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Do environmental policies affect global value chains? A new perspective on the pollution haven hypothesis

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ECONOMICS DEPARTMENT

DO ENVIRONMENTAL POLICIES AFFECT GLOBAL VALUE CHAINS? A NEW PERSPECTIVE ON THE POLLUTION HAVEN HYPOTHESIS

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ABSTRACT/RÉSUMÉ

Do Environmental Policies affect Global Value Chains? A New Perspective on the Pollution Haven Hypothesis

Increasing international fragmentation of production has reinforced fears that industrial activity may flee to countries with laxer environmental policies – in line with the so-called Pollution Haven Hypothesis (PHH). If PHH effects are strong, domestic responses to environmental challenges may prove ineffective or meet strong resistance. Using a gravity model of bilateral trade in manufacturing industries for selected OECD and BRIICS countries over 1990s-2000s, this paper studies how exports are related to national environmental policies. Environmental policies are not found to be a major driver of international trade patterns, but have some significant effects on specialisation. More stringent domestic policies have no significant effect on overall trade in manufactured goods, but are linked to a comparative disadvantage in “dirty” industries, and a corresponding advantage in “cleaner” industries. The effects are stronger for the domestic component of exports than for gross exports, yet notably smaller than the effects of e.g. trade liberalisation.

JEL Classification codes: Q56, Q58, F18, F14.

Keywords: Pollution Haven Hypothesis, competitiveness, comparative advantage, environmental policy stringency, trade, global value chains.

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Les politiques environnementales ont-elles une incidence sur les chaînes de valeur mondiales ? Un nouveau point de vue sur l’hypothèse du havre de pollution

La fragmentation internationale croissante de la production a renforcé les craintes de voir l’activité industrielle migrer vers des pays dotés de politiques environnementales plus laxistes – selon ce qu’il est convenu d’appeler « l’hypothèse du havre de pollution » (HHP). Si cette hypothèse se vérifie effectivement, les efforts déployés au niveau national pour faire face aux défis environnementaux pourraient se révéler inopérants ou se heurter à une forte résistance. À l’aide d’un modèle gravitationnel des échanges commerciaux bilatéraux appliqué aux industries manufacturières de certains pays de l'OCDE et des BRIICS sur la période 1990-2009, ce rapport étudie le lien entre les exportations et les politiques environnementales nationales. Il en ressort que les politiques environnementales n’ont pas d’incidence déterminante sur les exportations globales, mais ont un effet significatif sur le spécialisation. Cependant, en modifiant les prix relatifs des intrants, les politiques nationales plus rigoureuses vont de pair avec un désavantage comparatif dans les industries « polluantes », et un avantage correspondant dans les industries « plus propres ». Ces effets sont particulièrement perceptibles pour la composante de valeur ajoutée nationale des exportations, mais sensiblement moins que ceux de la libéralisation des échanges, par exemple.

Classification JEL : Q56, Q58, F18, F14.

Mots-clés : hypothèse du havre de pollution, compétitivité, politiques environnementales, échanges commerciaux, chaînes de valeur mondiales.

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DO ENVIRONMENTAL POLICIES AFFECT GLOBAL VALUE CHAINS? A NEW PERSPECTIVE ON THE POLLUTION HAVEN HYPOTHESIS[1]

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SUMMARY

The ongoing fragmentation of industrial production into different stages and geographical locations has paved the way for the rise of Global Value Chains (GVCs) leading to significant gains in economic efficiency. However, this phenomenon has also intensified concerns about the economic and environmental consequences of cross-country differences in the stringency of domestic environmental policies. In fact, the so-called Pollution Haven Hypothesis (PHH) stipulates, that by increasing the costs of polluting, environmental policies provide industries with incentives to relocate some stages of production to jurisdictions with laxer environmental regulations or to source inputs from them. If the PHH effects are strong, significant differences in environmental policy stringency (EPS) across countries could partly undermine the domestic environmental policy effort (e.g. in the case of greenhouse gasses), create distortions in the global production structure and possibly pose health and environmental concerns in less stringent countries.

Using a gravity model of bilateral trade flows for manufacturing industries from 23 OECD and 6 BRIICS countries over the period 1990-2009, this paper studies how bilateral trade patterns are related to national environmental policies of the trading partners. Trade patterns are assessed both in terms of gross exports and, in particular, in terms of domestic value added in exports, coming from the OECD-WTO Trade in Value Added (TiVA) dataset. The latter data provides a more accurate source of evaluation of the effects of environmental policies in the context of global value chains.

The bottom line result is that environmental policies are not found to be a major driver of international trade patterns, but still have some significant effects on specialisation – in line with the Pollution Haven Hypothesis. An increase in the gap in environmental policy stringency between two trading countries does not have a significant effect on overall trade in manufactured goods. However, by changing the relative input prices, higher environmental stringency in a country is linked to a comparative disadvantage in "dirty" industries, and a corresponding advantage in "cleaner" industries. These effects are stronger for the domestic component of exports than for gross exports. All in all however, even these EPS-induced changes in specialisation have been small when compared with the effects of e.g. trade liberalisation measures.

With a certain caution, a number of tentative policy implications can be sketched:

- First of all, the link between the EPS induced shifts in comparative advantages and the overall performance of economies is likely to depend on the ability to reallocate resources from declining "loser" sectors and companies to cleaner and innovative ones - i.e. to a large extent on the general framework policies. In addition, by supporting the adjustment, adequate framework policies can facilitate the achievement of environmental objectives and possibly a first-mover advantage in "cleaner" goods and sectors. While the analysis is limited to "dirty" versus "clean" sectors, the results are likely extendable to more granular within-industry effects – whereby "cleaner" companies gain in competitiveness, and "dirty" ones lose out as a result of tightening environmental policies.

1 . Tomasz Kozluk is a Senior Economist at the Economics Department/Environment Directorate of the OECD. Christina Timiliotis was an intern at the OECD at the time of writing this paper. The authors are grateful to Asa Johansson, Przemyslaw Kowalski and Eduardo Olaberria for making their gravity models available and Kirsten Wiebe and Norihiko Yamano for making the TiVA data set available. Gratitude is also due to external reviewers Maria Bas, Ulrich Oberndorfer and Inmaculada Martinez-Zarzoso as well as numerous colleagues in the ECO, ENV, TAD, STI, CTPA Directorates of the OECD, as well as. OECD delegates to the WP1, EPC and WPIEEP meetings for helpful comments. Further thanks go to Zoey Verdun and Silvia Albrizio for the help in collecting environmental policy data for the BRIICS and to Catherine Chapuis and Sarah Michelson for editorial support.

- Second, political economy considerations related to PHH can be significant – changes that lead to the decline of existing industries or companies are likely to meet strong resistance, while the gains for cleaner sectors and firms may be perceived as more abstract hence receive less support ex ante. As a result, adopted environmental policies may be less stringent or favour particular groups, such as high-polluting incumbents – with potentially significant economic and environmental costs.
- Third, as trade liberalisation proceeds, constituencies that fail to tighten environmental policies risk "artificially" preserving the competitiveness of some "dirty" sectors, increasing future political economy pressures and negative environmental effects. In this context, border carbon adjustments are often mentioned as a potential solution to the leakage of greenhouse gas emissions in the presence of unilateral climate action and preserving the competitive advantage of domestic emission intensive industries. Such adjustments may however, be extremely difficult to implement in practice , and, would, in line with the findings of this paper, hamper the counter-balancing comparative advantage of "cleaner" sectors, reduce incentives to invest in cleaner technologies and any potential first-mover advantages.
- Finally, a global climate agreement leading to tightening policies across the globe, would, according to our results, have limited effects on trade and specialisation patterns. More generally, as (and if) global economic development convergence leads to a convergence in environmental policy stringency, the EPS gaps would become smaller leaving even less scope for the PHH effect. Again, such extensions are beyond the scope of this exercise, but some indications can be seen in recent activity in increasing the stringency of EPS in a number of BRIICS. On the other hand, arrangements that facilitate the sharing or transfer of (clean) technologies may help reduce environmental leakage concerns and facilitate the tightening of environmental policies in emerging markets.

1. Introduction

1. Integration into an increasingly globalised world economy has proven to be a powerful engine of economic growth. As suggested by the Heckscher-Ohlin (HO) model of trade countries produce goods in a comparatively advantageous manner – i.e. one that is consistent with their factor endowments, such as labour, capital, institutions and natural capital. In parallel, over the past two decades, there has been a fragmentation of production into multiple stages of specialisation to exploit differences in factor endowments and efficiencies across jurisdictions (Baldwin and Yan, 2014). Such global value chains (GVCs) allow firms to minimise production costs across the entire production. As GVCs become a dominant feature of trade, the principle of comparative advantage operates at a more granular level, with trade reflected in terms of stages of production, rather than "bundled" goods and services.

2. In order to address environmental concerns, governments have introduced and strengthened policies that implicitly or explicitly increase the price of using the environment as a factor of production. In line with the traditional model, compliance with environmental regulations obliges firms to devote a part of their production inputs into pollution prevention and abatement. The pursuit of a cleaner, more sustainable environment is hence seen as economically costly – damaging firms' economic performance and global competitiveness. But the differences in environmental policy stringency affect the relative costs of environmental inputs and can change comparative advantages across countries. More stringent policies will move a country's relative cost advantage towards less polluting production. In the same vein, increasing the stringency of environmental policies may put polluting domestic firms at a competitive disadvantage.

3. The implications for trade of the co-existence of these two recent phenomena – the increased international fragmentation of production and the increased stringency of environmental policies – have hardly been investigated. So far, the relationship between national environmental policies and international trade patterns has been cast in the light of traditional measures of gross trade flows, which record gross flows of goods and services multiple times – whenever they cross the border. However, domestic environmental policies may affect particularly the domestic part of the production chain (i.e. the domestic value added) as most environmental policies aim at domestic environmental objectives. Therefore estimating the effects of such policies using data on gross exports is prone to a measurement problem. To

avoid this problem and reveal the economic significance the PHH we use the domestic value added in exports from the OECD-WTO data on Trade in Value Added (TiVA).

4. *A priori*, it is unclear if and how trade will be affected by more stringent environmental policies. Environmental policies that increase the costs of polluting can provide an incentive to relocate some stages of production to jurisdictions with laxer environmental regulations or source inputs from them. The process of offshoring due to more stringent environmental regulations is known as the Pollution Haven Hypothesis (PHH). At the same time, by stimulating technological innovation, stricter environmental policies may lead to efficiency gains on top of higher environmental standards. If firms are incited to reconsider existing production routines, this could provide them with an opportunity to improve business performance, and potentially competitiveness (Porter, 1991, and Porter & van der Linde, 1995)[2] and reorient towards cleaner production.

5. Empirical evidence on the validity of the PHH has been mixed. This has been partly due to the difficulty of evaluating the stringency of environmental policies across countries and time. Such evaluation is challenging due to the large and increasing number of environmental issues and environmental policy instruments, problems with identification of effects (for example, due to varying degrees of enforcement) and the lack of data (Brunel and Levinson, 2014; Koźluk and Zipperer, 2014).

6. The aim of this paper is twofold. First, we estimate a gravity model augmented by a recently developed measure of environmental policy stringency (EPS, Botta and Koźluk, 2014) to study how bilateral trade patterns are related to national environmental policies of the trading partners. Second, we re-estimate the model with new data on domestic value added embodied in exports – the value that domestic firms add to exported goods - providing a more appropriate framework to analyse the PHH in light of global value chains.

7. The main findings suggest no effect of environmental policies on aggregate trade and hence overall competitiveness. However, the composition effects on specialisation patterns appear significant. More stringent domestic environmental policies raise the costs of environmental "inputs", putting the more polluting industries at a comparative disadvantage, lowering their exports and raising imports from countries with laxer environmental policies - in line with the PHH. On the other hand, less polluting industries see a boost in their exports associated with more stringent domestic environmental policies. The results are stronger when focused on the domestic component of exports, rather than gross exports. Nevertheless, the influence of tighter environmental policy tightening on trade patterns among sectors is modest in comparison with, for example, those induced by trade liberalisation.

8. The paper is organised as follows. Section 2 provides a short overview of the literature highlighting some of the common issues that are addressed in this paper. Section 3 introduces the proxy of environmental stringency used in the empirical analysis. Section 4 describes the empirical approach. Sections 5 and 6 present estimation results for gross exports and domestic value added in exports respectively as well as their interpretation and some robustness checks. Section 7 discusses some remaining issues and suggests further areas of work. The final section concludes and discusses policy implications. Appendices provide a detailed summary of the relevant literature, data sources and descriptions and estimation results.

2 . In a world without market imperfections companies would identify opportunities to save costs without any inducement from government policies (Lanoie et al., 2008). The Porter Hypothesis (PH) therefore hinges upon the existence of market imperfections and behavioural biases (Ambec and Barla, 2007).

2. Short review of the literature and methodologies

9. The linkages between trade and environmental policies have been widely addressed in empirical research (see Table A1.1 in Appendix 1 for a summary of selected relevant papers). Two recent reviews summarise the *ex post* empirical approaches finding evidence of no - or very small - effects of environmental policies on competitiveness. Dechezlepretre and Sato (2014) conclude that “[t]here is little evidence to suggest that strengthening environmental regulations deteriorates international competitiveness. The effect of current environmental regulations on where trade and investment take place has been shown to be negligible compared to other factors such as market conditions and the quality of the local workforce.” Arlinghaus (2015), looking specifically at papers analysing the effects of carbon pricing states in a similar vein that “[m]ost studies reviewed […] fail to measure any economically meaningful competitiveness effects as a consequence of these policies.” These views seem in line with the earlier conclusion of Jaffe et al. (1995), that “studies attempting to measure the effect of environmental regulation on net exports, overall trade flows, and plant location decisions have produced estimates that are either small, statistically insignificant, or not robust to model specification”.

10. Pollution haven effects have been analysed in the context of both trade flows, as well as, the siting of plants and foreign direct investment (Brunnermeier and Levinson, 2004; Riedinger and Raspiller, 2005; Kalamova and Johnstone, 2011; Kahouli et al., 2014). Earlier studies revert to a Heckscher-Ohlin (HO) type of model, where revealed comparative advantages are explained by factor endowments (Tobey, 1990; Grossman and Kruger, 1993), while more recent ones tend to use gravity models, often augmented with factor endowments and potential policy-related drivers of trade.

11. Bilateral trade data has been of central interest in the context of the PHH and studies used gross trade flows, or sometimes net trade flows in an attempt to wash away re-exports. But domestic fragments of the GVC, which are most directly affected by domestic environmental policies, are arguably the most interesting from the PHH point of view. So far however, data on domestic value added in exports have not been employed in PHH testing in the international context, aside from Kellenberg (2009) who finds evidence of PHH looking at value added in affiliates of US-owned multinationals.

12. Approaches range from cross-sections to panels, depending on data availability and questions of interest. The cross-sections allow only very limited control of other potentially relevant developments – such as in endowments or policies - whereas the potential of panels in this respect is not always fully exploited. For instance, Van Beers and van den Bergh (1997) estimate a gravity equation to verify the impact of environmental policy stringency on bilateral exports of OECD countries. The authors find a negative and significant impact of more stringent regulations on total exports, though not on “dirty” trade flows.[3] However, their setup has been argued to be misspecified as it lacks so-called multilateral resistance terms (MRTs) (Harris et al., 2002). The concept of MRTs (coined by Anderson and van Wincoop, 2004) refers to the fact that bilateral trade may not only hinge upon bilateral trade costs, but also on the relative trade costs with respect to the rest of the world. To address this challenge, Harris et al. (2002) added importer and exporter fixed effects to their gravity equation only to find that the indicator for environmental policies is no longer statistically significant. MRTs have become an important concern in the empirical trade literature, with most authors arguing the use of various structures of fixed effects – constant or varying over time (Adam and Cobham, 2007; Fally, 2015).

13. Time series properties have not been of primary preoccupation in research based on gravity models, even though there are good reasons to think that the main variables (trade flows, GDP) are non-

3. The authors argue that “dirty” trade flows often originate from resource-based industries in which competitiveness is not determined by environmental policies but by the resource itself. At the same time however, tighter regulations are also found to reduce total and “dirty” imports which does not support the PHH.

stationary. However, in practice, static fixed effects estimation appears to have many advantages – while in practice reflecting longer-run relationships.[4] In the particular case of many "zero" observations, the Poisson Pseudo Maximum Likelihood estimator have been advocated (Santos-Silva and Tenreyro, 2006).

14. A number of papers explicitly worry about a possible endogeneity bias, arising from the fact that trade can increase GDP per capita and hence the demand for more stringent environmental policies. Instrumenting environmental policies with a range of trade, economic, environmental and political economy variables Ederington and Minier (2003) and Levinson and Taylor (2008) find that the positive effect of environmental regulation on US import growth was larger than previously estimated using OLS.

15. While some papers look at the effects of environmental policies on aggregate trade and overall competitiveness (Van Beers and van den Bergh, 1997), most are particularly interested in effects on highly-polluting sectors – which are most likely to suffer competitiveness losses from more stringent policies. For this purpose, research adopts various ways of defining "dirty" and "clean" sectors, primarily via some definition of pollution or resource intensity, which can be continuous or discrete. However, none of the papers test the sensitivity to alternative definitions of "dirty" versus "clean". Ederington et al. (2005) and Kellenberg (2009) additionally distinguish "footloose" industries, i.e. industries that are more likely to relocate due to their structure (which the authors basically define as low capital-intensity), finding that indeed effects are significant.

16. Approaches differ significantly with regard to proxies of environmental policy stringency. Pollution abatement costs reported by firms, such as those collected by the US PACE survey (Tobey, 1990; Grossman and Kruger, 1993; Levinson and Taylor, 2008), are among the most popular measures of EPS used in empirical research. Their main weakness is related to the problem of identifying the true effect of environmental policies on expenditures reported in such firm- or plant-level surveys. For example, investment in pollution abatement will be driven by environmental policies, but also by the state of technology, degree of competitive pressures, access to capital, resource prices, R&D policies, etc. Some of these issues can be dealt with by including appropriate controls in the analysis – e.g. factors that may shape firms' decisions to invest in capital, efficiency and R&D or corporate image (Botta and Koźluk, 2014) - but in practice this is not the case. Another problem of such surveys is related to the fact that it can be difficult for respondents to accurately allocate expenditures to "environmental" objectives. This would be particularly true of investment in integrated pollution abatement which can have implications for both production efficiency and pollution abatement (Brunel and Levinson, 2014). In such surveys there may, therefore, be a bias toward inclusion of expenditures on end-of-pipe equipment, which are often less cost-effective and are likely to be induced by more prescriptive and less economically efficient policy measures.

17. The Executive Opinion Survey of the World Economic Forum (WEF) provides a stringency measure, based on policy perceptions. It asks company managers to rate the stringency of policies in their country on a 1 to 7 scale (7 being most stringent). The survey has a number of advantages, including a large cross-country dimension and a time-series starting in the early 2000s, but it is by nature exposed to self-reporting bias, problematic interpretation of the time series and respondent sample selection issues. Using the WEF indicator, Kellenberg (2009) finds evidence of the PHH in the behaviour of US-owned foreign multinationals. The result is robust to a large set of controls and different estimation approaches.

4 . According to the Fidrmuc (2009), in practice, fixed effects estimates which largely ignore the time-series properties do not appear to lead to notable biases or wrongful inference, despite the potential long-term relationships between the variables. Moreover, such an approach may have practical advantages in the presence of large-cross sectional variation and interdependence, limited time series and numerous zero observations – usually the case in trade data. Additionally, we test different lags of the variable of interest and different fixed effects specifications in the robustness section.

18. Proxies of environmental policy stringency related to economic and environmental outcomes are also fairly common. Some are rather crude, such as GDP per capita, and unlikely to allow confident identification (Grether and de Melo, 2003; De Santis, 2012). Others, such as CO_2 emissions per capita (Kahouli et al., 2014) or differences in observed and predicted pollution levels (Combes et al., 2014; conceptually similar to the indicator advocated by Brunel and Levinson, 2015) appear more convincing, but all outcome-based measures may be difficult to link to environmental policies directly because their levels may be driven by factors such as endowments, history, geographical and market conditions, availability of technologies. A similar critique applies to composite combinations of outcomes, such as those used in Van Beers and van den Bergh (1997) such as energy intensity and recycling rates, an option also exploited in Harris et al. (2002). Another recent proposal in this context is the use of industry level energy prices (Sato et al., 2015; used in Sato and Dechezlepretre, 2015).

19. Finally, proxies based directly on the measurement of the stringency of policy instruments are an attractive option. For example, Broner et al. (2012) focus on gasoline lead content limits. As such selective policies may fail to capture the general policy stringency, composite indexes aggregating information over different instruments have also been proposed. Dasgupta et al. (1995) were among the first to produce a composite, cross-country indicator, though covering only one year. Subsequently, the CLIMI index (Climate Laws, Institutions and Measures Index), was developed by the EBRD for 2010, building on UN country reports and UNFCCC submission reports. Most attempts combine both policy and outcome information into a single index. The main hurdles to such an attempt are the lack of cross-country data, the lack of time variation that renders the index unsuitable for econometric analysis in a panel dimension and the question of selecting and aggregating data across different policies.

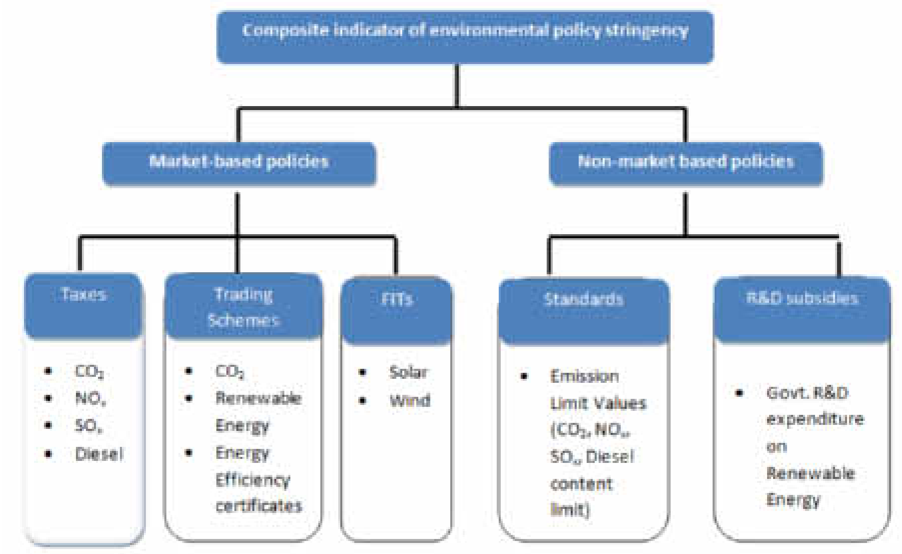
20. The environmental policy stringency (EPS) proxy chosen is possibly the most important difference among studies. None of the proxies is ideal; yet, robustness checks using alternative EPS measures have not been common in the PHH literature.

3. The proxy of environmental policy stringency

21. Estimating the impact of environmental policies in a meaningful way requires an adequate proxy for environmental stringency – something that is not straightforward to come by. Brunel and Levinson (2013) emphasize two particular challenges for the measurement of environmental policies: multidimensionality and simultaneity. Multidimensionality refers to the large variety of environmental media (e.g. air, water and land), pollutants and policy instruments (market based and non-market) that are difficult to capture in one proxy. Simultaneity, on the other hand, arises from the fact that environmental policies may be related to environmental problems, geographical characteristics, industrial composition and political and economic development, etc., in ways that are not straightforward to disentangle.

22. The analysis in this paper is based on a new composite index of environmental policy stringency (EPS) developed by the OECD (for a detailed description see Botta and Koźluk, 2014). Originally, the index covers 24 OECD countries over the period 1990-2012 combining information on 15 market-based and nonmarket policy instruments. Regulations are equally weighted within each category and aggregated into a single indicator. The regulations included focus primarily on energy and transport activities and address mainly climate and air pollutants. The indicator ranges from 0 to 6, where 0 is associated with lax and 6 is associated with more stringent policies (Figure 1).

Figure 1. The structure of the EPS indicator



Note: individual policy indicators are scored on a 0 to 6 scale (6=more stringent). They are aggregated using equal weights at each level.

23. For the purpose of trade estimations the EPS indicator has been slightly modified and provisionally extended (see Appendix II for details): [5]

- The original indicator was refocused even more on air and climate, by excluding the data on deposit and refund schemes. The refocused EPS has several advantages – a more concise and cost-focused set of policies, concerning primarily (potential) cross-border pollutants. Moreover, deposit and refund schemes are regarded a negligible determinant in the context of international production location (Brunel and Levinson, 2013).
- The indicator has been extended to the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa), since international trade and global value chains increasingly rely on the participation of emerging economies. The extension required a new data collection effort and assumptions in order to include countries where few data were available. A snapshot comparison shows that, in line with expectations, BRIICS generally have less stringent environmental policies than OECD countries throughout the sample (Figure 2).

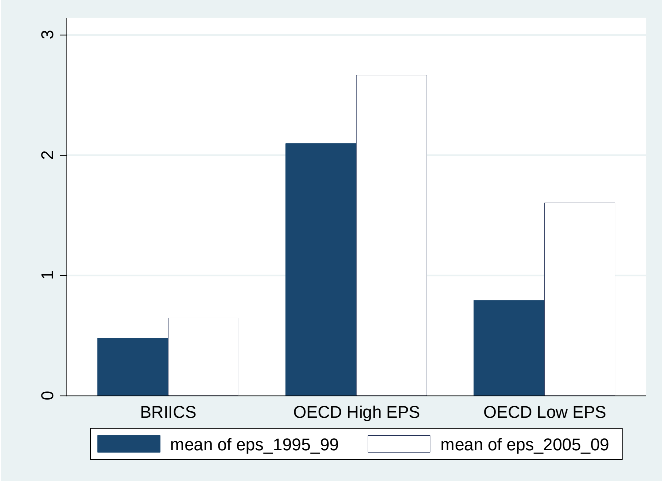
24. The main intention of the EPS indicator remains to provide a general proxy of environmental policy stringency. Most notable omissions include areas of water pollution and natural resource preservation, as well as various important policy instruments. Nevertheless, the modified EPS exhibits highly significant correlations with other potentially available measures of stringency, including survey-based perceptions of overall stringency, increasing the confidence in this measure (see Appendix II for such comparisons).[6] Still, we check the robustness of our estimations using an alternative proxy based on electricity prices provided by Sato et al. (2015).

5 . The extension of the EPS indicators to BRIICS is part of a wider project, which benefits from the support of the United Kingdom.

6 . Botta and Koźluk (2014) discuss various advantages and properties of the EPS measure, as well as its weaknesses.

Figure 2. Environmental policy stringency in OECD and BRIICS

Average EPS over 1995-99 and 2005-09



Notes: Higher value is associated with higher stringency. Sample averages over 1995-99 and 2005-09 reported. Country groupings: BRIICS, OECD High EPS - most stringent countries over the sample (Denmark, Germany and Switzerland) OECD Low EPS – least stringent countries over the sample (Australia, Ireland and the Slovak Republic).

4. Empirical setup

25. More stringent domestic environmental policies generate higher costs of production in a country by raising the price of environmental inputs. In practice, almost all manufacturing is associated with some kind of negative environmental impacts; hence the competitiveness of the entire economy may suffer.

26. While the costs of production rise already in the short-term, in the longer-term, real exchange rate adjustments can eventually compensate overall competitiveness – the ultimate effect on exports being an empirical question. Still, the stringency of environmental policies affects relative input factor costs. "Dirty" industries, where reliance on environmental inputs is higher, are likely to see a more significant rise in production costs. At the same time, goods that are produced in a "cleaner" process will be less affected. So, with more stringent policies, the country's comparative advantage will shift towards cleaner production – incentivising the reallocation of resources to less-polluting companies and industries. As such a reallocation is not immediate; the performance of the entire economy may be subdued in the meantime.

27. On the other hand, Porter's Hypothesis advocates that well-designed environmental policies could spur productivity and competitiveness gains in concerned companies (Porter, 1991; Porter and van der Linde, 1995). While evidence on the Porter Hypothesis is inconclusive (Koźluk and Zipperer, 2014; Ambec et al., 2013; Albrizio et al., 2014), such developments could potentially spark first-mover advantages in specific "clean" sectors and goods, leading to increased export performance (Sauvage, 2014). The Porter Hypothesis could be broadly consistent with the comparative advantage effects, if as a result of the shifts in specialisation, firms and sectors became more efficient. Moreover, in the longer term, policy-induced innovation can lead "dirty" sectors and firms to adopt cleaner production technologies – and hence eventually regain the comparative advantage.

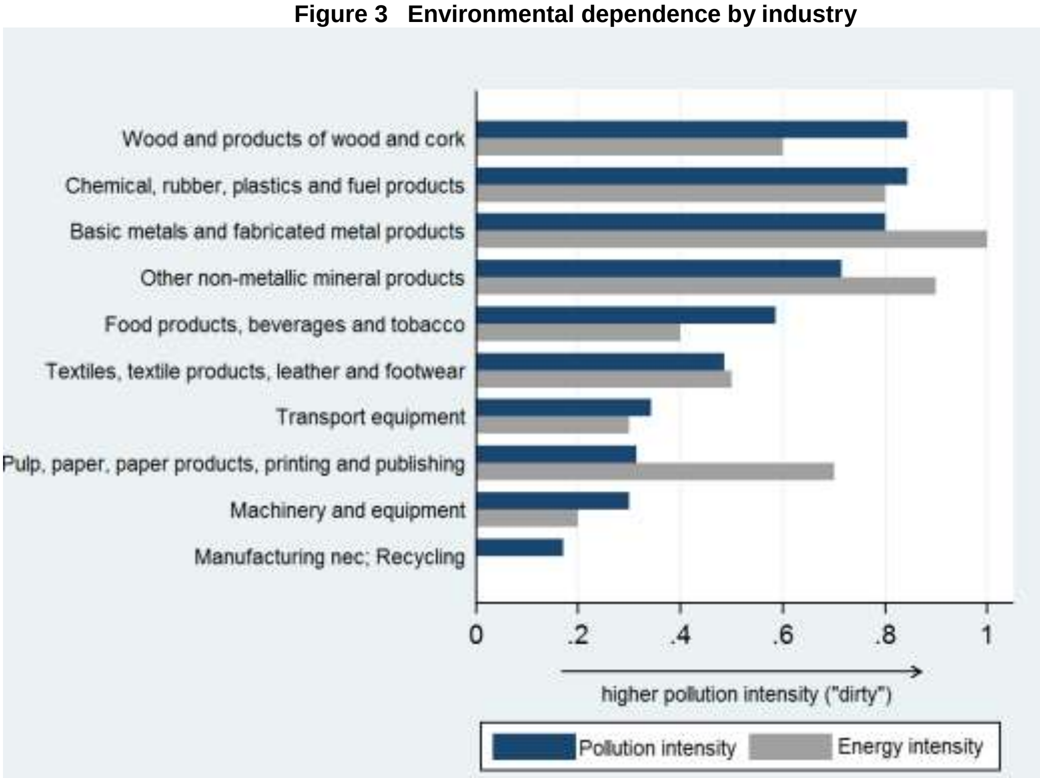
28. As part of the response, a pollution haven effect would imply that "dirty" sectors shift their production to countries with laxer regulations. However, as the relocation is usually not directly observable, our working hypothesis is that tighter domestic environmental regulations may lead to a decline in exports, other things equal, in particular for the sectors most sensitive to changes to environmental regulations (i.e. more pollution intensive) (Box 1). Similarly, in line with the PHH, if domestic regulation puts domestic "dirty" sectors at a disadvantage, imports of goods produced by these sectors from countries with less stringent environmental regulation should increase, reflecting the outsourcing of domestic production.

Box 1. "Dirty" versus "clean" – the environmental dependence of industries

To allow for the impact of environmental policies to differ by industry, we introduce an "environmental dependence" interaction term (Figure 3). In the basic specification, this is based on an index of industry pollution intensity (see Albrizio et al., 2014). Pollution intensity is derived as the average of scores on pollution emissions as a ratio to value added in seven pollution categories (two water pollutants, four air pollutants, one toxic substance) in an attempt to proxy overall pollution intensity of a sector. It takes values from zero to one (one meaning high pollution intensity or "dirty"). It is constructed from the IPPS Pollution Intensity and Abatement Cost World Bank dataset and covers the manufacturing sector in the United States for the year 1987. A major potential disadvantage of such a measure is related to possible lack of representativeness. Pollution intensity is that of the industries in United States, and hence may reflect US environmental policies at that time, but not necessarily general characteristics of the industry. It is also measured pre-sample and hence may also have changed over time, in part due to environmental policies. However, such an approach has also a number of advantages in terms of identification, and the potential non-representativeness issues are partly mitigated by taking rankings of individual pollution intensities, rather than direct scores. Industries are likely to have changed their pollution intensities over time; but they are less likely to have changed their relative position.

Nevertheless, to improve robustness of the conclusions we have also used a measure of industries' energy intensity. This alternative measure of environmental dependence is based on the share of electricity, water and gas inputs in total inputs to the production of each industry. It is an in-sample country average, covering 1990-2009. Data for the construction of this variable are sourced from the OECD STAN Input-Output tables. Both dependence measures have been demeaned before application.

Figure 3 Environmental dependence by industry



Notes: Both indexes of environmental dependence rank sectors from zero to one (1=most pollution intensive). *ED* represents the pre-sample pollution intensity measure while *Energy Intensity* is the in-sample proxy derived from the OECD Input-Output tables, and rescaled between 0 and 1. By construction the least energy intensive sector scaled to 0 and the most energy intensive scaled to 1. Both measures are demeaned before estimation.

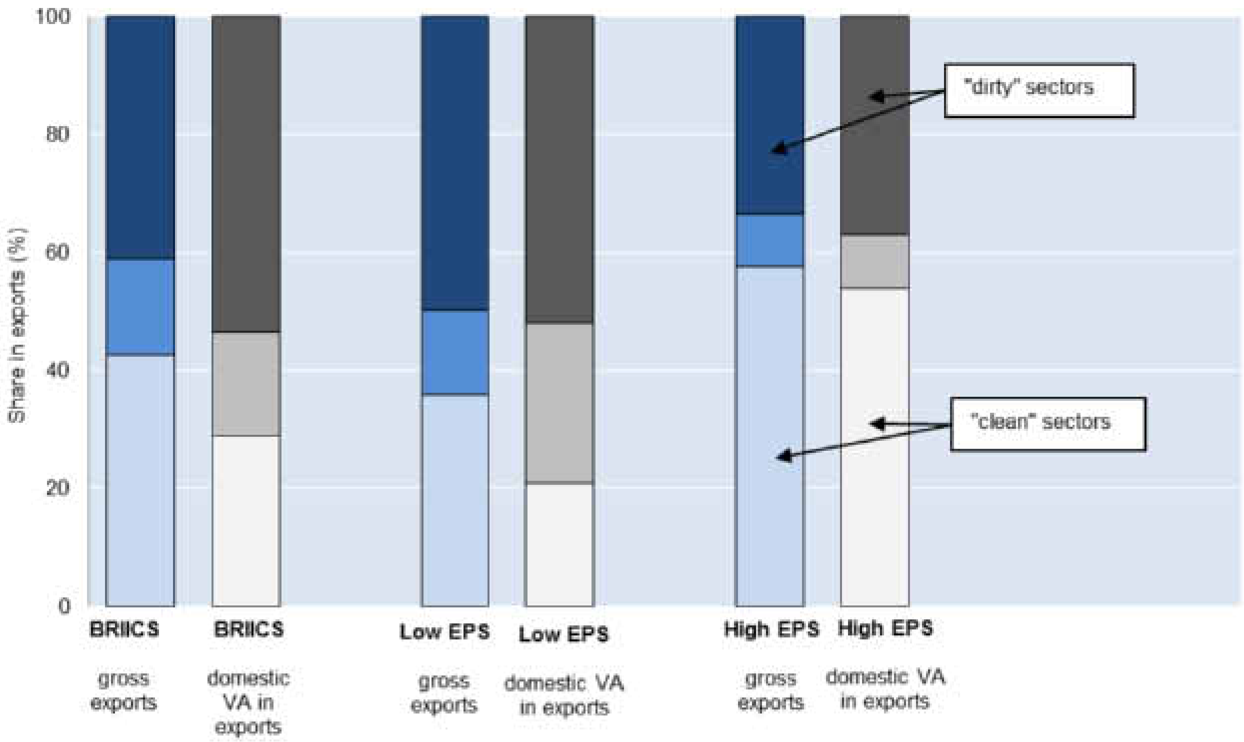
Source: based on Albrizio et al., 2014.

4.1. Environmental policies and trade - what the descriptive statistics say

29. Overall, “dirty” sectors tend to have higher export shares in countries with laxer environmental policies than in countries with the most stringent policies (Figure 4). However, the evolution of sectors may be driven by numerous factors, such as geography, endowments, level of development or trade liberalisation, hence this paper attempts a more rigorous analysis of the phenomenon.

Figure 4. Export shares by sector environmental dependence

Across country groups with different levels of EPS



Notes: Figure 4 shows the share of exports (domestic VA in exports and gross exports) of three industry group, by pollution intensity: “dirty” (4 sectors with highest pollution intensity in Figure 3), “medium” (2 sectors with average pollution intensity) and “clean” (4 sectors with lowest pollution intensity in Figure 3). Averages over the sample 1995-2008 are reported. Countries are grouped into BRIICS (generally lowest EPS), low EPS (OECD countries with lowest average EPS across the sample: Australia, Ireland and the Slovak Republic) and high EPS (OECD countries with highest EPS across the sample: Denmark, Germany and Switzerland).

4.2. Estimating the determinants of trade

30. Our working hypothesis is tested using a gravity model of bilateral trade – a standard tool in trade theory (e.g. McCallum 1995; Frankel, 1997; Frankel and Rose, 2002). In line with recent literature, we adopt a version that combines gravity features (*i.e.* geographical distance, free-trade agreements, common language, common border, common currency, etc.) with Heckscher-Ohlin type explanatories of the potential sources of comparative advantage. The Heckscher-Ohlin model has long been a prevailing approach to trade theory, explaining patterns of inter-industry trade by differences in factor endowments[7] but has become increasingly inadequate in its simple form (Helpman, 2010). Hence, extensions have focused on so-called "new sources of comparative advantage" – i.e. policy-related endowments, such as legal institutions (Nuun, 2007) or financial development (Manova, 2013). These are also included, as for instance in Nicoletti et al. (2003).

31. Endowments and policies are observed at the national level, but may have different impacts on various industries – industries can be more (or less) sensitive to such determinants, depending on their characteristics. For example, Rajan and Zingales (1998) have shown that disparities in financial development affect industry real growth to a different extent, depending on the needs for external financing of the particular sector. In their investigation they interacted country-level financial development with an industry level dependence ("sensitivity") on external financing. The approach has been recently applied to trade equations by, among others, Johansson et al. (2014) and to environmental policies by Albrizio et al. (2014). We follow the same approach allowing the effects of endowments, financial development and regulatory quality to vary across sectors with their sensitivity to these factors. In the same vein, we allow effects of environmental policies to vary with the pollution intensity of the industry, under the assumption that more polluting industries may be subject to stronger effects of environmental policies (Box 1).

32. This paper further incorporates the heterogeneous effects of tariffs on intermediate and final goods (following Johansson et al., 2014). Intermediate goods tend to be more vulnerable to trade barriers than final goods, as they tend to be easier to substitute (Miroudot et al., 2009). To address this issue, tariffs are divided into *Output* and *Input* tariffs. *Output tariffs*$_{sjit}$ capture the bilateral tariffs imposed by importer j on a given industry *s* (average) coming from country *i*, whereas *Input Tariffs* are constructed as the weighted average of tariffs on the intermediate goods used in that industry, coming into country *i*. Input tariffs of importer *i* for a given year *t* in a sector *s* are thus built as

$$InputTariffs_{sit} = \sum_{z} a_{s,z}\tau_{i,z,t}$$

where $a_{s,z}$ represents the share of input *z* in the production of the final good, constructed using the value shares for the United States.

33. Multilateral resistance terms and other unobservable effects are dealt with various combinations of fixed effects specifications. Furthermore, to account for its multiplicative form, the gravity model is log-linearised.[8] We then estimate the following regression (see Appendix II for details on the variables and data used):

7 . The original approach to explaining trade patterns was formulated by David Ricardo. In his model, trade is due to sectorial differences in labour productivity rather than factor endowments.

8 . All value variables (i.e. not indexes and indicators) are taken in logs.

$$\ln \mathrm{Exp}_{ijst} = \alpha + \gamma \mathrm{Gravity}_{ijt} + \beta_1 \mathrm{Endowment}_{it} * \mathrm{Intensity}_s + \beta_2 \mathrm{Endowment}_{jt} * \mathrm{Intensity}_s + \beta_3 \mathrm{Policy}_{it} * \mathrm{Sensitivity}_s + \beta_4 \mathrm{Policy}_{jt} * \mathrm{Sensitivity}_s + \delta_1 \mathrm{Endowment}_{it} + \delta_2 \mathrm{Policy}_{it} + \delta_3 \mathrm{Endowment}_{jt} + \delta_4 \mathrm{Policy}_{jt} + \gamma_1 \mathrm{InputTariffs}_{sit} + \gamma_2 \mathrm{OutputTariff}_{sjit} + \lambda_1 EPSgap_{ijt} + \lambda_2 EPSgap_{ijt} * \mathrm{EnvironmentalDependence}_s + \theta_i + \theta_j + \theta_s + \theta_t + \varepsilon_{ijst}$$

where:

- *i* is the exporting country, *j* is the importing country, *s* is the sector and *t* is the year.
- Exp_{ijst} is the USD value of the total gross manufacturing exports (or equivalently gross manufacturing imports) going from country *i* to country *j* in a given year *t* for a given sector *s*. In the second part of this study, Exp_{ijst} is replaced by the domestic value added in i's exports to j ($\mathrm{DVA\_Exp}_{ijst}$).
- $Gravity_{ijt}$ denotes a set of gravity variables that characterise the country pair *(i,j)*. For example, the geographical distance between capitals, dummies for the existence of a common border, common language, participation of both countries in a regional trade agreements (RTA) or a common currency. It also includes GDP of each of the partner countries. Some of these will be constant across time, others like GDP or RTAs can change over time.
- $Endowment_{it}$ is a set of variables at the country level, included for both the exporter and importer country. Including variables that may affect comparative advantages follows the HO model. They include the stock of physical capital per worker, human capital per worker and energy supply per capita.[9] The variables $Intensity_s$ are measures of the intensity with which industry *s* uses the respective factor of production and enter as interactions with the $Endowment_{it}$ variables.
- $Policy_{it}$ denotes the domestic policy and institutional variables for both the exporter and importer such as financial development, institutional quality. $Sensitivity_s$ measures the dependence of a given sector on either, the country's financial development or the institutional quality (see Table A2.1 for details).
- $InputTariffs_{sit}$ is a weighted average of tariffs on intermediate goods imported into country i and used in the production of final goods in sector *s*.
- *Output* $Tariffs_{sjit}$ are average tariffs that importer *j* imposes on products of industry *s*.
- $EPSgap_{ijt}$ is a proxy for the environmental policy stringency gap between the exporter i and the importer j. It is computed as $EPSgap_{ijt} = (EPS_{it} - EPS_{jt})$, where EPS_{it} captures a level of country's environmental policy stringency. *EPSgap* is interacted with a sensitivity measure to environmental policies at the industry level - environmental dependence (ED) measured as an index of industry pollution intensity (Box 1).[10]

9 . Due to potential multi-collinearity with the EPS and ED proxies, the baseline specification does not include the energy endowment and energy intensity interaction. However, results including this variable are reported in the robustness tests, without significant changes to the results.

10 . In the preferred specification, the difference between exporter and importer environmental policies is used (EPSgap) rather than the individual environmental policy levels. There are a number of reasons for this, primarily due to the nature of EPS and the PHH concept. These issues are discussed and tested in the Robustness tests section.

- $\theta_i, \theta_j, \theta_s$ and θ_t are respectively exporter, importer, sector and time fixed effects, included in the basic specification. Additionally, we explore different combinations of fixed effects, such time-varying importer and exporter or country-pair and time fixed effects.

34. We estimate the model using a Poisson Pseudo Maximum Likelihood (PPML) estimator, given the 5.6% share of zero observations for bilateral gross trade flows.[11]

5. Estimation results: Gross exports

35. The dataset is an unbalanced panel of yearly data over the period 1990-2009 for a subset of 23 OECD and the 6 BRIICS countries, classified into 10 ISIC Rev. 3.1 sectors, for which data are available (see Appendix II for details).[12]

36. The estimation results for the coefficients on the relative environmental policy stringency are presented in Table 1 (specification 1 and 2). The magnitude and statistical significance of the estimated coefficients for the other explanatory variables are in line with previous findings of Johansson et al. (2014) and reported in Appendix III.

Table 1. Main estimation results (gross exports)

Estimation method: Poisson

Dependent variable: Gross exports (in logs)

	(1)	(2)
Environmental Policy Stringency		
EPSgap	-0.0183	-0.0230
	(0.0166)	(0.0163)
EPSgap*ED		-0.142***
		(0.0366)
Exporter, importer, industry and year fixed effects	Yes	Yes
Pseudo R squared	0.850	0.850
Observations	121,240	121,240

Notes: Robust standard errors in parentheses. ***, ** and * represent p<0.01,* p<0.05 and p<0.1 respectively. The coefficients of interest reported are extracted from Table A3.1.

11 . Standard errors are heteroscedasticity-consistent (HAC) standard errors. To control for potential error correlation within country pairs errors are clustered in this dimension (Wooldridge, 2002). Results are presented in Appendix III. In addition, the same model has been re-estimated using OLS – the results are somewhat weaker but not significantly different.

12 . Due to the collapse of global trade in 2009 (starting already late 2008), the data for 2009 was not used in the basic specification to avoid potential confounding factors. However, a robustness check using 2009 data confirms that results hardly change (Table A3.4).

37. The estimated coefficient of *EPSgap* is negative, but insignificant even at 90% (Specification 1). This suggests that on average, trade between the two countries is not affected by the difference in environmental policy stringency. However, the EPS indicator measures regulatory stringency only at a country level and assumes homogeneity across sectors with respect to environmental exposure – possibly leading to biased inference. The assumption of homogeneity may hide a composition of underlying effects for different, "dirty" and "clean" industries, as exports for such industries may be affected in different ways by stringent environmental policies, in line with the changing comparative advantage. For example, tighter environmental policies may squeeze out exports in "dirty" goods, but favour specialisation in "cleaner", less polluting sectors.

38. Consequently, we allow for heterogeneity in the sector sensitivity to the difference in environmental policies in Specification (2). The magnitude of the total estimated marginal effect will hence depend on the exposure to environmental regulations at the sector level (*ED*):

$$\frac{\partial \ln Exp_{ijst}}{\partial EPSgap_{ijt}} = \lambda_1 + \lambda_2 ED_s$$

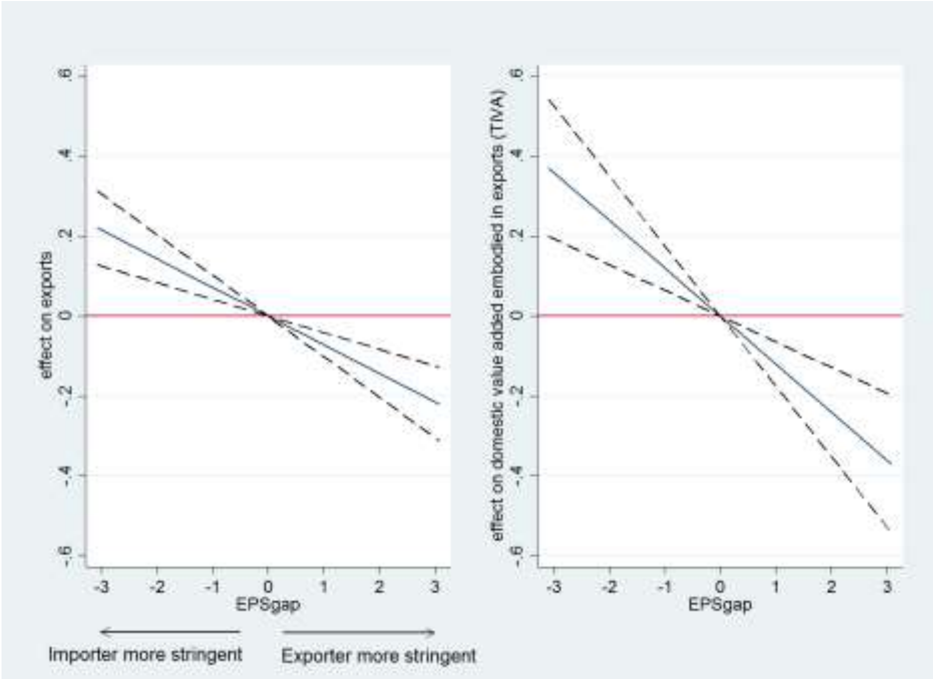
39. Estimated results show that when environmental policies are more stringent in the exporting country (high *EPSgap*), exports in "dirty" sectors are significantly lower than in the case when environmental policies are equally stringent in the two countries (Figure 5, Panel A). At the same time exports in "clean" sectors are higher, though only slightly and not significantly (Figure 5, Panel B). While weak, the latter seem in line with some earlier work suggesting that more stringent environmental policies may be associated with higher exports of so-called environmental goods (Sauvage, 2014). Conversely, when stringency is lower in the exporting country, exports of "dirty" sectors tend to be higher than in the equal EPS case and exports in "clean" sectors tend to be lower (again, not significantly).

40. In line with a traditional Heckscher-Ohlin point of view, countries seem to specialise in the sector where they have a comparative advantage. Since "dirty" sectors face higher compliance costs due to environmental policies, more stringent regulations translate to a loss in comparative advantage – a finding in line with the PHH. At the same time, this mechanism may lead industry composition to shift towards industries that are not subject to high compliance costs, explaining a gain in comparative advantage of "clean" industries. Nevertheless, the results for gross trade are fragile and need to be interpreted cautiously.

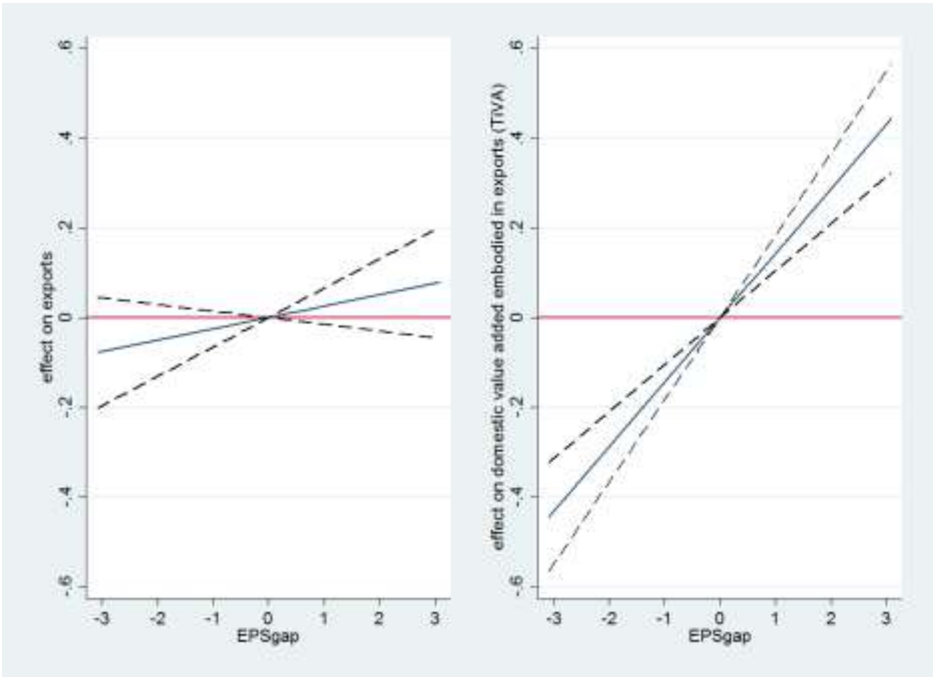
Figure 5. Effects of EPSgap on exports

Gross exports | **Domestic VA in exports**

A: High pollution intensity (“Chemical, rubber, plastics and fuel products”)



B: Low pollution intensity (“Manufacturing n.e.c. and recycling”)



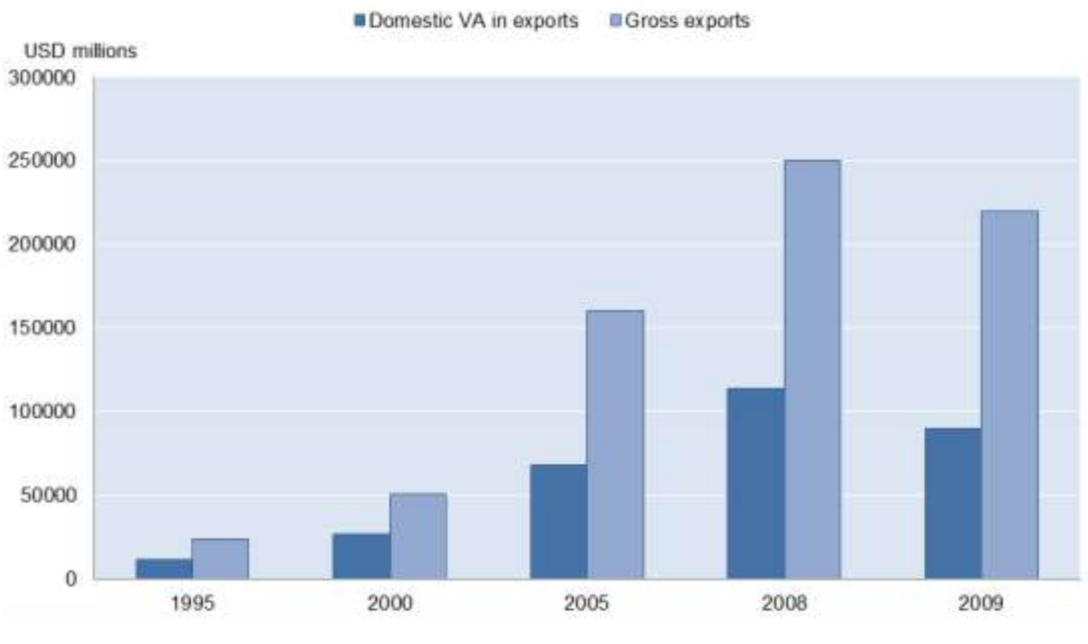
Note: 90% confidence intervals reported.

6. Empirical results: domestic value added in exports (TiVA)

41. In May 2015, the OECD and the WTO released the updated Trade in Value Added (TiVA) database.[13] Trade in Value Added is a statistical approach used to identify the source of value (by country and industry) that is added in producing goods. For a long time, trade in intermediate goods was proportional to trade in final goods; however, this relationship was altered by the rise of global value added chains (Yi, 2003). The international fragmentation of production has led to a situation where gross exports are becoming increasingly decoupled from the domestic value added component of exports. As opposed to traditional measures of trade which record gross flows of goods, the TiVA approach recognises the significant share of parts and components imports used to produce exports.

42. For instance, when a motor vehicle is exported by country A, this requires parts, such as the engine, seats etc., which can be produced in country B. In turn, country B may import the input material from a third country C. The TiVA approach can then trace back the value added by each country and industry. Currently, more than 50 percent of global trade in manufactured imports are intermediate goods (De Backer and Miroudot, 2013). China is a popular example used to illustrate the difference in bilateral trade patterns in terms of value added and gross exports (Figure 6). The domestic value added embodied in shipped goods from China to the US has been smaller than the value of gross exports flows, reflecting the large share of foreign content in Chinese exports (Baldwin and Taglioni, 2011; label this as the "Factory Asia phenomenon").

Figure 6. Gross exports and domestic value added in exports from China to the United States



Note: Value of goods traded across all sectors from China to the US (in millions current USD).

43. National environmental policies can be expected to have a more direct impact on the domestic component of production and exports - that is on value added in the production of the exported goods that is generated in the country implementing the environmental policies - than on gross exports. Gross exports include a large share of imported intermediate components, while most environmental policies, such as

13. The TiVA data are available here: http://www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

pollution taxes, norms or restrictions will primarily target environmental externalities associated with domestic production. Intermediate imports will hence be primarily indirectly affected and hence estimates based on gross (or even net) imports could suffer from a measurement problem. Hence, to investigate further the PHH, the basic gravity model is re-estimated using domestic value added embodied in foreign demand as the dependent variable.

6.1. Estimation results: domestic value added embodied in exports

44. Estimation using domestic value added in exports confirms the negative impact of environmental policy stringency on exports of "dirty" industries and even more so the positive impact on exports of "clean". They are also in line with the claim of the greater importance of EPS for the domestic export component than for gross exports. Table 2 reports the estimations results with Specification 1 showing the results for the pooled effect and Specification 2 showing the main (average) and the interaction effects. The estimation coefficient for the pure *EPSgap* (country-level) is statistically insignificant, underlining the lack of evidence for an overall effect across sectors (Specification 2).[14] Allowing for the differentiated, sectoral effects yields highly significant results (99% significance level) which turn out to be robust to a number of tests (Appendix III and Robustness Section).

45. Marginal effects allow for similar, but stronger conclusions as in the first part of this study (Figure 5).[15] Exports of "cleaner" industries benefit, this time significantly, from a tighter domestic environmental regulations (relative to that of the trading partner) in terms of value added shipped, but "dirty" industries experience a comparative disadvantage and lower total value added exported.

Table 2. Main estimation results (Domestic VA in exports)

Estimation method: Poisson

Dependent variable: Domestic VA in exports (TiVA)

	(1)	(2)
Environmental Policy Stringency		
EPSgap	0.00364	0.00188
	(0.0284)	(0.0282)
EPSgap*ED		-0.362***
		(0.0616)
Exporter, importer, industry and year fixed effects	Yes	Yes
Pseudo R-squared	0.841	0.842
Observations	32,480	32,480

Notes: Robust standard errors in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively. The coefficients of interest reported are extracted from Table A3.2.

14 . As ED is demeaned, the EPSgap coefficient can be interpreted as the effect for an industry with average pollution intensity.

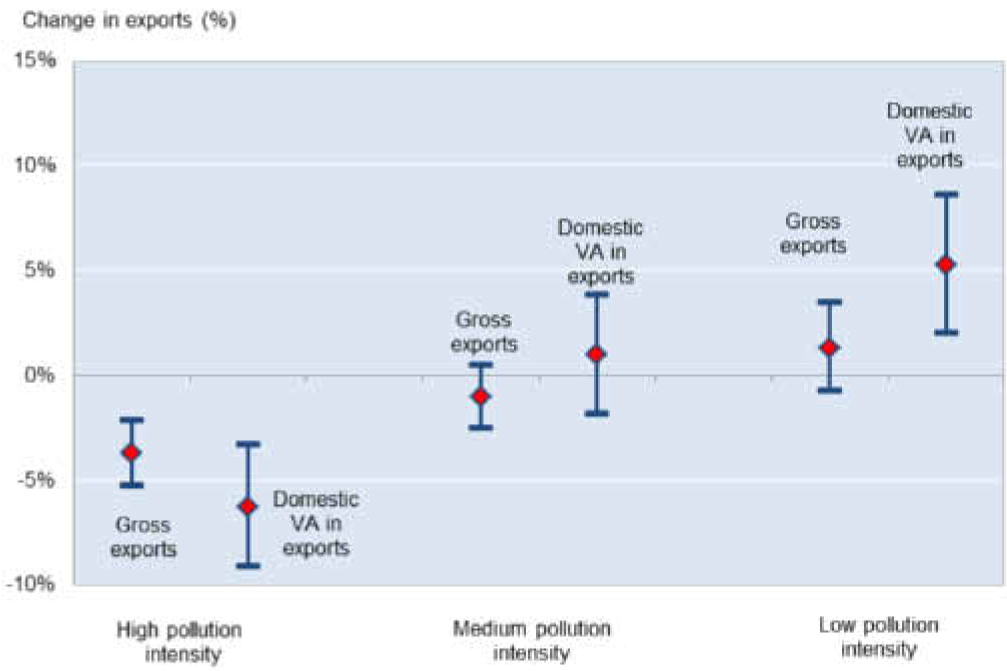
15 . The TiVA dataset covers a more limited time series (1995, 2000, 2005, 2008 and 2009), compared to the gross trade dataset. Re-estimating the gross trade specification on the same restricted sample yields insignificant results.

6.2. Economic significance of estimated effects

46. To get a sense of the economic significance of the effects of environmental policies on trade Figure 7 illustrates the findings graphically. The graph shows the difference in the effect on gross exports and domestic VA in exports between two different levels of *EPSgap*. For three industries (low, median and high polluting) the Figure shows the increase in exports associated with moving from scenario (i) where both countries have equal stringency, to the scenario (ii) where the stringency in the exporter is higher than in the importer by 0.42, which is equivalent to moving from the median to the 75^{th} percentile of the distribution of *EPSgap* (or alternatively to the difference in *EPS* between Spain and Denmark in 2005), other things being equal. The estimates suggest that if the exporter has more stringent policies, then it exports to its trading partner 4 per cent less in "dirty" industries. For gross exports, the 2 per cent gain in "clean" industries is not significant. However, the estimates for domestic value added which, as argued, give a better picture in terms of impacts of environmental policies; suggest the loss in terms of "dirty" sectors (around 5 per cent) is of similar magnitude to the gain in "clean" industries (6 per cent).[16]

Figure 7. Effects of a higher EPSgap on exports of different industries

(higher EPS gap = exporter's policies are more stringent)



Note: The effect on trade flows (exports from country i to country j) associated with a change in the *EPSgap* from the situation where environmental policies are equally stringent (median) in the two countries to a situation where the difference in stringency is at the 75^{th} percentile of the *EPSgap* distribution (exporter i stringency is higher than that of importer j). Effects shown for three industry examples: high pollution intensity (Chemical, rubber, plastics and fuel products), medium pollution intensity and low pollution intensity (Manufacturing n.e.c. and recycling). The red point represents the point estimate, while the ranges report 90% confidence intervals.

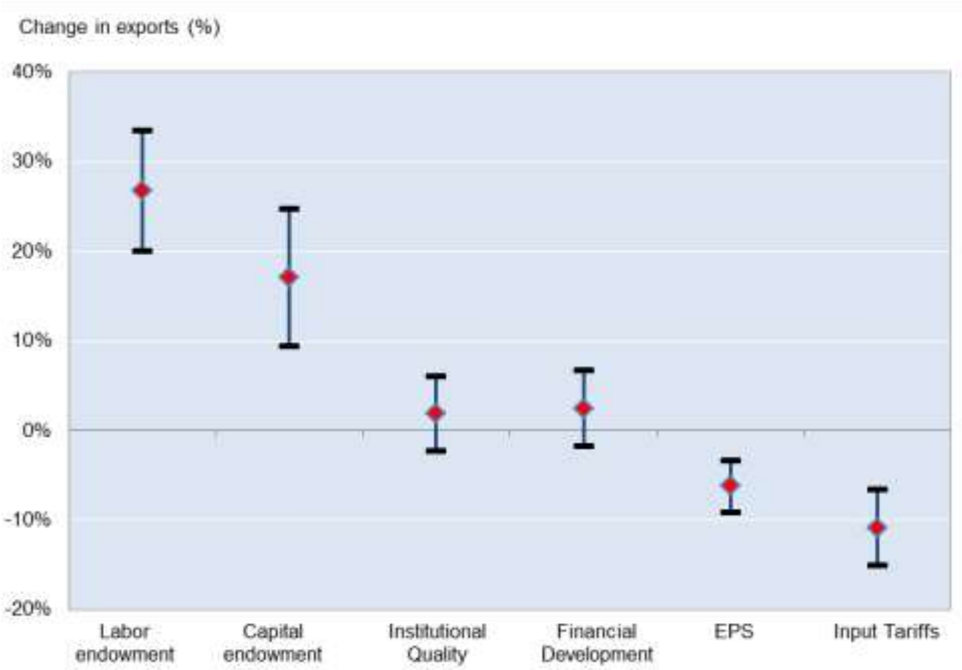
47. The effects can also be compared with those of other trade determinants. The estimated negative effect on exports (of a 0.42 change in *EPSgap*) would be equivalent to a 4 per cent increase in output tariffs for "dirty" sectors. For TiVA, where estimates are stronger - similar effects could be obtained by an 8 per cent increase in output tariffs. Finally, the effects are an order of magnitude smaller than those of being

16 . Effects for domestic value added in exports are significant at 99% confidence.

members of a regional trade agreement (RTA) – which tends to be associated with exports 50-70% higher.[17] Further insights can be gained when looking at particular cases of impacts of a change in determinants of trade. Figure 8 shows the estimated effects on the domestic value added component of the difference in each type of endowment and regulatory variable – for the "most sensitive" respective industry. Interestingly, the effects of EPS appear non-negligible as they are in line with those of financial development or institutional quality, while being statistically significant.

Figure 8. Estimated effects on domestic VA in exports of "sensitive" industries

By various trade determinants



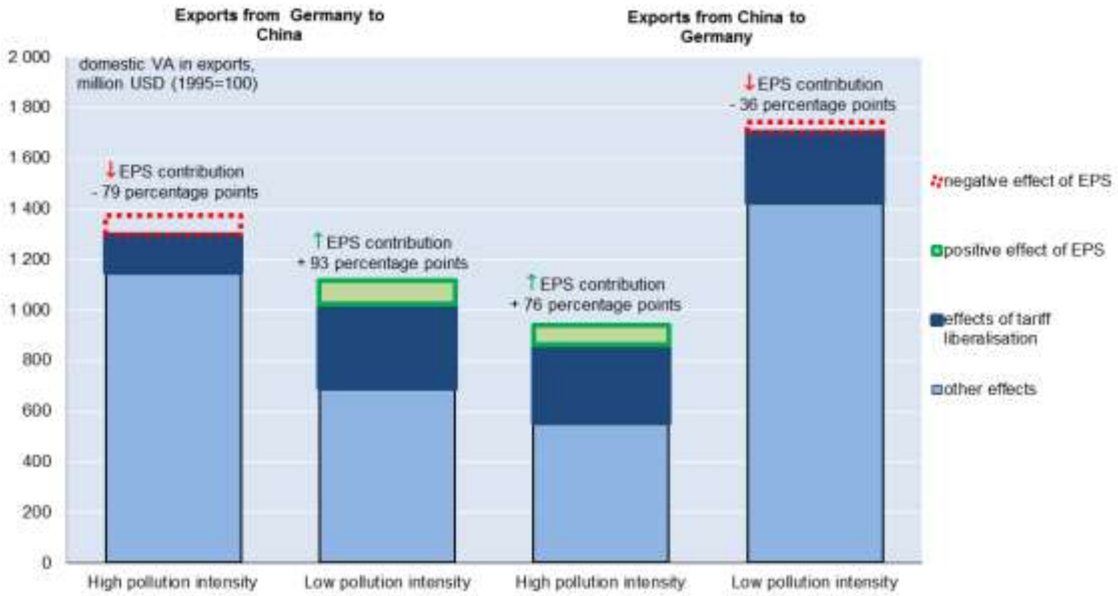
Note: Based on the specification using domestic value added in exports (TiVA). Simulated effects on trade flows (exports from country i to j) associated with an increase from the median to the 75th percentile of the sample in industries most sensitive to changes in the respective endowment/regulation of the exporter. In the absence of a sensitivity measure for import tariffs the change applies to all sectors. The red point represents the point estimate, while the ranges report 90% confidence intervals.

48. Another way to gauge the economic relevance of environmental stringency for trade is to assess the share of bilateral trade developments that can be explained by the changes in EPS – based on the empirical model. For example, Figure 9 uses the model estimates to assess the change in domestic value added in exports (TiVA) over 1995-2008 between Germany (among the highest EPS in the sample) and China (among the lowest EPS in the sample) – a pair of countries with relatively important international trade flows in most industries. During this bilateral trade between the two countries grew rapidly: total gross manufacturing exports measured in USD increased about tenfold, while the domestic value added increased even more. For both high and low pollution intensive sectors the increase in domestic value added in exports can be primarily attributed to the GDP growth, increases in endowments and a reduction in tariffs. Changes in relative EPS contributed only a minor role in explaining the developments – between 36 and 93 percentage points of the total increase. Similar conclusions can be drawn by looking at trade flows between the BRIICS, i.e. countries with lowest EPS values, and the three OECD countries with the highest EPS: Denmark, Germany and Switzerland (Figure 10).

17. RTAs are often claimed to be endogenous, so this interpretation requires some caution.

Figure 9. Contribution of EPS to trade growth between China and Germany

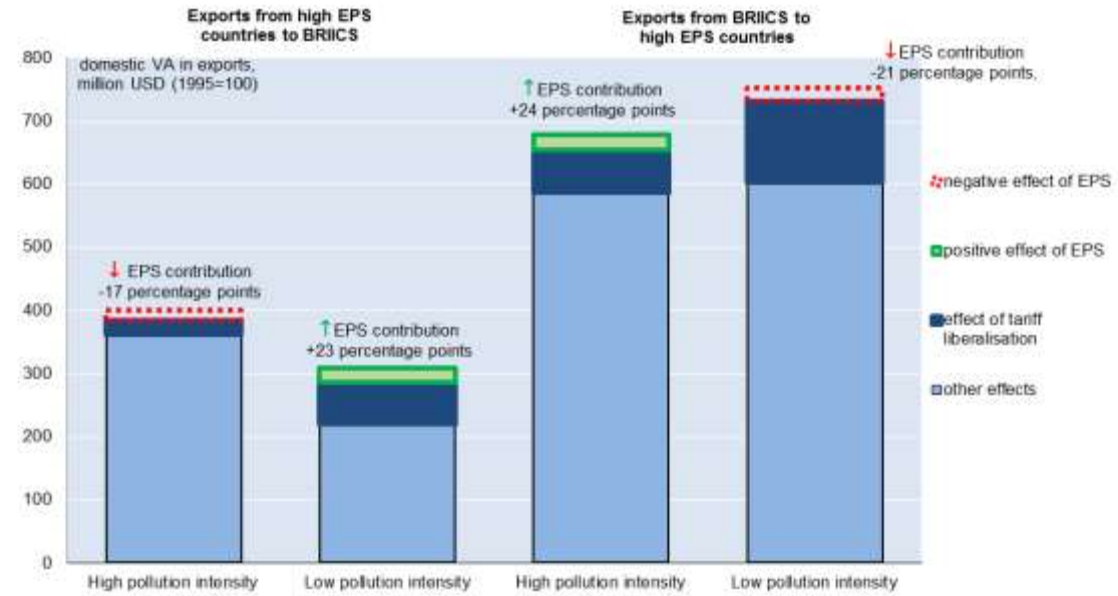
Trade growth for selected sectors (1995-2008)



Note: The growth in domestic VA in exports (nominal, USD) between 1995 and 2008 has been decomposed according to the estimated gravity model predictions. The graph shows trade flows between China and Germany in high (Chemical, rubber, plastics and fuel products) and low (Machinery and equipment) polluting sectors. "Other effects" include also effects not explained by the empirical model.

Figure 10. Contribution of EPS to trade growth between BRIICS and high EPS countries

Trade growth for selected country groups and sectors (1995-2008)



Notes: The growth in domestic VA in exports (nominal, USD) between 1995 and 2008 has been decomposed according to the estimated gravity model predictions. The graph shows trade flows between BRIICS and high EPS countries (Germany, Switzerland and Denmark) in high (Chemical, rubber, plastics and fuel products) and low (Machinery and equipment) polluting sectors relative to 1995. "Other effects" include also effects not explained by the empirical model.

6.3. Robustness of results

49. The results are robust to the use of an alternative proxy of environmental policy stringency – electricity prices proposed by Sato et al. (2015) (Table A3.7). Such a proxy is very different in nature from the policy-based EPS, but can be used to capture stringency in an economically meaningful way. On the one hand, such a *de facto* measure by definition already reflects various degrees of enforcement of policies and does not suffer from the potential omission of instruments (such as fossil fuel subsidies) or exemptions that affect the industry-level energy price. On the other hand, energy prices can also reflect fossil fuel prices and endowments, the structure of the energy market or the electricity production technology. Nevertheless, the consistency of the results is comforting, as the two measures have little in common aside developments due to precisely environmental policies.[18] Additionally, the results are not affected by focusing on in-sample energy intensity of industries rather than pre-sample pollution intensity as a "sensitivity" proxy (Table A3.8). Again, while both measures are highly imperfect, they are so in different ways, and the consistency of results can be treated as a sign of robustness of the effects.

50. When estimating PHH effects on domestic value added in exports, the assumption related to our pollution intensity proxy may be flawed. The domestic value added may come from various sectors in the economy, each of which has a different level of pollution intensity – a fact not captured by the main ED measures. Production can be divided between upstream tasks (such as the procurement or manufacturing of basic components, but also R&D) and downstream tasks (assembly stages, distribution and retail, accompanying services) (Antràs and Chor, 2013). An index that measures "the distance to final demand", counting the number of production stages left before the good reaches the final consumer and assigning each country-industry pair a value is available in the TiVA dataset.[19] In many cases upstream sectors can be associated with more pollution intensive production, though there may be exceptions - for example, some of the production stages upstream, such as R&D, may generate more value added and less pollution than downstream stages of production. The assumption where "upstreamness" (measured by distance to final demand) can be used as an alternative proxy of environmental dependence hardly affects the results (Table A3.9).

51. Environmental policies may impact trade with lags, and the exact timing of the effect is difficult to establish. This timing can depend on policy instrument choice and design, their implementation details as well as transmission associated with different industry characteristics (degree of competition, trade exposure, state of technology). On the other hand, expansion of a polluting industry can increase pollution levels and eventually encourage policy makers to tighten their level of environmental policies – posing a potential endogeneity problem. To deal with such issues and to test the robustness of the results to different time horizons, estimations using different lags of the *EPSgap* variables are reported in Table A3.10. The results are robust, highly significant, and the strength of the estimated lagged effect is higher than that of the contemporaneous in the baseline specification. As past environmental policies are less likely to be influenced by current economic performance, this indicates that the issue of endogeneity may not be particularly worrying. It also indicates, that the PHH effects found can be of a more permanent nature – that the increased imports (and decreased exports) of "dirty" industries in countries with higher EPS is likely not just a short-term substitution with imports, that could be later reversed as the domestic "dirty" industry adapts. Finally, the outcome is in line with the fact that firms are likely to take time to adjust to the

18 . The use of other potentially appealing measures such as WEF-based perceptions or the index of Dasgupta et al. (1995) with the TIVA database is problematic due to poor data overlap. The WEF survey starts early 2000s, while the Dasgupta et al. index is constructed on older data, as a single point in time observation and with limited country coverage.

19 . The idea is based on Antràs et al. (2012).The available index covers manufacturing only, over the years identical to the updated TiVA coverage: 1995, 2000, 2005 and 2008.

changing relative costs induced by environmental policies, and the reallocation of resources across industries in the economy is not instantaneous.

52. The PHH stipulates losses in competitiveness – be it overall or specifically for pollution intensive industries. In order to be more confident that we do not underestimate these effects by imposing symmetry across sectors in our main specification, we opted for allowing different coefficients for high and low pollution intensity sectors. The results indicate slight, albeit insignificant differences between the coefficients for the two types of sectors (Table A3.11). While gravity models provide very limited room for inference on timing of effects, we estimate the above effects using longer lags – aiming to capture possible differences in the dynamics of the effects on high and low pollution intensity sectors, and hence the underlying adjustment in view of more stringent policies. The magnitude of the coefficient for "dirty" sectors increases consistently with higher lags, which may be a sign of the longer-term nature of the effects, but the differences are not found significant.

53. Environmental policy stringency in both the exporter and importer can be as important as the difference between them. Our basic specification includes the difference in environmental policy stringency (*EPSgap*) rather than the levels of EPS in the importer and exporter countries. There are several good reasons for specifying this variable differently than other endowment variables. First of all, in the context of the PHH, it makes sense to look at relative EPS, as PHH would imply outsourcing to countries with a laxer EPS regime. Second, the issue of timing is also important, and the different potential timing of effects in countries is further complicated when including both importer and exporter EPS together. The inclusion of two trending, potentially collinear variables may also pose some practical problems.[20] In practice, inclusion of domestic and foreign EPS policies measured separately results in similar conclusions as for the gap, in particular regarding the domestic value added data (Table A3.10). They point to higher domestic ("exporter") EPS being associated with a negative effect on "dirty" industry exports. It is also associated with higher exports in "clean" sectors – confirming the specialisation argument. Importantly, higher stringency in the partner country (the "importer") is also associated with higher domestic exports of "dirty" industries to that country. Taken together, these results further confirm the PHH. Moreover, we find some (weak) evidence that overall effects are stronger for countries more integrated in global production chain (Table A3.12)

54. Additionally, the results are robust to a wide range of sensitivity tests (detailed results are reported in Appendix III). These include estimation on country and year subsamples and the inclusion of the potentially problematic crisis year 2009 (Table A3.4). Similarly, they are robust to different fixed effects specifications which may potentially be better suited to deal with time-varying multilateral resistance terms and the clustering of residuals (Table A3.5). They are also practically unaffected by potential non-linearities in the *EPSgap* variable (Table A3.7) and alternative gravity model specifications (Table A3.6).

7. Environmental policy stringency, trade and outsourcing - open issues

55. Several aspects merit further investigation:

- *Environmental policy induced technological change.* Despite efforts with using different proxies for environmental dependence, the analysis is not geared to capture the effects of a major "cleaning" of a particular industry. In the longer term, sectors that have been historically polluting may be able to innovate and develop in a cleaner fashion, precisely because of more

20. Correlations between importer and exporter EPS are 0.33 and 0.55 (for the ED weighted version), both significant at 99%.

stringent policies and induced innovation (Acemoglu et al., 2012). More granular investigation into the investment decisions of firms (and industries) related to environmental policies could help unravel such effects.

- *The link with productivity and outsourcing.* The estimated results can shed some light on the findings of the effects of environmental policies on productivity growth (Albrizio et al., 2014). This work found that more stringent policies are associated with higher productivity growth in the most technologically advanced industries. Preliminary evidence suggests that the polluting sectors that gained most in productivity are also those that been subject to the PHH, and are more prone to outsourcing. On the other hand, this paper shows that the overall PHH effects are relatively small. Future work could focus on a more scrupulous analysis of the productivity link and of broader economic impacts, such as those on employment consequences in affected industries.[21]

- *The role of the design of environmental policies.* Using very general proxies of stringency does not allow controlling for the design of environmental policies or the presence of special clauses or exemptions for high polluters. Environmental policies may differ in the flexibility of the instrument in terms of mode of compliance (e.g. market-based instruments versus command and control), stability and credibility of the policy signal, "push" (e.g. taxes) and "pull" (e.g. subsidies) characteristics or the stance with respect to competition and entry (Kozluk, 2014). For instance, special provisions that reduce the environmental policy signals for incumbents or large polluters are often adopted due to political economy considerations and intended to preserve the competitiveness of some parts of "dirty" sectors or allow them time to adjust. However, such policies can distort the level playing field, reduce incentives for innovation and adoption of cleaner technologies and hence reduce expected gains from the increasing overall stringency of environmental policies. They can also imply a need to increase overall stringency more than otherwise in order to achieve overall environmental objectives, potentially leading to inefficiencies and high costs of abatement for the economy. While important, such direct effects of policy design are better captured and exploited in analyses of specific policies in a quasi-natural experiment setting, as for instance in Flues and Lutz (2015).

- *The link with environmental impacts.* The changes in specialisation induced by EPS developments may have varying environmental impacts – the assessment of which is beyond the scope of this paper. For relatively local pollutants, leakage may not be a concern of domestic policy makers. However, for global environmental issues, such as climate, the resulting shifts in competitiveness of the "dirty" sectors may imply that part of the environmental benefits are lost due to carbon leakage to countries with less stringent policies. The effect is not straightforward as, due to technology transfer, the development of such industries in the less stringent countries may nevertheless be cleaner than otherwise. Overall, further work would be needed to infer the impact of domestic environmental policies on the extent of leakage of environmental externalities, for example via a general equilibrium modelling framework.[22]

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21 . A detailed comparison of the results of the two papers is a task of its own, as the papers rely on somewhat different samples (country and years) and explanatory variables (including slightly different EPS definitions), but could yield valuable insights on the links between environmental policies, productivity and outsourcing.

22 . Several dynamic aspects would need to be taken account, including those listed above (technological change, type of externality and its global or local aspects), but also issues like the link between actual domestic production and exports as well as the effects of out-of-sample values of environmental policies,

- *Broader trade effects and speed of adjustment.* The focus on trade in manufacturing sectors poses some limitations regarding the overall conclusions on specialisation. Primary sectors, which are likely to be highly environmentally dependent (agriculture, energy, forestry, mining and extraction) are also likely to be prone to costs resulting from environmental policies – though performance in these sectors is probably also more strongly linked to endowments. On the other hand, many traded services are likely to be less directly linked to the environment. Whether the conclusions of this paper can be extended to trade in such markets is yet another empirical question. Additionally, gravity models may not be well-suited to provide insight on the speed of adjustment – that is, on the timing and detailed evolution of the competitiveness losses in pollution intensive industries associated with more stringent policies and counter-balancing competitiveness gains in less pollution intensive industries. Again, more micro-level analysis can provide evidence on how such effects play out, what are the associated costs of transition and how framework policies can help reduce such costs.

more disaggregated industry coverage and potentially a more complete global sample, covering in particular other developing countries. Past OECD work on leakage in a computable general equilibrium framework is summarised in Lanzi et al. (2013).

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APPENDIX I – RELEVANT LITERATURE SUMMARY

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Broner et al. (2012)	Import market share per industry relative to average market share into the U.S.	80 exporter countries and 1 importer country (US). Manufacturing industries at the 4-digit NAICS level in the U.S. in 2002.	OLS and IV.	Endowments of physical and human capital (interacted with intensities), income, institutional quality, country- and industry-FE.	Grams of lead content per litre of gasoline. Pollution intensity of industry (based on US pollutant release inventories) is used as sensitivity for interactions. IV: Meteorological determinants of pollution dispersion	Causal relationship between environmental regulation and trade, comparable in magnitude to effects of physical and human capital.
Combes et al. (2014)	Gross exports	72 exporter- and 128 importer countries from 1980-2010. Distinction between manufactured- and primary commodity exports.	OLS, FE and RE.	Gravity setup augmented by institutional variables.	Difference between observed pollution levels and "structural" pollution, i.e. pollution predicted by determinants of environmental degradation. Robustness checks include income inequality and square of income per capita as proxies.	No significant effect of environmental regulatory gap on trade independent of the goods characteristics.

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Ederington and Minier (2003)	Net Imports	US imports at the 4-digit SIC level for manufacturing industries from 1978-1992.	OLS and two- and three-stage least squares.	Endowments of physical- and human capital, trade barriers and industry FE.	Ratio of PACE to total costs by sector. IV: Trade flows, tariffs and a vector of political economy variables.	Positive effect of PACE on imports. However, results are sensitive to instruments chosen, in particular when using lagged values of net trade. Without the use of instruments the PACE coefficient is practically negligible.
Ederington, Levinson and Minier (2005)	Net imports	US imports at the 4-digit SIC level for manufacturing industries from 1978-1992. Breakdown: (I) developed vs. developing exporter countries, (II) only footloose industries, (III) only industries with small PACE	FE	Endowments of physical- and human capital, trade barriers and industry and time-specific FE.	PACE over total costs of production.	The least geographically “footloose” (immobile) industries are the most polluting ones, hampering the existence of PHH. Restricting the sample to countries with the lowest standard suggests a higher effect of environmental regulations on trade patterns as when measured overall trade flows.
Grether and de Melo (2003)	Gross imports	52 trading partners from 1981-1998. Manufacturing industries at the 3-digit ISIC level. Industries are classified as “dirty” or “clean” according to their emission intensity (WB IPPS)	FE	Gravity setup augmented by country-pair-time, country-pair and time-FE.	Difference across countries in GDP per capita.	No significant effect of environmental stringency on bilateral trade.

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Grossman and Kruger (1993)	Gross imports	US imports from Mexico to 3-digit SIC manufacturing sectors in 1987.	OLS	Endowments of physical- and human capital, tariff- and injury rates for U.S. sectors.	US PAOC to value added ratio, by sector.	Mexico draws a comparative advantage from its low labour costs, not from PACE. Environmental regulations are found to be statistically insignificant (or only at the 10% level) thus a negligible factor in guiding resource allocations.
Harris et al. (2002)	Gross imports	24 OECD countries from 1990-1996. Industries are divided between (I) dirty and (II) non-resource based (footloose) pollution intensive industries.	OLS and FE.	Gravity setup (following van Beers and van den Bergh)	Index similar to Van Beers and van den Bergh (1997) based on energy consumption and supply.	No significant effect of environmental index on trade patterns when the specification includes fixed effects.
Jug and Mirza (2005)	Gross exports	12 importer countries from the EU and EU15+CEEC exporter countries from 1996-1999. Manufacturing sectors at the ISIC Rev. 3 level are divided into “clean” and ”dirty”, defined by emissions per unit of output.	FE and 2SLS.	Gravity setup augmented by wages and importer-, exporter-, sector-, and time-FE.	Environmental expenditure (Eurostat) by industry. Instruments for environmental expenditure. IV: Public environmental expenditure lagged environmental investment, lagged wages.	Negative effects of environmental stringency on exports. Environmental regulations matter even more for central and eastern European countries and when using IV estimation.

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Kahouli et al. (2014)	Gross exports and FDI	14 home countries and 30 host countries from 1990-2011.	OLS, FE, RE, HT, Diff-GMM and SYS-GMM.	Gravity setup augmented by FDI.	Difference in CO_2 emissions per unit of GDP.	Positive and significant impact of environmental regulations on trade for static estimations, insignificant for dynamic estimations. The impact of environmental regulation on FDI is negative and insignificant for all estimations.
Kellenberg (2009)	Value added of majority owned U.S. multinational affiliates in partner countries	50 countries and 9 industries from 1999 to 2003.	OLS and IV-GMM.	Gravity variables, IPR policy, average manufacturing tariffs, capital/labor ratio, institutional quality, infrastructure, schooling quality and organised crime. Region-, industry- and time-FE.	Based on WEF.	For the top 20th percentile of countries in terms of growth in U.S multinational affiliate value added, as much as 8.6% of that growth between 1999 and 2003 can be attributed to declining relative stringency and enforcement of environmental policies. Relatively ‘footloose’ industries are more sensitive than traditional “dirty” industries.

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Levinson and Taylor (2008)	Net imports	US imports from Mexico and Canada in 133 3-digit SIC industries from 1977-1986.	FE and 2SLS.	Industry-, time-FE and import tariffs.	PACE IV per industry: state characteristics (GDP per state, emissions produced by all other industries).	Positive relationship between industry PACE and net imports, effect is even reinforced when accounting for endogeneity by using IV
Raspiller and Riedinger (2005)	Gross imports	3856 import flows from foreign affiliates to French multi-nationals (53 categories, 48 source countries), based on a 2000 industrial survey.	Cross-section	Two specifications, one allowing for differences in factor costs across countries	Synthetic index created based on Esty and Porter (2001, using also WEF Executive Opinion Survey) and Dasgupta et al. (1995, extended by Eliste et Fredriksson (2002))	A relatively larger share of pollution-intensive goods is sourced from more stringent countries. Results suggest that “other” factors are more important in driving industry location (and import flows) and that the stringency of environmental policies is not a factor that plays a role (PHH rejected).
De Santis (2012)	Gross exports	15 exporter countries (EU-15) and 25 importer countries (15 EU + 10 OECD) from 1988-2008.	FE and HT.	Gravity setup augmented by exporter- and importer FE.	GDP over population per country.	Environmental regulations in the exporting country negatively affect bilateral trade.

Author and year	Dependent variable	Sample	Empirical Approach	Independent Variables	Environmental policy variable	Main findings
Sato and Dechezlepretre (2015)	Gross exports	42 trading partners in 62 sectors at the 2-digit SITC Rev.3 level (60% of global merchandise trade) from 1996-2011.	OLS with standard errors clustered at country-pair-sector level.	Gravity setup augmented by wages and a GDP similarity measure.	Industrial level energy prices interacted with industry level dummies.	Small, significant effects of electricity price gap on imports (higher price associated with higher imports). Strongest for energy intensive sectors, but still explains less than 0.01% of trade flows.
Tobey (1990)	Net exports	23 developed and developing countries, 24 SITC 3-digit industries, pollution intensity defined as PACE to total costs ratio, 1975 and change between 1970 and 1984	OLS	Capital, labour, land and natural resource endowments	1976 UNCTAD survey (Walter and Ugelow, 1979)	No significant effects found.
van Beers and van den Bergh (1997)	Gross imports	21 trading partners in 1975 and 1992. Industries are divided between (I) pollution-intensive and (II) pollution-intensive sectors that are non-resource based.	OLS	Gravity setup.	Environmental index based on a combination of (I) 7 output-oriented indicators (broad) or (II) two measures of energy intensity (narrow).	Negative and significant effect of environmental stringency (exporter and importer) on bilateral trade. The findings confirm that the effect of environmental regulation is stronger on non-resource based than on resource-based industries.

Note: PACE=Pollution Abatement Costs and Expenditures survey, PAOC= Pollution Abatement Operating Costs; IV=Instrumental variable approach, RTA=Regional trade agreement, OLS=Ordinary least square, FE=Fixed effects, RE=Random effects, HT=Hausman-Taylor estimator, 2SLS= Two stage least square estimator, GMM= Generalised method of moments.

APPENDIX II – DESCRIPTION OF THE DATA AND VARIABLES USED

1. The estimation dataset covers 23 OECD countries: Australia, Austria, Belgium, Canada, Denmark, France, Finland, Germany, Greece, Hungary, Ireland, Italy, Japan, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, the United Kingdom, and the United States as well as Brazil, Russia, India, Indonesia, China and South Africa.[23] The 10 manufacturing industries covered in the sample are food, beverages and tobacco (ISIC Rev.3.1 code 1516); textiles and footwear (1719); wood and wood products (2000); pulp, paper and printing (2122); chemical, rubber, plastics and fuel products (2325); other non-metallic mineral products (2600); basic metals and fabricated metal products (2728); machinery and equipment (2933); transport equipment (3435); and manufacturing n.e.c. and recycling (3637). The gross trade data ranges over 1990-2009. The updated and revised data for domestic values added in exports (TiVA) data is available only for 1995, 2000, 2005, 2008 and 2009 (older, but less detailed TiVA estimates were available also for 2009-2011). Variables used are described in Tables A2.1 and A2.2, with a more detailed subsection for the environmental policy stringency variable following.

Table A2.1 Description of variables and sources

Variable	Description	Dimension	Source
Gross imports	Gross Imports	Country-pairs, sector, year	OECD STAN database
Distance	Distance between countries' capitals.	Country-pairs	CEPII database,
Common Language	Dummy that equals to 1 if country's population speak a shared language	Country-pairs	CEPII database,
Common Border	Dummy that equals to 1 if countries share a land border	Country-pairs	CIA World Factbook
RTA	Dummy that equals to 1 if the countries jointly signed a regional trade agreement	Country-pairs, year	WTO
Currency Union	Dummy that equals to 1 if countries are in a currency union	Country-pairs, year	De Sousa, J. (2012)

23 . Korea was not included due to the absence of the financial development variable in our dataset. However, dropping this variable and including Korea in the estimations does not have a significant impact on the coefficients of interest (EPSgap and EPSgap*ED) in nether the gross exports or domestic VA in exports specification.

Variable	Description	Dimension	Source
Distance to final demand	Index showing the production stage in a GVC (high values indicate upstream, low values downstream stages)	Country, industry, time	OECD-WTO TiVA Database 2015
Stock of physical capital per worker	Capital to labour ratio	Country, time	Kowalski (2011)
Stock of human capital	Average years of schooling	Country, time	Barro and Lee (2010)
Energy supply	Energy production per capita	Country, time	World Energy Indicator Base
Financial development	Ratio of domestic credit to GDP	Country, time	World Development Indicators (WDI, 2012)
Institutional quality	Proxied by the indicator "rule of law". A higher number indicates better quality of institutions	Country, time	World Bank Governance database
Physical capital intensity	Share of capital in the industry's total use of factors of production	Sector	GTAP database, Johansson et al. (2014)
Human capital intensity	Share of skilled labour in the industry's total use of factors of production	Sector	GTAP database
Sensitivity to financial development	Measures the degree of external financial dependence of US firms	Sector	Kowalski (2011) and Braun (2003)
Sensitivity to the quality of institutions	Based on an index (Herfindahl) of intermediate input dispersion based on input-output tables for the Unites States	Sector	Kowalski (2011)
Input tariffs	Weighted average of tariffs on the intermediate goods used in the production of final goods	Country, sector, time	Most Favourite Nation (MFN) in the sample from the WITS/TRAINS/WTO database, the input-output tables for the United States sourced from GTAP (2004)

Variable	Description	Dimension	Source
Output tariffs	Average tariffs that the importer imposes on imports	Country pair, sector, time	Most Favourite Nation (MFN) in the sample from the WITS/TRAINS/WTO database, the input-output tables for the United States sourced from GTAP (2004)
EPS	EPS Index	Country, time	Botta and Koźluk (2014)
Environmental Dependence	Index of pollution intensity	Sector	IPPS Pollution Intensity and Abatement Cost World Bank dataset
Energy intensity	Alternative index of environmental dependence	Sector	OECD STAN Input-Output

Table A2. 2 Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Exports (level)	165300	387.19	2003.60	0	120270.7
Domestic VA in exports (level)	34800	253.87	1104.55	0	38990.71
Distance	165300	8.23	1.07	5.08	9.80
RTA	165300	.39	.49	0	1
Common currency	165300	.064	.24	0	1
Contiguity	165300	.07	.25	0	1
Common language	165300	.08	.28	0	1
GDP (log)	165010	26.76	1.28	23.26	30.32
Capital endowment (log)	165300	11.18	1.37	7.46	13.04
Human capital (log)	165300	2.22	0.26	1.27	2.57
Energy supply (log)	165300	-6.28	1.11	-8.13	-2.96
Financial development (log)	158050	4.33	0.66	2.12	5.44
Institutional quality (log)	130500	4.34	0.30	3.04	4.61
Capital intensity	165300	-0.01	0.07	-0.11	0.15
Human capital intensity	165300	0	0.02	-0.02	0.05
Energy supply intensity	165300	0.01	0.12	-0.08	0.36
Financial development sensitivity	165300	0	0.17	-0.15	0.44
Institutional quality sensitivity	165300	0.01	0.05	-0.1	0.07
Output Tariffs (log)	165300	.07	.08	0	.73
Input tariffs (log)	165300	.04	.05	0	.48
EPS	165300	1.26	.74	.25	3.38
ED (environmental dependence)	165300	0	.24	-.37	.30
ED (energy intensity)	165300	0	0.30	-0.54	0.46
Distance to final demand	121800	2.38	1.62	.95	18.45

Note: the table presents statistics for the entire dataset. In the estimations, individual observations may be dropped due to unavailability of a particular variable or the decision to focus on particular years or countries.

Environmental policy stringency variable

2. The environmental policy stringency (EPS) proxy is based on Botta and Koźluk (2014). The original index covers 24 OECD countries over 1990-2012. It focuses primarily on energy and transport policies addressing climate and air pollutants. For the purpose of this paper, the index has been provisionally extended to major emerging market trading partners: Brazil, Russia, India, Indonesia, China and South Africa (BRIICS). The data for individual policies were collected by the authors with help from Zoey Verdun and Silvia Albrizio, OECD. The resulting EPS measures are reported in Figures A2.1 and A2.2.

3. The extension necessitated some minor modifications to the indicator and working assumptions. First, the subindicator on deposit and refund schemes was exclude for three reasons: (i) insufficient data availability, (ii) arguments such as that of Brunel and Levinson (2014) that deposit and refund schemes are unlikely to have significant impacts on firms location decisions and trade, and, (iii) the focus in this paper on air and climate pollutants related to energy. Second, due to poor data availability for the public expenditures on R&D in renewable energy for the BRIICS, the working assumption was to allocate a score of 1 out of 0 to 6 (i.e. lowest value for an existing policy) to reflect the fact that such public support is likely, but potentially low. The relationship of the EPS used with other proxies available on a cross-country and across time dimension is reported in Table A2.3. As discussed in Koźluk and Zipperer (2014), each single measure is far from ideal; hence this paper provides robustness checks with alternative measures to test the fragility of the results.

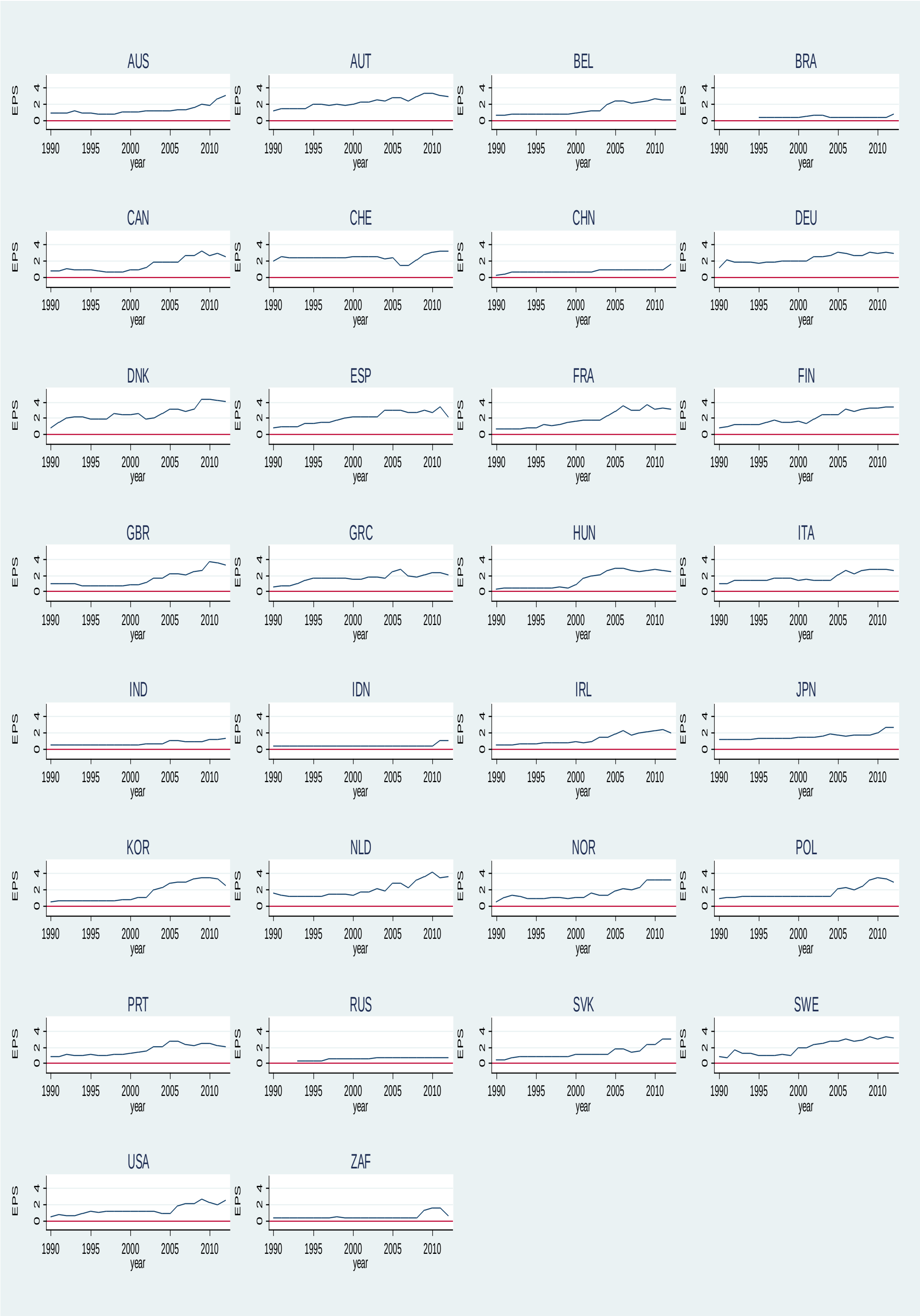
Table A2.3 Correlations of EPS with other proxies of environmental policy stringency

Spearman rank correlations over maximum available sample

EPS measure	Correlation with EPS used in this paper	Sample characteristics
Original EPS (Botta and Koźluk, 2014)	0.93***	24 OECD countries only, 1990-2012
World Economic Forum's Executive Opinion Survey	0.49***	All countries, 2001-2012
Energy Prices (Sato et al. 2015)	0.59***	All countries except for ESP, IRL, NOR.1995-2011
Environmental Patents (share)	0.28***	All countries, 1990-2009

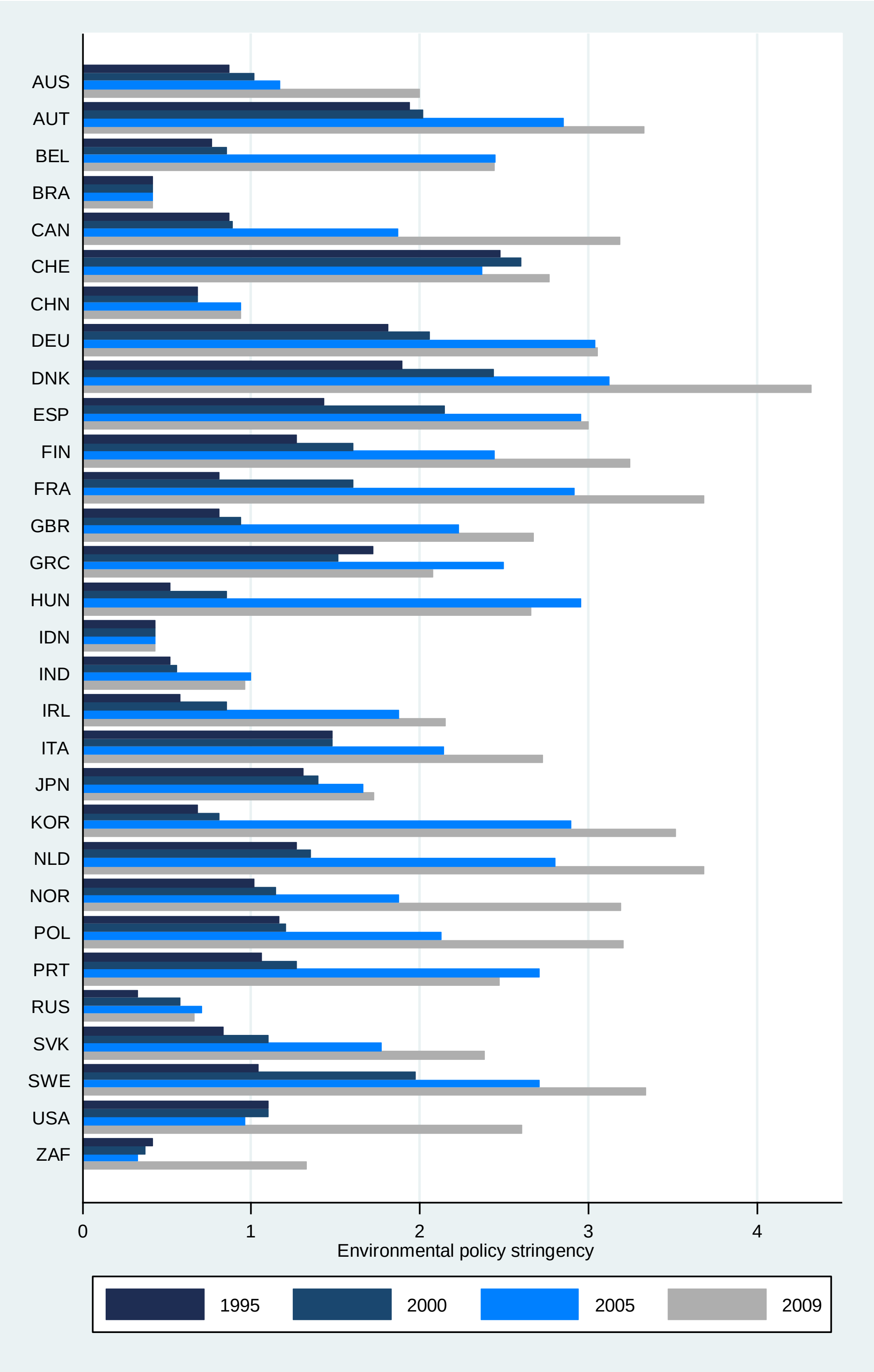
Note: ***, **, * denote significance at 99%, 95% and 90% respectively.

Figure A2.1 Evolution of the EPS proxy over 1990-2012



Source: Extension of Botta and Koźluk (2014)

Figure A.2.2 Values of EPS per country (selected years)



Note: EPS values on a 0 to 6 scale, where 6 represents more stringent.

APPENDIX III – ESTIMATION RESULTS AND ROBUSTNESS CHECKS

1. Tables A3.1 and A3.2 report the full results related to Tables 1 and 2 in the main text. Additionally, the specification in Table A3.1 is estimated with net import figures, yielding similar results.

Table A3.1 Estimation results (gross exports)

Estimation method: Poisson

Dependent variable: Gross exports (in logs)

	(1)		(2)	
Gravity variables				
Distance	-0.640***		-0.640***	
	(0.0196)		(0.0196)	
Contiguity	0.238***		0.239***	
	(0.0211)		(0.0211)	
Common language	0.249***		0.248***	
	(0.0247)		(0.0247)	
Regional trade agreement	0.654***		0.652***	
	(0.0367)		(0.0368)	
Common currency	0.163***		0.163***	
	(0.0244)		(0.0244)	
GDP exporter	0.606***		0.607***	
	(0.0719)		(0.0720)	
GDP importer	0.679***		0.680***	
	(0.0704)		(0.0705)	
Output-Tariffs of the importing country	-0.919***		-0.877***	
	(0.256)		(0.253)	
Input-Tariffs	-6.954***		-6.993***	
	(0.729)		(0.728)	
Exporter	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**
Stock of capital per worker	-0.0652	1.433***	-0.0636	1.483***
	(0.0828)	(0.0932)	(0.0829)	(0.0954)
Stock of human capital	0.0149	30.31***	0.00859	29.72***
	(0.221)	(1.720)	(0.220)	(1.710)
Energy supply	0.319***		0.315***	
	(0.0691)		(0.0689)	
Financial development	-0.259***	1.064***	-0.260***	1.053***
	(0.0491)	(0.0677)	(0.0494)	(0.0677)
Regulatory Quality	0.312**	-1.747**	0.314**	-1.916***
	(0.126)	(0.733)	(0.126)	(0.732)
Importer	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**

Stock of capital per worker	0.0566	0.145*	0.0565	0.0873
	(0.0747)	(0.0866)	(0.0746)	(0.0886)
Stock of human capital	0.0166	0.818	0.0236	1.008
	(0.251)	(1.606)	(0.252)	(1.599)
Energy supply	0.265***		0.266***	
	(0.0597)		(0.0597)	
Financial development	0.00739	-0.109*	0.00540	-0.0883
	(0.0390)	(0.0653)	(0.0386)	(0.0656)
Regulatory Quality	0.341***	3.329***	0.344***	3.525***
	(0.124)	(0.624)	(0.125)	(0.628)
Environmental Policy Stringency				
EPSgap	-0.0183		-0.0230	
	(0.0166)		(0.0163)	
EPSgap*ED			-0.142***	
			(0.0366)	
Exporter, importer, industry and year fixed effects	Yes		Yes	
Pseudo R-squared	0.850		0.850	
Observations	121,240		121,240	

Notes: For each policy and endowment variable, the coefficient represents the main and the differential effect the interaction term. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Table A3.2 Estimation results (Domestic VA in exports (TiVA))

Estimation method: Poisson

Dependent variable: Domestic VA in exports (TiVA)

	(1)		(2)	
Gravity variables				
Distance	-0.761***		-0.762***	
	(0.0331)		(0.0328)	
Contiguity	0.286***		0.289***	
	(0.0373)		(0.0372)	
Common language	0.328***		0.326***	
	(0.0400)		(0.0398)	
Regional trade agreement	0.456***		0.453***	
	(0.0611)		(0.0607)	
Common currency	0.00653		0.00769	
	(0.0403)		(0.0398)	
GDP exporter	0.529***		0.532***	
	(0.127)		(0.127)	
GDP importer	0.698***		0.700***	
	(0.109)		(0.109)	
Output-Tariffs of the importing country	-0.839**		-0.770**	
	(0.395)		(0.391)	
Input-Tariffs	-4.244***		-4.311***	
	(1.039)		(1.025)	
Exporter	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**
Stock of capital per worker	0.266**	1.251***	0.266**	1.415***
	(0.125)	(0.227)	(0.123)	(0.229)
Stock of human capital	0.816**	31.90***	0.787**	31.49***
	(0.329)	(3.018)	(0.323)	(3.020)
Energy supply	0.169		0.158	
	(0.106)		(0.106)	
Financial development	-0.197***	0.697***	-0.196***	0.631***
	(0.0681)	(0.115)	(0.0688)	(0.113)
Regulatory Quality	0.152	1.329	0.160	0.625
	(0.254)	(1.774)	(0.251)	(1.725)
Importer	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**
Stock of capital per worker	0.139	0.112	0.141	-0.0634
	(0.104)	(0.169)	(0.103)	(0.171)
Stock of human capital	0.872**	-0.632	0.886**	-0.649
	(0.354)		(0.354)	
Energy supply	-0.0373		-0.0345	
	(0.0956)	(3.140)	(0.0947)	(3.092)

Financial development	0.0674	-0.243**	0.0626	-0.175
	(0.0598)	(0.116)	(0.0594)	(0.116)
Regulatory Quality	0.460**	2.633**	0.469**	3.270***
	(0.214)	(1.178)	(0.214)	(1.191)
Environmental Policy Stringency				
EPSgap	0.00364		0.00188	
	(0.0284)		(0.0282)	
EPSgap*ED			-0.362***	
			(0.0616)	
Exporter, importer, industry and year fixed effects	Yes		Yes	
Pseudo R-squared	0.841		0.842	
Observations	32,480		32,480	

Notes: For each policy and endowment variable, the coefficient represents the main and the differential effect the interaction term. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Robustness checks

Subsample estimations

2. Restricting the sample to the years where TiVA data is available: the baseline specification for gross exports has been also re-estimated for the 4 year subsample which overlaps that of the TiVA dataset (1995, 2000, 2005, and 2008). This is a significant restriction of the number of observations and causes the gross exports results to lose significance. Again, this can be seen as a confirmation of the effects being more tangible for the domestic component of production (Table A3.3).

Table A3.3 Estimation results (gross exports, restricted years)

Estimation method: Poisson **Dependent variable: Gross exports**	(1)	(2)
Gravity variables		
Distance	-0.650***	-0.650***
	(0.0356)	(0.0356)
Contiguity	0.233***	0.234***
	(0.0405)	(0.0404)
Common language	0.250***	0.249***
	(0.0468)	(0.0468)
Regional trade agreement	0.601***	0.600***
	(0.0655)	(0.0656)
Common currency	0.126***	0.126***
	(0.0466)	(0.0466)
GDP exporter	0.607***	0.608***

	(0.125)		(0.125)	
GDP importer	0.668***		0.668***	
	(0.121)		(0.121)	
Output-Tariffs of the importing country	-0.894*		-0.862*	
	(0.480)		(0.478)	
Input-Tariffs	-6.728***		-6.752***	
	(1.323)		(1.324)	
Exporter	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**
Stock of capital per worker	-0.117	1.666***	-0.116	1.695***
	(0.134)	(0.176)	(0.134)	(0.181)
Stock of human capital	-0.0227	29.52***	-0.0262	29.20***
	(0.372)	(3.267)	(0.372)	(3.240)
Energy supply	0.311***		0.308***	
	(0.109)		(0.109)	
Financial development	-0.237***	0.947***	-0.237***	0.938***
	(0.0869)	(0.120)	(0.0873)	(0.120)
Regulatory Quality	0.336	-0.201	0.340	-0.351
	(0.255)	(1.478)	(0.255)	(1.469)
Importer	**Avg. effect**	**Interaction**	**Avg. effect**	**Interaction**
Stock of capital per worker	0.0468	0.134	0.0476	0.0988
	(0.117)	(0.170)	(0.117)	(0.174)
Stock of human capital	0.222	0.893	0.227	0.957
	(0.417)	(2.988)	(0.417)	(2.982)
Energy supply	0.318***		0.320***	
	(0.103)		(0.103)	
Financial development	0.0802	-0.124	0.0787	-0.110
	(0.0711)	(0.118)	(0.0708)	(0.119)
Regulatory Quality	0.289	2.359*	0.291	2.527**
	(0.228)	(1.250)	(0.228)	(1.258)
Environmental Policy Stringency				
EPSgap	-0.00223		-0.00466	
	(0.0305)		(0.0300)	
EPSgap*ED			-0.0798	
			(0.0674)	
Exporter, importer, industry and year fixed effects	Yes		Yes	
Pseudo R-squared	0.852		0.852	
Observations	32,480		32,480	

Notes: For each policy and endowment variable, the coefficient represents the main and the differential effect the interaction term. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Including 2009 data

3. The above regressions did not include the year 2009, despite data being available. However, 2009 is marred by the collapse of global trade, which started already in late 2008. While there is potential to control for such effects in the regression, the weight of 2009 in the TiVA dataset which covers only 5 years, the fact that the controls could interfere with our problem of interest and the potential measurement issues e.g. for capital stock and financial variables in that year, we adopted a cautious approach and excluded 2009 altogether. A robustness check based on the same specifications but including 2009, yields similar but weaker results (Table A3.4).

Table A3.4 Estimation results with 2009

Estimation method: Poisson

Dependent variable: Gross imports (in logs)

	Gross exports		Domestic VA in exports (TiVA)	
Environmental Policy Stringency				
EPSgap	-0.0252	-0.0289*	0.000246	-0.000733
	(0.0154)	(0.0151)	(0.0252)	(0.0250)
EPSgap*ED		-0.113***		-0.271***
		(0.0352)		(0.0516)
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes
Pseudo R-squared	0.848	0.848	0.834	0.834
Observations	129,080	129,080	39,760	39,760

Note: Robust standard errors in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Exclusion of countries from the sample

4. In order to check the robustness of the results to the inclusion or exclusion of specific countries, the estimations were repeated using the baseline specification for domestic value added in exports, but randomly excluding three countries. This was repeated 100 times, and results were practically unchanged – coefficients on *EPSgap* were insignificantly different from zero in all cases, while the coefficients on the interaction with *ED* were hardly affected in magnitude, negative and significant at 95% confidence. The results were also unchanged if selected countries were removed manually (e.g. China, United States, selected Asian and European countries), confirming that the estimates are not driven by the choice of trading partners. Importantly, the results also hold when estimating the specification over the 2000s only, where we can have more confidence on the EPS proxy, as it is possible to compare with other measures, such as the WEF survey responses.

Alternative specification of fixed effects and clustering of errors

5. To better control for unobserved effects, in particular multi-lateral resistance terms, we experiment with various fixed effect structure. Using time-variant importer exporter pair fixed effects (instead of separate importer, exporter, industry and year fixed effects), washes out the EPS gap variable. However, the coefficient on the interaction of *EPSgap* and environmental dependence remains similar to

the baseline specification, meaning the specialisation effect is robust to the alternative fixed effect structure (Table A3.5 and A3.6). Similar results are also obtained using importer-year and exporter-year fixed effects.

6. Furthermore, to control for the potential correlation of error terms for individual country pairs the baseline specification is re-estimated with clustered standard errors along that dimension. The results for TiVA remain practically unchanged, while the results for gross exports lose significance, even if the magnitude is preserved. This can be seen as a confirmation of the fact that effects on domestic value added are stronger and more robust than those for gross exports, in line with the expectations that environmental policies are likely to impact the domestic component of exports (Table A3.5 and Table A3.6).

Table A3.5 Estimation results with fixed effects and clustered standard errors – gross exports

Dependent variable:	Gross exports				
	(1)	(2)	(3)	(4)	(5)
Standard Errors	robust	robust	robust	clustered (i-j)	clustered (i-j-s)
Environmental Policy Stringency					
EPSgap	-0.023	-0.0166	-	-0.0166	-0.0166
	0,016	0,016		0,017	0,013
EPSgap*ED	-0.142***	-0.131***	-0.148***	-0.131	-0.131*
	0,037	0,033	0,035	0,103	0,075
Exporter, importer FE	Yes	No	No	No	No
Country pair FE	No	Yes	No	Yes	Yes
Exporter-year, importer-year FE	No	No	Yes	No	No
Industry FE	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	No	Yes	Yes
Observations	121240	121240	121240	121240	121240

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to specification 2 in Table A3.1, with different fixed effects combinations. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively. Columns 1, 2, 3 report robust standard errors, while 4 and 5 report clustered standard errors (by country pairs and country-pair-sector respectively).

Table A3.6 Estimation results with fixed effects and clustered standard errors – TiVA

Estimation method: Poisson

Dependent variable:	Domestic VA in exports (TiVA)							
Standard Errors	(1) robust	(2) robust	(3) robust	(4) robust	(5) clustered (i-j)	(6) clustered (i-j)	(7) clustered (i-j-s)	(8) clustered (i-j-s)
Environmental Policy Stringency								
EPSgap	0,002	0.008	-	-	0.008	-	0.008	-
	0,028	0,271			0,012		0,01	
EPSgap*ED	-0.362***	-0.345***	-0.366***	-0.380***	-0.345***	-0.380***	-0.345***	-0.380***
	0,062	0,056	0,062	0,059	0,086	0,093	0,071	0,076
Exporter, importer FE	Yes	No	No	No	No	No	No	No
Country pair FE	No	Yes	No	No	Yes	No	Yes	No
Exporter-year, importer-year FE	No	No	Yes	No	No	No	No	No
Country-pair-year	No	No	No	Yes	No	Yes	No	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	No	No	Yes	No	Yes	No
Observations	32480	32480	32480	32480	32480	32480	32480	32480

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to specification 2 in Table A3.2, with different fixed effects combinations. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively. Columns 1, 2, 3 and 4 report robust standard errors, while 5, 6 and 7, 8 report clustered standard errors (by country pairs and country-pair-sector respectively).

Alternative measure of environmental policy stringency

7. The EPS proxy used in the analysis has virtues, but is nevertheless highly imperfect. Hence, further estimations were performed with an alternative proxy of environmental policy stringency – an industry energy price index developed by Sato et al. (2015). The index is constructed by weighting prices for four energy “carriers” (oil, gas, coal and electricity) on a country level for the period 1995-2009, depending on industry inputs.[24]

8. Such a proxy is very different in nature than the policy based EPS index of Botta and Koźluk (2014). Sato et al. (2015) argue that a reduction in GHG emissions requires policy makers to increase costs

24 . The energy price indexes used in this study are the VEPL (variable-weighted energy price level) at the country level version from Sato et al. (2015) available at: http://www.lse.ac.uk/GranthamInstitute/publication/international-and-sectoral-variation-in-energy-prices-1995-2011-how-does-it-relate-to-emissions-policy-stringency/.

of production through market-based instruments, thereby raising the equilibrium price of electricity. As electricity constitutes a large share of energy consumption, the authors claim that energy prices reflect increased stringency in an economically meaningful way. The energy price is a *de facto* proxy of stringency, hence is able to circumvent some of the issues related to enforcement or the fact that the EPS focuses on a selected subset of policies in place – and for example does not include fossil fuel subsidies.

9. On the downside, energy prices are evidently subject to price effects resulting from fossil fuel endowments, the structure of the energy market or the technology related to the production of mineral fuels and electricity itself. Nevertheless, using the two instruments can increase the confidence that what is captured is the effect of environmental policies indeed, not other aspects possibly picked up by the EPS – e.g. related to development. In fact, this appears to be the case - Table A3.7 shows that the estimated coefficients are not significantly different than those for the EPS specification.

Table A3.7 Estimation results using an alternative EPS proxy (electricity prices)

Estimation method: Poisson

Dependent variable:	Gross exports		Domestic VA in exports (TiVA)	
	(1)	(2)	(3)	(4)
Environmental Policy Stringency				
Difference Energy Prices	0.0326 (0.0747)	0.0192 (0.0737)	0.0741 (0.0855)	0.0764 (0.0849)
Difference Energy Prices*ED		-0.433*** (0.112)		-0.894*** (0.121)
Pseudo R squared	0.865	0.865	0.850	0.852
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes
Observations	84,040	84,040	24,500	24,500

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to Specification 1 in Table 3.1 and 3.2 respectively for imports and Domestic values added in exports. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Alternative measures of environmental dependence

10. An alternative version of the environmental dependence proxy – energy intensity, instead of pollution intensity - was also tested, but the results were also robust to this change (Table A3.8).

Table A3.8. Results using an alternative Environmental Dependence proxy (energy intensity)

Estimation method: Poisson

Dependent variable:	Gross exports		Domestic VA in exports (TiVA)	
	(1)	(2)	(3)	(4)
Environmental Policy Stringency				
EPSgap	-0.0183	-0.0221	0.00364	-0.00111
	(0.0166)	(0.0161)	(0.0284)	(0.0280)
EPSgap*Energy Intensity		-0.0544*		-0.240***
		(0.0286)		(0.0477)
Pseudo R-squared	0.85	0.85	0.841	0.842
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes
Observations	121,240	121,240	32,480	32,480

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to Specification 1 in Table 3.1 and 3.2 respectively for imports and Domestic value added in exports. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

TiVA characteristics – using distance to final demand as a proxy for environmental dependence

11. Estimations that use distance to final demand as an alternative proxy for environmental dependency of industries yield similar results (Table A3.9).

Table A3.9. Estimation results using distance to final demand

Estimation method: Poisson	
Dependent variable:	Domestic VA in exports (TiVA)
Environmental Policy Stringency	
EPSgap	0.0261
	(0.0287)
EPSgap*distGVC	-0.275***
	(0.103)
Exporter, importer, industry and year fixed effects	Yes
Pseudo R-squared	0.841
Observations	32,480

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Robust standard errors in parenthesis. *** represent significance (at 99% confidence levels).

Timing issues

12. Due to potentially lagged effects of environmental policies, as well as a potential endogeneity problem, lagged effects of environmental policies are tested. Including the first, third and fifth lag of *EPSgap*, has little effect on the estimated coefficients apart from the fact that they are actually higher and more significant (Table A3.10). Past environmental policies are less likely to be determined by current export performance of industries than contemporaneous policies, implying that the potential endogeneity of *EPSgap* is much less likely in a setting with lags.

Table A3.10 Estimation results using lagged values of EPSgap

Estimation method: Poisson

Dependent variable:	Gross exports			Domestic VA in exports (TiVA)		
	(1)	(2)	(3)	(4)	(5)	(6)
Environmental Policy Stringency						
L1. EPSgap	-0.0184			-0.00647		
	(0.0172)			(0.0302)		
L1. Difference EPS * ED	-0.167***			-0.383***		
	(0.0367)			(0.0641)		
L3. Difference EPS		-0.0216			-0.00567	
		(0.0213)			(0.0301)	
L3. Difference EPS * ED		-0.207***			-0.380***	
		(0.0380)			(0.0597)	
L5. Difference EPS			-0.0196			-0.0173
			(0.0247)			(0.0381)
L5. Difference EPS * ED			-0.224***			-0.438***
			(0.0401)			(0.0714)
Exporter, importer, industry and year fixed effects	Yes	Yes		Yes	Yes	Yes
Pseudo R squared	0.850	0.851	0.851	0.842	0.843	0.843
Observations	120,680	118,480	109,260	31,920	31,380	31,380

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to Specification 2 in Table 3.1 and 3.2 respectively for exports and domestic VA in exports. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Inclusion of importer and exporter stringency

13. The basic specification includes the difference in environmental policy stringency (*EPSgap*) rather than levels in EPS in the importer and exporter country. Nevertheless, we attempt to test the robustness of the conclusions with respect to the individual EPS measures. The results, particularly for the domestic value added in exports, are similar in terms of interpretation. They point to higher domestic EPS as the driver for increase in imports from other countries for "dirty" industries. But it is also associated with lower imports in "clean" sectors – confirming the specialisation argument. Importantly, domestic stringency also reduces exports; in particular for "dirty" industries, and increases them for "clean" ones (Table A3.11).

Table A3.11. Estimation results for individual levels of EPS

Estimation method: Poisson				
Dependent variable:	Exports	Exports	Domestic VA in exports	Domestic VA in exports
	(1)	(2)	(3)	(4)
Environmental Policy Stringency				
Exporter EPS	0.000	0.00406	-0.0663*	-0.0680*
	(0.0247)	(0.0240)	(0.0365)	(0.0363)
Exporter EPS*ED		0.147***		-0.274***
		(0.0427)		(0.0716)
Importer EPS	0.0355	0.0503**	-0.0657	-0.0632
	(0.0260)	(0.0252)	(0.0423)	(0.0420)
Importer EPS*ED		0.434***		0.452***
		(0.0438)		(0.0721)
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes
Pseudo R-squared	0.850	0.852	0.841	0.842
Observations	121,240	121,240	32,480	32,480

Notes: Robust standard errors in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Allowing for differentiated effects for high and low pollution intensity industries

14. The possibility that the effects of environmental policy stringency are different for "clean" and "dirty" sectors has also been tested (Table A3.12). The PHH would primarily imply a loss in competitiveness of highly polluting sectors in countries with more stringent policies. By imposing a common coefficient for all sectors, such effects could be underestimated, while the effects on clean industries could be overestimated or even falsely attributed. Additionally, testing such effects across different lag lengths may provide some insight on the timing of effects on different sectors, though in principle the extent to which gravity models can yield insight on timing is very limited.

15. The results show no significant difference between the effects for "clean" and "dirty" industries – confirming the comparative advantage story proposed in the paper. While the coefficient for "dirty" industries seems to increase in magnitude and strength with longer lag lengths, this could point to the fact that some effects on these industries need time to fully materialise.

Table A3.12 Estimation results allowing for differential effects for high and low pollution intensity industries

Estimation method: Poisson				
Dependent variable	Domestic VA in exports (TiVA)			
	(1)	(2)	(3)	(4)
Difference EPS (adequate lag)	-0.0178	0.00635	0.00662	0.00671
	(0.0460)	(0.0344)	(0.0291)	(0.0281)
Difference EPS *ED(low)	-0.454**			
	(0.183)			
Difference EPS *ED(high)	-0.281*			
	(0.155)			
L1.Difference EPS *ED(low)		-0.394***		
		(0.122)		
L1.Difference EPS *ED(high)		-0.371**		
		(0.157)		
L3.Difference EPS *ED(low)			-0.348***	
			(0.110)	
L3.Difference EPS *ED(high)			-0.416***	
			(0.132)	
L5.Difference EPS *ED(low)				-0.357***
				(0.125)
L5.Difference EPS *ED(high)				-0.529***
				(0.159)
Exporter, importer, industry and year fixed effects	yes	yes	yes	Yes
Pseudo R squared	0.842	0.842	0.843	0.843
Observations	32,480	31,920	31,380	31,380

Notes: Only coefficients on *EPSgap* reported. Specifications equivalent to Specification 2 in Table 3.1 and 3.2 respectively for exports and domestic VA in exports. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Effects of integration in global value chains

16. Our basic specification assumes uniform effects for countries that are highly integrated in GVCs as well as countries that have a relatively low level of integration. In principle, a high level of integration in international production fragmentation could imply higher proneness to outsourcing and hence stronger PHH effects. We test this assumption using an additional dummy based on the degree of a countries' participation in GVCs,[25] obtaining weak confirmation of these assumptions (Table A3.13). The effect

25. The degree of participation in GVCs indicates the extent to which a country is involved in a vertically fragmented production process measured as the share of foreign inputs (backward participation) and domestically-produced inputs used in third countries' exports (forward participation) of gross exports (De

appears higher for countries that are highly involved in GVCs, albeit the difference in the coefficients is not statistically significant (p-value of the chi-squared test of 0.2).

Table A3.13. Estimation results depending on degree of integration in global value chains

Estimation method: Poisson Dependent variable:	Domestic VA in exports (TiVA)
Environmental Policy Stringency	
EPSgap	0.00223 (0.0281)
EPSgap*ED*High GVCparticipation	-0.446*** (0.0808)
EPSgap*ED*Low GVCparticipation	-0.293*** (0.0890)
Exporter, importer, industry and year fixed effects	Yes
Pseudo R-squared	0.842
Observations	32,480

Note: Robust standard errors in parenthesis. *** represent significance (at 99% confidence levels).

Non-linearity of effects of EPSgap and GDP

17. The possibility of the non-linear effects of GDP and EPSgap are also tested. Omitting GDP (or including squared GDP) in the estimations does not affect the environmental policy coefficients (Table A3.14). Regarding the gap in environmental policies a quadratic term is tested. Such an approach can allow lifting the implicit symmetry assumption in the model, as well as, for the effects to change for particularly large EPS discrepancies among the trading partners. The results are mixed. There does seem to be some sign of non-linear effects (Table A3.15), but a graphical representation of the marginal effects shows that for the majority of in-sample *EPSgap* values, the effects do not change, aside from becoming less significant which could be due to multicollinearity (Figure A3.1). Only for less than 1% of the extreme values ("dirty" industries), the effect changes signs, while remaining insignificant.

Backer and Miroudot, 2013). It is constructed as a dummy taking the value 1 for countries which exhibit above average shares and 0 otherwise.

Table A3.14. Using different specifications of GDP

Estimation method: Poisson

Dependent variable:	Gross exports			Domestic VA in exports (TiVA)		
	(1)	(2)	(3)	(4)	(5)	(6)
Environmental Policy Stringency						
GDP exporter		0.607***	4.108***		0.532***	0.137
		(0.0720)	(0.491)		(0.127)	(0.777)
GDP importer		0.680***	2.508***		0.700***	-0.233
		(0.0705)	(0.595)		(0.109)	(0.817)
GDP exporter^2			-0.0655***			0.00730
			(0.00937)			(0.0150)
GDP importer^2			-0.0344***			0.0173
			(0.0111)			(0.0151)
EPS gap	-0.0216	-0.0230	-0.0230	0.00332	0.00188	0.00228
	(0.0163)	(0.0163)	(0.0163)	(0.0276)	(0.0282)	(0.0281)
EPS gap * ED	-0.140***	-0.142***	-0.141***	-0.359***	-0.362***	-0.362***
	(0.0367)	(0.0366)	(0.0366)	(0.0615)	(0.0616)	(0.0615)
Pseudo R-squared	0.849	0.850	0.851	0.840	0.842	0.842
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	121,240	121,240	121,240	32,480	32,480	32,480

Note: Robust standard errors in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Table A3.15 Estimation results using a squared EPS gap term

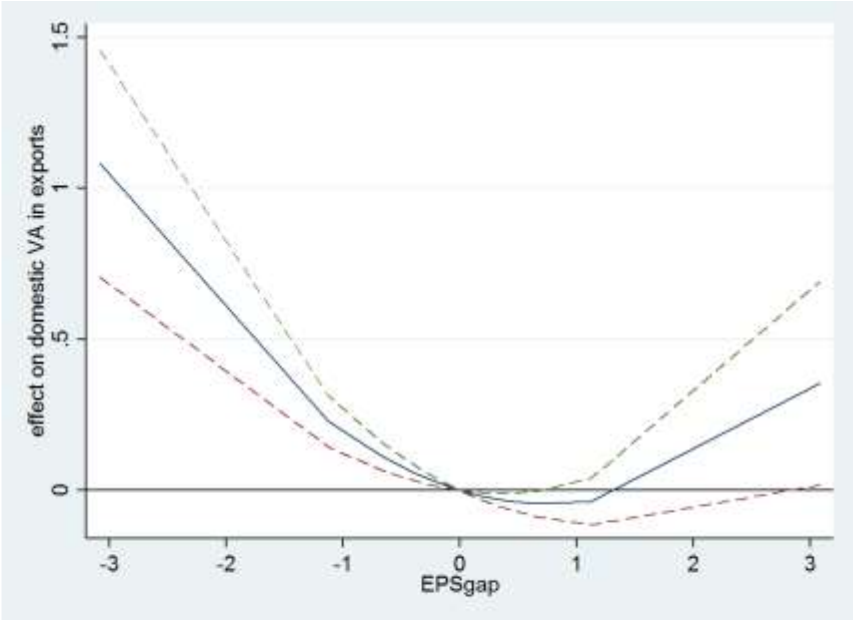
Estimation method: Poisson

Dependent variable:	Gross exports		Domestic VA in exports (TiVA)	
	(1)	(2)	(3)	(4)
Environmental Policy Stringency				
EPSgap	-0.0182	-0.0234	0.000501	0.00128
	(0.0164)	(0.0162)	(0.0283)	(0.0282)
$EPSgap^2$	0.0309***	0.0283***	0.0393***	0.0355***
	(0.00716)	(0.00688)	(0.0107)	(0.0104)
EPSgap*ED		-0.140***		-0.352***
		(0.0351)		(0.0596)
$EPSgap^2$*ED		-0.0672***		0.0848**
		(0.0260)		(0.0385)
Pseudo R-squared	0.850	0.851	0.841	0.842
Exporter, importer, industry and year fixed effects	Yes	Yes	Yes	Yes
Observations	121,240	121,240	32,480	32,480

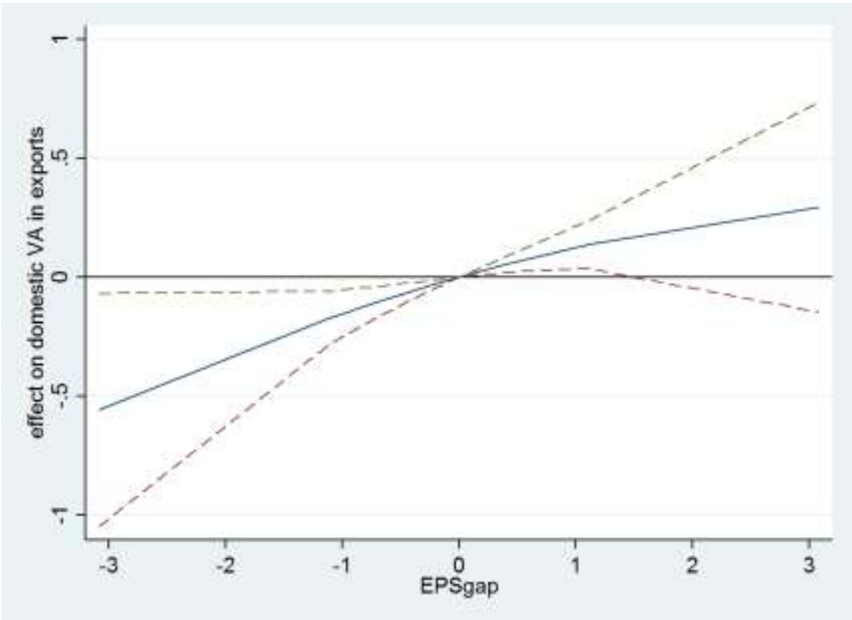
Note: Robust standard errors in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.

Figure A3.1 Marginal effect using a squared EPS gap term on domestic VA in exports

A: High pollution intensity ("Chemical, rubber, plastics and fuel products")



B: Low pollution intensity ("Manufacturing n.e.c. and recycling")



Note: 90% confidence intervals reported.