's imports per dollar. In other words, the PTT is the ratio of the value-weighted average emission intensity of exports to that of imports. If PTT_i is greater (smaller) than 1, country i suffers (does not suffer) the environmental load through international balanced trade.

4. Testing Emission Convergence Hypothesis

4.1 Absolute convergence model

In order to investigate whether the PTT's absolute (unconditional) pollution β-convergence holds true for the sample of 40 countries, we formulate equation (12) in the following panel data equation:

$$(1/T)\log(PTT_{i,t} / PTT_{i,t-T}) = \alpha + \beta \log PTT_{i,t-T} + \delta_i + \eta_t + \varepsilon_{i,t} \tag{12}$$

where δ_i is a country-specific dummy; η_t is a time-specific dummy and ε_{it} is the disturbance term. Because shorter-period estimates cannot capture long-term adjustment (Barro and Sala-i-Martin, 2004), we divided the sample period 1995–2009 into three subperiods, i.e. t = {1999, 2004, 2009}.

In line with the defensive effect, a relationship whereby the growth rate of emissions per capita is negatively related to the level of emissions per capita, found in Ordás Criado et al. (2011), the negative sign of β in equation (12) indicates PTT convergence. For the negative value of β, a developing country with a high PTT at the initial stage lowers its PTT in the subsequent periods.[7] This improvement in the PTT can be expected if there is substantial scope for developing countries to replace outdated production processes with new alternatives that incorporate the latest pollution abatement technology. For developed countries, the curtailment of emissions by developing countries implies shrinkage of the denominator in the PTT and therefore an increase in the PTT.

It should be noted that all countries can become cleaner in their exports even when PTT convergence holds true. As a reminder, the PTT reflects the cleanness of a country's own exports when compared with those of trade partners' exports. PTTs converge as long as the pace at which a country with relatively dirty exports at the initial stage becomes cleaner is faster than the pace at which a country with relatively cleaner exports at the initial stage becomes cleaner.

[7] Different from the growth rate of emissions per capita that is taken as the explained variable in Ordás Criado et al. (2011), the PTT depends not only on the home country's environmental regulations but also on those of the foreign country. Hence, we do not denote the negative relationship described in equation (12) as the defensive effect.

4.2 Conditional convergence model

Even if PTTs of all countries converge, the speed of convergence may not be homogeneous. The speed of PTT convergence may be affected by other macroeconomic conditions. A faster-growing and more open-to-trade country may improve its PTT faster than a slowly growing and less open-to-trade country would even if they start at the same PTT level. Unlike absolute convergence, conditional convergence allows us to assume possible heterogeneous paths of convergence among countries. The conditional version of convergence is tested by the following equation:

$$(1/T)\log(PTT_{i,t}/PTT_{i,t-T}) = \alpha + \beta \log PTT_{i,t-T} + \boldsymbol{\gamma}\mathbf{z}_{i,t} + \delta_i + \eta_t + \varepsilon_{i,t} \qquad (13)$$

where $\mathbf{z}_{i,t}$ is a vector of exogenous variables to capture country-specific factors. The rejection of the null $\gamma = 0$ supports conditional convergence, where the degree of convergence depends on a country's characteristics. Our primary concern is still regarding β—whether or not conditional variables are statistically significant.

The first candidate for a conditional variable is a country's income level. Empirically, the relationship between emissions and income has long been investigated in the environmental Kuznets curve (EKC) literature (see Dinda, 2004 and Carson, 2010 for the survey therein). Theoretically, Ordás Criado et al. (2011) emphasise the important bidirectional link between emissions and income growth.

With the multicountry open-economy framework of this study, additional control variables need to be introduced to explore the robustness of the empirical results. The second conditional variable is obvious given our international setting, i.e. trade openness. Trade openness is directly linked to the PTT almost by definition. If trade openness is zero, i.e. there is no international trade at all, the PTT cannot be calculated. However, the effect of increasing trade openness on the PTT is not straightforward once international trade is opened.

The third conditional variable is the capital-labour ratio. In previous studies examining the effect of international trade on the environment, many empirical models included the capital-labour ratio as an explanatory variable to reflect the comparative advantage effect of the Venek-Hecksher-Ohlin model (Managi, et al., 2009; Cole and Elliot, 2003). In general, higher economic growth rates lead to higher levels of investment and more accumulation of capital stock. If we take the traditional view that capital-intensive industries are similarly pollution-intensive, capital-labour ratio growth is likely to induce deterioration of the PTT, i.e. greater PTT values. However, if newly replaced capital stock is environmentally benign, the capital-labour ratio may not affect the PTT.

In line with the above discussion, equation (13) becomes the following equation with specific conditional variables:

$$
\begin{aligned}
&(1/T)\log(PTT_{i,t} / PTT_{i,t-T}) = \\
&\qquad \alpha + \beta \log PTT_{i,t-T} + \gamma_1 \log(y_{i,t-T}) + \gamma_2 \log(TO_{i,t-T}) + \gamma_3 \log(K_{i,t-T} / L_{i,t-T}) \qquad (14) \\
&\qquad + \delta_i + \eta_t + \varepsilon_{i,t},
\end{aligned}
$$

where $y_{i,t}$ is real GDP per capita; $TO_{i,t}$ (measured as the sum of exports and imports over GDP) is trade openness; $K_{i,t}/L_{i,t}$ is the capital-labour ratio; and $\varepsilon_{i,t}$ is the disturbance term. The expected sign of γ_1 is negative if fast-growing economies would adopt cleaner technology for producing goods for export, i.e. the technique effect. However, if a quadratic inverted-U relationship that is sometimes observed between emissions and income in the environmental Kuznets curve literature similarly holds true between the PTT and income, the sign of γ_1 cannot be determined. Because the PTT index is abstracted from the scale effect, the expected sign of trade openness γ_2 is ambiguous. The expected sign of γ_3 may be positive if the capital intensity of industries is correlated with their dirtiness. However, this is a controversial issue. Overall, the expected sign of conditional variables cannot be predetermined because the linkage between the PTT and conditional variables is complex and possibly nonlinear.

Finally, following Ordás Criado et al. (2011) for the idea of a bivariate dynamic model of emissions and output (or capital), we consider an extended model with the growth variables of three conditional variables as follows:

$$\begin{aligned}(1/T)\log(PTT_{i,t}/PTT_{i,t-T}) = \\ &\alpha + \beta \log PTT_{i,t-T} + \gamma_1 \log(y_{i,t-T}) + \gamma_2 \log(TO_{i,t-T}) + \gamma_3 \log(K_{i,t-T}/L_{i,t-T}) \\ &+ \gamma_4 (1/T)\log(y_{i,t}/y_{i,t-T}) + \gamma_5 (1/T)\log(TO_{i,t}/TO_{i,t-T}) \\ &+ \gamma_6 (1/T)\log\{(K_{i,t}/L_{i,t})/(K_{i,t-T}/L_{i,t-T})\} \\ &+ \delta_i + \eta_t + \varepsilon_{i,t}\end{aligned} \tag{15}$$

In estimating the above equation, we suspect that assumption of homogeneity variance structure of disturbance term holds because of large discrepancy of the roles in world trade among the sample countries, especially between China and other countries. Therefore, we adopt White robust estimates for standard deviations of disturbance terms in the following sections.

5. Empirical Results

Data on inputs, outputs, carbon emissions and trade balance are taken from the World Input-Output Database (WIOD).[8] Data on real GDP, real GDP per capita, trade balance and trade openness are taken from the Penn World Table 8.0. Our model contains

[8] Data are publicly available on the website with the following URL http://www.wiod.org/new_site/data.htm . Carbon emissions in the WIOD database are computed based on the use of different energy sources in each industry. Therefore, emission intensities, D_{is} in equation (1), are time-varying because of shifts in the use of different energy sources. Energy sources are the followings: anthracite; lignite; coke oven and gas coke; gas and diesel oil; motor gasoline; jet kerosene; gas and diesel oil; residual fuel oil; naphtha; other oil; natural gas (dry); other gaseous fossil; municipal wastes (non-biomass fraction) and industrial wastes.

40 economies and 35 sectors. Details regarding the countries (Table A1) and industries (Table A2) are provided in the Appendix.

Using the world (40 countries plus the rest of the world) gross output matrix (*Q*, 1,435 by 41) and demand matrix (*C*, 1,435 by 41) combined with an input requirement matrix (*B*, 1,435 by 1,435) and vector of direct emission intensity (*D*, 1 by 1,435), PTTs are calculated and reported in Table A3 in the Appendix. Among the 40 economies, the PTT indices decreased for 25 economies during the sample period. The decline in the PTT is particularly substantial for two countries with the greatest (dirtiest) initial values. For Russia and China, the PTT improved from 7.565 and 4.126, respectively, in 1995 to 4.497 and 1.665, respectively, in 2009. For all countries with PTT values greater than 1 in 1995, PTTs declined in 2009, except for Indonesia. It is noteworthy that the PTTs for the rest of the world, including more than 100 countries, are not shown in Table A3.

PTT convergence can be seen from the scatter plots of the average change rate of log PTT against initial log PTT in Figure 2. The dotted horizontal line indicates 0 change and the dotted vertical line indicates that the initial PTT was 1. As clearly shown in Figure 2, we can find a negative relationship between the PTT change rate and the initial PTT. However, a substantial number of countries fall in the southwest area that is divided by two dotted lines. The PTTs of these countries further declined from their initially low PTTs. We formally investigate PTT convergence in the following regression analysis.

{place Figure 2 around here}

5.1 Testing absolute convergence and conditional convergence

We now turn to our estimation results including country fixed effects and time fixed effects, which are reported in Table1.[9] Column (1) reports estimates of equation (12) without control variables. The sign of the T-year lagged level of the PTT in column 1 is negative and statistically significant. This result suggests that convergence holds true for carbon emissions embodied in trade when trade in intermediate goods is considered.

{place Table 1 around here}

Next, to test whether the convergence is unconditional or conditional, we first introduce the initial level of GDP per capita to the estimation. In column (2) of Table 1, the estimated coefficient of the initial GDP per capita is not statistically significant. This suggests that the income level at the initial stage does not affect the later change in the PTT. In column (3), the initial level of trade openness is tested as a conditional variable.

[9] For most specifications, a Hausman test rejected the null that there is no correlation between regressors and the individual effects. Therefore, fixed effects model results are presented herein.

The estimated coefficient is negative and statistically significant at the 10% level, suggesting weak evidence that freer trade is beneficial to the environment. In column (4), the initial level of the capital-labour ratio is tested as a conditional variable and is found not to be statistically significant. In column (5), all three conditional variables are included as per equation (14). The result is qualitatively identical to those obtained using single conditional variables. The initial level of trade openness is statistically significant at the 5% level. Note that adding conditional variables does not affect the impact of the initial level of the PTT and that it remains negative and statistically significant at the 1% level throughout all specifications.

5.2 Convergence conditional on growth variables?

In this subsection, we follow Ordás Criado et al. (2011) to include growth variables as per equation (15). In the model of Ordás Criado et al. (2011), emissions and income appear as bivariate dynamic equations, including both initial level and growth variables. We extend Ordás Criado et al. (2011) and include the growth variables, namely, trade openness and capital-labour ratio.

{Insert Table 2 around here}

In column (2) of Table 2, GDP per capita is introduced in terms of both the initial level and the growth rate. The estimated coefficient for the initial level of GDP per capita is not statistically significant as shown in the previous subsection. However, the growth rate of GDP per capita is negative and statistically significant at the 1% level. This is consistent with Brock and Taylor (2010) and Ordás Criado et al. (2011). Their models suggest that a country starts with a dirty trade structure when income is low at the initial stage; however, the trade structure becomes cleaner as income grows. This is attributed to both the composition effect and the technique effect. Trade openness and capital-labour ratio are introduced similarly at the initial level and for growth in columns (3) and (4), respectively. These conditional variables are not statistically significant. The results in column (5) with all conditional variables as per equation (15) are similar to the previous results. More importantly, the signs and the statistical significance of the lagged PTT are robust to any conditional variable specifications.

5.3 Robustness check

The analysis thus far has concerned three five-year subperiods in a panel context and has found strong evidence that the PTTs among 40 economies have converged in the past 15 years. However, PTT convergence may not have occurred smoothly over this time period. Please note that the last subperiod includes the year 2009, in which world trade declined substantially, more than the decline in world income: the so called Great Trade Collapse[10]. To explain a possible shift in the convergence path, we run cross-section regressions by each subsample. The estimation results are shown in Table 3. Results for the first (1995–1999), middle (2000–2004) and last (2005–2009) subsamples are in columns (1), (2) and (3), respectively. There are four noteworthy points, and we discuss each of them in turn.

{insert Table 3 around here}

First, PTT convergence advanced the most in the first half of the 2000s. The initial PTT has the correct sign in each subsample; however, it is not statistically significant in the first and last subsamples[11]. However, note that the point estimate of the first subsample is exactly the same as that of the middle subsample. Second, the negative effect of income growth on PTT growth is robust. Income growth has a negative sign in all subsamples and is statistically significant except for the last subsample. This result supports the bivariate dynamic modelling results of Ordás Criado et al. (2011), in which income growth affects emissions. Third, the growth of trade openness may influence the PTT. The estimates of growth in trade openness are statistically significant in the first and

[10] One of the most recent studies on the Great Trade Collapse is Eaton, Kortum, Neiman and Romalis (2016) where the decline in world trade in 2009 is expounded.

[11] The p-value for the initial PTT in the first subsample is only slightly greater than 10%; namely, it is 10.1%.

middle subsamples. However, the opposite signs in the two subsamples indicate that the countries that liberalised trade in the late 1990s (early 2000s) improved (worsened) their PTTs. Further inquiry into this issue may be of importance for future research. Last, none of the explanatory variables are statistically significant in the last subsample. This result might be influenced by the Global Financial Crisis and condequent Global Trade Collapse. To address this issue, we re-estimated for the last sample excluding 2009 as in column (4). As expected, one of the explanatory variables, change in GDP per capita, become statistically significant. The Great Trade Collapse was so devastating that the PTT was cut loose from any linkages to other economic variables.

6. Concluding Remarks

Using the international input-output table to explain intermediate trade, we constructed a world panel dataset for the carbon dioxide emissions embodied in international trade among 40 countries in 35 sectors between 1995 and 2009. Among the two indices measuring pollution-associated international trade, we chose the PTT over the BEET because the former avoids the nuisance effects of trade imbalance and scale. Moreover, we focused on investigating the pollution dynamics of trade and the environment in a convergence framework. In particular, we examined whether the PTTs have converged among 40 countries in recent years.

The main contribution of this paper is the evidence posited for PTT convergence. Our main empirical results indicate that the PTT change rate is negatively related to the level of the initial PTT and the growth rate of GDP per capita. This is strong evidence for trade-related emission convergence. This implies that a low-income economy starting with a dirty trade composition in general improves its PTT and that this catch-up process is accelerated when the economy grows faster. This mechanism contrasts the one assumed in the PHH.

There are two caveats to our analysis. First, our results are only based on a single pollutant, namely CO_2. CO_2 is a globally mixing pollutant unlike Sox, for example, which is characterised by regionally limited dispersal. Consequently, the results obtained for CO_2 should not be extended to other pollutants because the characteristics and impacts of these pollutants can differ greatly. For example, in EKC studies examining various pollutants, CO_2 tends to monotonically increase with income (Holtz-Eakin and Selden, 1995).

Second, the selection of countries in this study is solely based on the availability of WIOD data. Thus, the sample is biased towards developed countries. In the growth convergence literature, convergence among similarly developed economies is well established; however, nonconvergence is often found when the sample is extended to cover both developed and developing economies. Our finding of PTT convergence may not be robust to a larger sample that better represents developing economies.

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Figure 1. Emissions per capita, BEET, PTT, and Export emissions intensity (per thousand dollar) for China

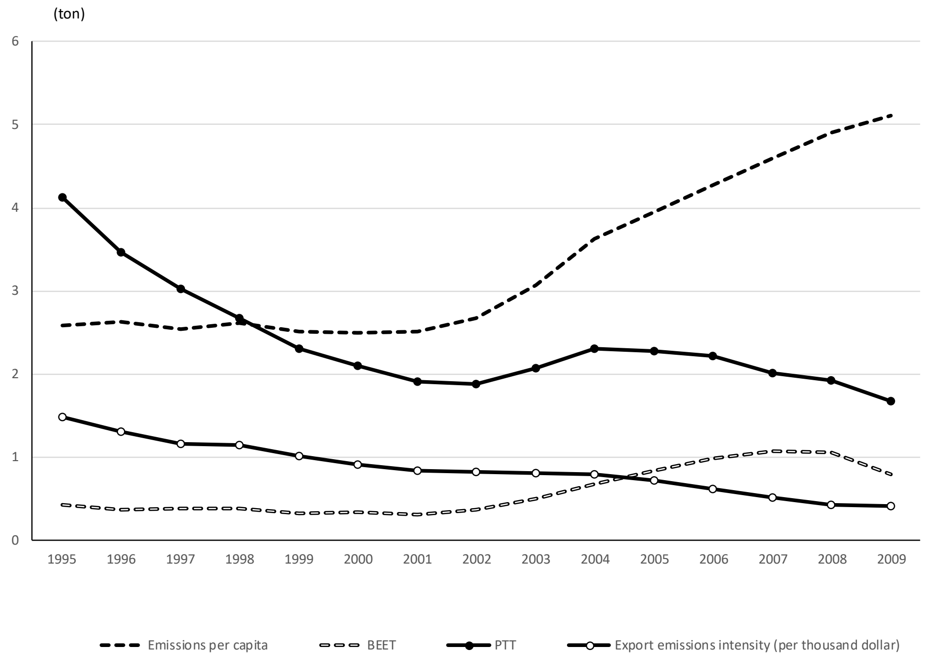

Figure 2. Change rate of PTT vs initial PTT

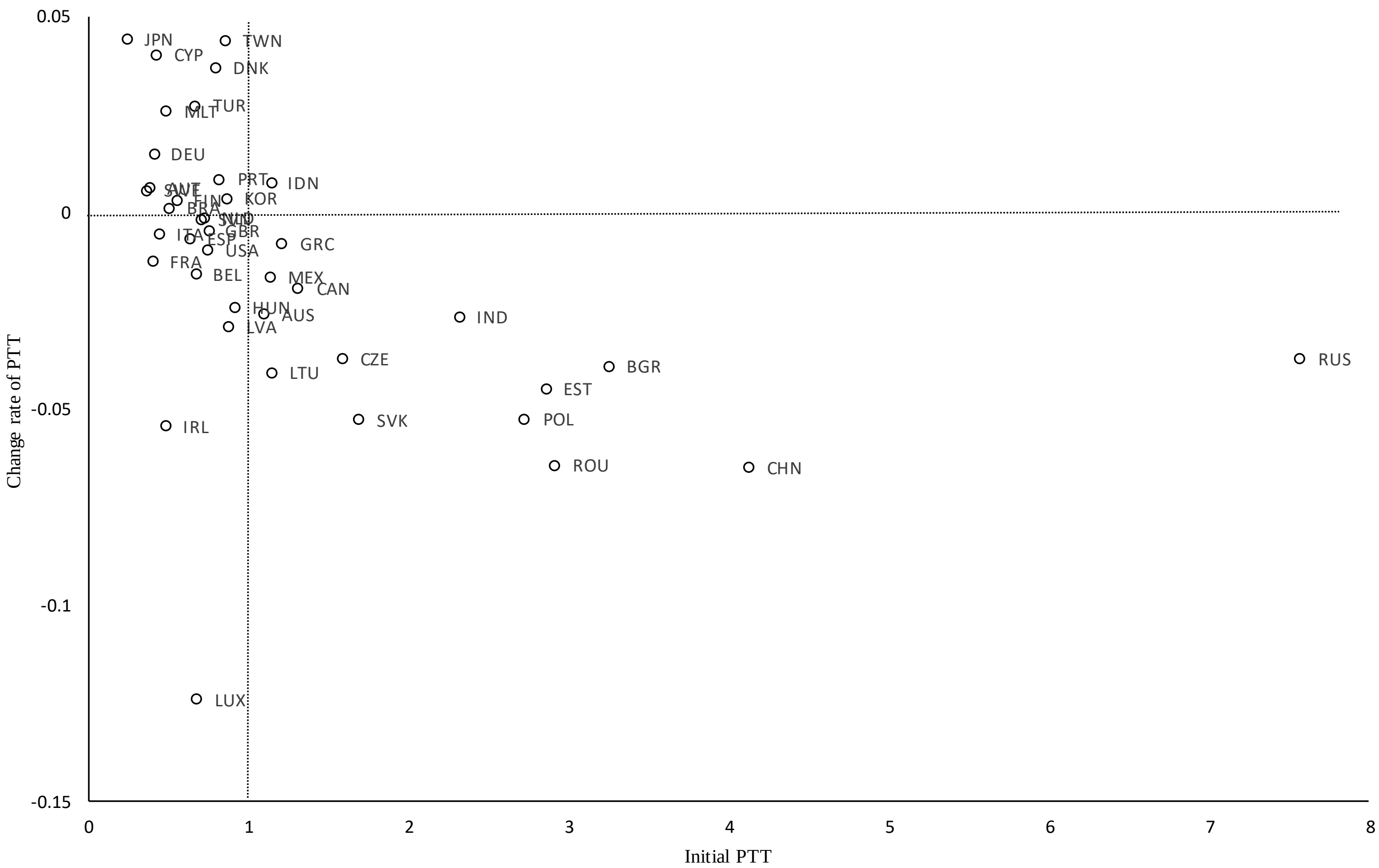

Table 1. Panel estimates of pollution convergence

	(1)	(2)	(3)	(4)	(5)
Constant	-0.037***	-0.276	-0.103***	-0.957	-1.030
	[0.008]	[0.901]	[0.038]	[1.018]	[1.231]
$\log(PTT_{i,t-T})$	-0.202***	-0.198***	-0.211***	-0.197***	-0.213***
	[0.035]	[0.040]	[0.040]	[0.035]	[0.041]
$\log(y_{i,t-T})$		0.025			-0.039
		[0.094]			[0.079]
$\log(TO_{i,t-T})$			-0.081*		-0.092**
			[0.045]		[0.043]
$\log(Ki,_{t-T}/L_{i,t-T})$				0.080	0.113
				[0.089]	[0.077]
Adjusted R^2	0.508	0.504	0.539	0.514	0.550
NOB	120	120	120	120	120

Note: The dependent variable is the period-average change in pollution terms of trade, $(1/T)\log(PTT_{i,t}/PTT_{i,t-T})$. White heteroskedasticity consistent standard errors are shown in brackets. Statistical significance at the 1%, 5% and 10% levels is indicated by ***, ** and *, respectively.

Table 2. Panel estimates of pollution convergence with additional conditional variables

	(1)	(2)	(3)	(4)	(5)
Constant	-0.037***	1.123	-0.087**	-0.733	0.157
	[0.008]	[0.769]	[0.040]	[1.050]	[1.011]
$\log(PTT_{i,t-T})$	-0.202***	-0.217***	-0.210***	-0.206***	-0.220***
	[0.035]	[0.047]	[0.040]	[0.039]	[0.045]
$\log(y_{i,t-T})$		-0.118			-0.196*
		[0.080]			[0.111]
$\log(TO_{i,t-T})$			-0.055		0.035
			[0.048]		[0.051]
$\log(K_{i,t-T}/L_{i,t-T})$				0.062	0.153
				[0.091]	[0.097]
$(1/T)\log(y_{i,t}/y_{i,t-T})$		-0.938***			-1.260***
		[0.331]			[0.335]
$(1/T)\log(TO_{i,t}/TO_{i,t-T})$			0.206		0.086
			[0.211]		[0.190]
$(1/T)\log(K_{i,t-T}/L_{i,t-T})$				-0.535	-0.177
				[0.444]	[0.662]
Adjusted R^2	0.508	0.581	0.542	0.519	0.610
NOB	120	120	120	120	120

Note: The dependent variable is the period-average change in pollution terms of trade, $(1/T)\log(PTT_{i,t}/PTT_{i,t-T})$. White heteroskedasticity consistent standard errors are shown in brackets. Statistical significance at the 1%, 5% and 10% levels is indicated by ***, ** and *, respectively. Time dummy coefficients and standard errors are not reported.

Table 3. Subsample estimates of pollution convergence

	(1) 1995-1999	(2) 2000-2004	(3) 2005-2009	(4) 2005-2008
Constant	0.066	0.303	0.159	0.108
	[0.198]	[0.222]	[0.375]	[0.359]
$\log(PTT_{i,t-T})$	-0.029	-0.029**	-0.042	-0.017
	[0.017]	[0.013]	[0.031]	[0.016]
$\log(y_{i,t-T})$	-0.068	-0.003	-0.064	-0.038
	[0.052]	[0.046]	[0.062]	[0.046]
$\log(TO_{i,t-T})$	-0.009	0.008	-0.008	0.014
	[0.014]	[0.023]	[0.034]	[0.030]
$\log(Ki,t\text{-}T/L_{i,t-T})$	0.058	-0.024	0.041	0.026
	[0.049]	[0.045]	[0.052]	[0.035]
$(1/T)\log(y_{i,t}/y_{i,t-T})$	-2.070***	-0.895*	-0.890	-0.968***
	[0.432]	[0.528]	[0.809]	[0.321]
$(1/T)\log(TO_{i,t}/TO_{i,t-T})$	-0.946***	0.408**	-0.292	-0.329
	[0.244]	[0.179]	[0.362]	[0.429]
$(1/T)\log(K_{i,t-T}/L_{i,t-T})$	-0.672	-0.239	0.193	0.711
	[0.654]	[0.626]	[0.739]	[0.673]
Adjusted R^2	0.522	0.157	0.054	0.128
NOB	40	40	40	40

Note: The dependent variable is the period-average change in pollution terms of trade, $(1/T)\log(PTT_{i,t}/PTT_{i,t-T})$. White heteroskedasticity consistent standard errors are shown in brackets. Statistical significance at the 1%, 5% and 10% levels is indicated by ***, ** and *, respectively.

Appendix A: Sample economies and sector classification

Table A1. Sample economies

No.	Name
1	Australia
2	Austria
3	Belgium
4	Brazil
5	Bulgaria
6	Canada
7	China
8	Cyprus
9	Czech Republic
10	Denmark
11	Estonia
12	Finland
13	France
14	Germany
15	Greece
16	Hungary
17	India
18	Indonesia
19	Ireland
20	Italy
21	Japan
22	Republic of Korea
23	Latvia
24	Lithuania
25	Luxembourg
26	Malta
27	Mexico
28	Netherlands
29	Poland
30	Portugal
31	Romania
32	Russia
33	Slovak Republic
34	Slovenia
35	Spain
36	Sweden
37	Taiwan
38	Turkey
39	United Kingdom
40	United States

Table A2. Sector classification

WIOD ID	Sector
c1	Agriculture, Hunting, Forestry and Fishing
c2	Mining and Quarrying
c3	Food, Beverages and Tobacco
c4	Textiles and Textile Products
c5	Leather, Leather and Footwear
c6	Wood and Products of Wood and Cork
c7	Pulp, Paper, Paper , Printing and Publishing
c8	Coke, Refined Petroleum and Nuclear Fuel
c9	Chemicals and Chemical Products
c10	Rubber and Plastics
c11	Other Non-Metallic Mineral
c12	Basic Metals and Fabricated Metal
c13	Machinery, Nec
c14	Electrical and Optical Equipment
c15	Transport Equipment
c16	Manufacturing, Nec; Recycling
c17	Electricity, Gas and Water Supply
c18	Construction
c19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
c20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
c21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
c22	Hotels and Restaurants
c23	Inland Transport
c24	Water Transport
c25	Air Transport
c26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
c27	Post and Telecommunications
c28	Financial Intermediation
c29	Real Estate Activities
c30	Renting of M&Eq and Other Business Activities
c31	Public Admin and Defence; Compulsory Social Security
c32	Education
c33	Health and Social Work
c34	Other Community, Social and Personal Services
c35	Private Households with Employed Persons

Table A3. PTT indices for CO_2

ID	Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1	Australia	1.094	1.076	1.126	1.215	1.136	1.172	1.241	1.112	1.001	0.864	0.810	0.854	0.828	0.873	0.762
2	Austria	0.376	0.408	0.464	0.420	0.401	0.398	0.399	0.409	0.396	0.418	0.437	0.431	0.425	0.431	0.411
3	Belgium	0.668	0.705	0.721	0.727	0.693	0.678	0.671	0.622	0.588	0.560	0.545	0.526	0.520	0.519	0.537
4	Brazil	0.502	0.511	0.555	0.555	0.778	0.649	0.721	0.751	0.717	0.671	0.586	0.532	0.505	0.483	0.512
5	Bulgaria	3.254	3.498	4.914	3.512	2.118	2.676	4.520	4.064	3.968	3.467	3.205	3.247	2.927	2.481	1.884
6	Canada	1.308	1.309	1.328	1.370	1.249	1.090	1.089	1.140	1.073	0.937	0.908	0.856	0.948	0.987	0.999
7	China	4.126	3.458	3.025	2.674	2.310	2.098	1.902	1.880	2.074	2.306	2.269	2.209	2.014	1.925	1.665
8	Cyprus	0.421	0.627	0.767	0.814	0.843	0.745	1.049	0.943	0.810	0.630	0.664	0.787	0.769	0.575	0.740
9	Czech Republic	1.587	1.535	1.429	1.239	1.115	1.124	1.041	0.945	0.959	1.016	0.936	0.881	0.870	0.740	0.944
10	Denmark	0.794	0.952	0.793	0.982	1.006	1.010	0.968	0.979	1.050	1.027	1.101	1.383	1.447	1.456	1.333
11	Estonia	2.857	2.914	2.712	2.055	1.263	1.135	0.774	1.202	1.097	0.602	0.671	1.056	1.392	1.332	1.527
12	Finland	0.553	0.655	0.669	0.563	0.454	0.478	0.542	0.561	0.577	0.571	0.521	0.588	0.556	0.512	0.578
13	France	0.402	0.435	0.458	0.431	0.393	0.403	0.392	0.377	0.350	0.328	0.347	0.348	0.335	0.339	0.338
14	Germany	0.407	0.450	0.498	0.465	0.432	0.455	0.489	0.500	0.448	0.451	0.455	0.486	0.454	0.462	0.502
15	Greece	1.208	1.214	1.291	1.303	1.152	0.970	0.930	0.784	0.669	0.509	0.313	0.671	0.505	0.313	1.082
16	Hungary	0.917	0.900	0.884	0.863	0.642	0.582	0.613	0.555	0.524	0.521	0.494	0.535	0.530	0.580	0.655
17	India	2.320	2.481	2.298	2.237	2.053	2.082	1.922	1.715	1.537	1.410	1.270	1.521	1.434	1.562	1.603
18	Indonesia	1.140	0.904	0.966	2.209	1.733	1.579	1.665	1.355	1.502	1.586	1.565	1.515	1.465	1.177	1.270
19	Ireland	0.486	0.459	0.477	0.437	0.407	0.394	0.388	0.347	0.288	0.277	0.271	0.269	0.231	0.239	0.227
20	Italy	0.439	0.421	0.451	0.398	0.386	0.415	0.418	0.406	0.394	0.388	0.412	0.432	0.416	0.429	0.407
21	Japan	0.240	0.318	0.345	0.337	0.321	0.308	0.353	0.379	0.370	0.356	0.360	0.404	0.455	0.442	0.446
22	Latvia	0.870	0.866	0.969	0.853	0.698	0.605	0.730	0.733	0.717	0.674	0.650	0.640	0.621	0.578	0.580
23	Lithuania	1.140	1.260	1.065	1.038	0.691	0.654	0.800	0.722	0.629	0.758	0.757	0.724	0.693	0.676	0.646
24	Luxembourg	0.672	0.653	0.565	0.390	0.361	0.140	0.157	0.196	0.156	0.152	0.135	0.122	0.100	0.108	0.119
25	Malta	0.480	0.529	0.563	0.492	0.444	0.382	0.543	0.561	0.584	0.609	0.589	0.552	0.572	0.595	0.690
26	Mexico	1.133	1.061	0.926	0.892	0.797	0.687	0.646	0.651	0.728	0.705	0.706	0.674	0.703	0.708	0.902
27	Netherlands	0.718	0.744	0.776	0.745	0.711	0.696	0.698	0.691	0.655	0.635	0.629	0.627	0.622	0.619	0.705
28	Poland	2.720	2.599	2.537	1.995	1.734	1.555	1.533	1.538	1.694	1.573	1.395	1.377	1.249	1.145	1.306
29	Portugal	0.817	0.749	0.807	0.840	0.906	0.826	0.772	0.823	0.758	0.798	0.893	0.870	0.812	0.861	0.923
30	Republic of Korea	0.858	0.855	0.936	1.094	0.920	0.908	0.972	0.817	0.767	0.724	0.649	0.631	0.659	0.771	0.905
31	Romania	2.911	2.911	3.081	2.614	2.185	2.245	2.263	2.382	2.125	2.119	1.733	1.626	1.419	1.203	1.185
32	Russia	7.565	6.886	6.626	8.416	14.314	11.116	9.781	9.406	8.561	6.940	5.821	5.057	4.374	3.946	4.497
33	Slovak Republic	1.686	1.585	1.777	1.589	1.513	1.190	1.390	1.369	1.154	1.144	1.146	1.026	0.846	0.840	0.806
34	Slovenia	0.698	0.726	0.711	0.664	0.577	0.583	0.693	0.676	0.612	0.698	0.714	0.758	0.696	0.683	0.683
35	Spain	0.631	0.590	0.692	0.635	0.674	0.706	0.692	0.674	0.618	0.626	0.641	0.607	0.598	0.579	0.576
36	Sweden	0.359	0.336	0.359	0.357	0.351	0.316	0.365	0.327	0.311	0.336	0.334	0.327	0.324	0.330	0.390
37	Taiwan	0.850	0.851	0.904	0.990	0.936	0.971	1.066	1.090	1.176	1.112	1.212	1.302	1.328	1.286	1.572
38	Turkey	0.665	0.818	0.855	0.831	0.580	0.746	0.732	0.829	0.778	0.731	0.640	0.710	0.717	0.783	0.977
39	United Kingdom	0.749	0.756	0.683	0.608	0.587	0.600	0.639	0.616	0.614	0.575	0.599	0.555	0.541	0.623	0.703
40	United States	0.741	0.724	0.708	0.607	0.633	0.631	0.626	0.597	0.593	0.589	0.575	0.573	0.644	0.687	0.650