Structural Change, Trade and the Environment: An Application to WIOD Data

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Abstract: Structural change has been identified to have a significant impact on environmental issues just because of its impact on international trade patterns. The present paper provides insights into the driving forces of structural change and its close relationship to international trade. In a further step, the paper connects these economic forces with environmental issues based on recent econometric approaches in the literature. In addition to this guidelines by the literature, an econometric panel data approach using WIOD data is offered to shed some light on the impact of structural change and international trade on environmental pressure.

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Contents

I. Introduction **1**

II. Structural change and the environment **1**

A. A theory on structural change and trade 2

B. The environment and North-South trade 4

III.Trade, globalization and environmental indicators **7**

A. Introductory comments 7

B. Measuring the Pollution Haven Effect 8

C. Econometric Structural Decomposition Analysis of Pollutant Emissions 10

D. Trade and other environmental indicators 12

E. Summary 13

IV. Econometric Approach: A reference model from the literature **15**

A. Data issues 15

B. Addressing the endogeneity problems 16

C. Estimation strategy 27

D. Empirical results 30

V. Concluding remarks **37**

Appendix A: List of countries included in the regression **37**

Appendix B: Descriptive Statistics **38**

Appendix C: Alternative income estimation **38**

I. Introduction

Structural change. At times, this term has been used largely in debates regarding increasing unemployment in industrial nations because of movements of industries into low-wage countries. Therefore, structural change is often associated with negative connotations, even more in the recent debate on its impact on the environment. Whether these concerns can be justified or not will be discussed later in this paper. But to forecast the major insights from this section, structural change is, counter to conventional wisdom, necessary for industrialized countries to maintain economic growth and high wages, and furthermore, it spurs international trade which was identified to have positive influence on the environment for reasons going to be discussed in this section.

Often, it is argued by environmentalists and other opponents of free trade and globalization that structural change in connection with free trade harms the environment since these forces lead to an outsourcing of pollution-intensive industries into less developed countries with less stringent environmental protection. In the recent debate, these countries have become known as ”pollution havens”. This supposed phenomenon which is called Pollution Haven Effect or Pollution Haven Hypothesis (see Copeland and Taylor (2004)) will be investigated in section III. This is of high importance since ”The debate over the role international trade plays in determining enviromental outcomes has at times generated more heat than light” (Antweiler et al. (2001), p. 877).

The remainder of this paper is organized as follows. Section II. will provide a theoretical background on structural change and its impact on international trade patterns and vice versa. Besides, environmental issues related to this topic will be adressed. Since this paper provides an econometric analysis on structural change, trade and the environment, section III. provides an overview on common approaches to deal with these topics. A special focus in this section will be on econometric issues, especially for employing structural decomposition analysis (SDA). The SDA allows to decompose national environmental pressure indicators, like total pollutant emissions, into its consisting parts: Economic growth, change in national industry composition, especially regarding changes in industry composition due to international trade, and finally, technological change. The change in industry composition is obviously a structural change, additionally we will ask for the impact of trade on structural change. The outcomes of the own econometric approach of this paper will be presented in section IV. Section V. concludes.

II. Structural change and the environment

This paper deals with the impact of structural change and trade on the environment. Structural change is a steady progress of economic change, initiated mainly by two key factors: Technological change and international trade. Thus, the impact of structural change on the environment is strictly conneted with questions of technological change and trade. Regarding the factor of technological change, structural change is initiated by a process which Schumpeter (1934) would call ”creative destruction”. This term describes the process through which a new technology, or even a new industry arises because technological innovation displaces other older technologies and industries. Reasons for that may be that these older technologies are no longer needed or that production in other countries, for instance developing countries with low wages, is more cost efficient. Thus, technological change forces also a shift in international trade patterns. By itself, this shift in trade patterns is both a cause of structural change and also a consequence of it. Having this insight, the present paper will focus on structural change by its impact on trade and vice versa in order to shed light on the impact of these forces on the environment.

A. A theory on structural change and trade

Before presenting our empirical strategy we will give the interested reader an overview about the different facets of structural change and its consquences for an economy. We think that this is necessary for the understanding of the impliations of our results. Then we will narrow the focus on the environmental issues of trade and the ongoing process of the worldwide economic integration.

To study the impact of structural change on the environment through its impact on trade, suppose for the moment a situation where two countries are completely identical in regard to capital and labor endowments, wages, and other factors which may influence trade. Both countries can produce a set of goods. Thus, there is initially no need for trade. The only difference we will allow in the first step is that one of the countries, which we call the North, is able to innovate, and thus, to introduce new products into the market. Now assume that the North introduces a new product into the market. This leads to an absolute availability advantage of the North since the other country, the South, is not in the position to produce new goods[1]. If we assume full employment of all production factors, in favor of the new product the North has to give up the production of an older commodity, which can also be produced by the south. This situation is the begin of structural change in the North which initiates a trade relation with the South. This is because the North has an absolute availability advantage in producing the new good and the South a comparative advantage in producing the old good, since opportunity costs in the North in producing the old goods have been increased due to the possibility of being able to be the single producer of the new good and thus earn monopoly rents. After a given amount of time (imitation lag), the South becomes able to produce the new good as well so that there is no longer a need for trade. These considerations were first made by Posner (1961).

This basic model was expanded by

[1] Kravis (1956) points out that other factors than classical reasons for trade, especially the availability of goods or commodities are important factors determining the composition of international trade patterns.

Hufbauer (1966), by implementing that the South can produce the imitated good at lower costs because of having lower wages than the North which thus will give rise to further trade flows. Vernon (1966) improved the model by introducing a multi-period consideration. Furthermore, structural change becomes more obvious in his model by relying on the product life cycle. To be more precisely Vernon (1966) argues that the new product will be produced in the North as long as the product is in the introduction stage where high flexibility, high-skilled work force and proximity to supplieres, customers and competitors is needed. In later stages of the product life cycle, the production process becomes standardised and the North shifts production into the South, where average production costs are lower. The model of Vernon (1966) is formalized by Krugman (1979).

But what do all these models of product life cycle and North-South trade have to do with the environment? Let us introduce a further factor into to model, capital. Following Antweiler et al. (2001), capital intensive production is by its nature a dirty, pollution-intensive production. Thus, introducing capital into the model may allow to find some insights how structural change and international trade can influence environmental issues.

A dynamic model which allows to consider the factor capital is offered by Dollar (1986). It is a similar model to the important contribution of Krugman (1979) but takes capital flows as a consequence of structural change more directly into account than the model of Krugman (1979) who does not pay much attention to this factor.

Now suppose the North introduces new goods into the market. This leads to increasing demand for these products at the expense of some older products in both countries. In the short-run, this leads to an increase in the price of Northern new developed goods and increases the terms of trade. The very important assumption is that the model allows capital to be the only factor which is perfectly mobile between the North and the South. The increase in the terms of trade increases the return to capital in the North and forces capital to move to the North because capital is the only mobile factor.

The higher the terms of trade - that means the higher the differential between Northern and Southern prices is - the larger are the incentives for technology transfer. Following Dollar (1986), technology transfer occurs as long as the terms of trade are unequal to one. As Krugman (1979) argues the North will contiously introduce new products into the market in order to ensure high levels of wages. Thus, the terms of trade will never euqal one and the product cycle of innovation in the North and the technology transfer to the South remains to be persistent. But since this product cycle model offers no further insights of technology transfer which are interesting for environmental aspects, technology transfer will not be discussed at this point. In the long-run equilibrium of this model, structural change induced by technological change in the North leads to a higher capital-to-labor ratio in the North than in the South. Difference in production costs gives rise to technology transfer into the South, so that new (Northern) products become old products. In the model of Dollar (1986), Northern firms are supposed to relocate production after a given time into the South because of lower production costs.

In summary, the North specializes on capital intensive production and the South on labor intensive production. As said, by assuming that capital intensive production is more pollution-intensive than labor-intensive production, the more developed country, the North becomes dirtier if structural change occurs if, and only if, we take structural change separated from other factors influencing total pollution into account. As we have also seen, structural change increases wages in the North which improves the Northern welfare and increases per capita GDP. By assuming that the environmental quality is a normal good, demand for environmental protection should also increase which may cause an effect different to the effect of structural change alone. For this reason, the next subsection presents theoretical studies taking also such aspects into account. This allows us to shed light on other factors which influence pollution in the North and in the South but are nevertheless the consequence of structural change and foreign trade.

B. The environment and North-South trade

In the previous subsection, some theoretical considereations were made regarding the direct impact of structural change on pollutant emissions in a country by taking the changes of capital-to-labor ratio into account. In other words: The impact of structural change on the composition of industries was studied based on a simple model where the industry composition in the North changes in direction of more capital intensive production. But as we have also seen, structural change and trade increase the income in the Northern country. Thus, structural change and trade also induce an income effect which may have an impact on pollution in this country. For this reason, we will study the impact environmental policy on trade and structural change by taking a different view. Now we will only consider cross-country differences in environmental policy to be the only reason for trade.

In environmental economics, this impact of changes in per capita income on environmental quality is well known as the Environmental Kuznets Curve (EKC). It predicts an increase in pollution as economic activities in a country increases until the a certain peak of this inverted U-shaped functional form is achieved. For instance Grossman and Krueger (1991) identified turning points at an approximately per capita income between 4000 an 5000 U.S. Dol-

[2]Stern (2004) provides a good survey that compares the estimated turning points from different studies, see Stern (2004, p. 1425). Further surveys on the relevant literature dealing with the EKC are offered in Dasgupta et al. (2002) and most recently Carson (2010).

lars, measured in 1985 prices[2]. After having passed this peak, environmental damage is supposed to decrease. This is the case if environmental quality is a normal good. Thus, for increasing income the demand for environmental quality rises and environmental policy will force firms to use cleaner production technologies. In a nutshell, the rich North and the poorer South are expected to differ in their enforcement of environmental policy, because of differences in income.

What we are interested in at this point is whether such income induced cross-country differences in environmental policy give rise to international trade and thus forces structural change. Exactly this relationship is modeled theoretically by Copeland and Taylor (1994). In their model, environmental policy is endogenous. This means that increasing income leads to a demand for more environmental quality as the EKC predicts and if environmental is a normal good and if pollution is due to local pollutants[3].

A very simple summary of the model of Copeland and Taylor (1994) will now be presented. Suppose that the policy-makers in a country impose a tax on pollutant emissions and that the demand for this environmental policy increases as income increases. Once again, there are only two countries. The North has a high per capita income for reasons presented before. The South has a low level of per capita income. Furthermore, we assume that there is a continuum of consumption goods and that producing these goods emitts pollution. The extent towards production causes pollutant emissions varies across the continuum of goods, so that the goods can be ordered in terms of pollution intensity. There is also an abatement technology available that allows reducing pollutant emissions for the respective good at the expense of more input of other production factors which are only labor in the model of Copeland and Taylor (1994). In summary, the cost minimizing factor input combination depends on the wage and on the pollution tax, which can be seen as the price for one unit of input of pollutants.

If income in the North increases due to an increase of economic activity (economic scale), the demand for environmental protection increases and finally forces the pollution tax to increase as the EKC predicts. In other words, the input factor pollution is now more expensive than before. Cost minimizing firms will now substitute the more expensive factor pollution through the cheeper factor labor; or in brief, they will engage in pollution abatement (this is the technique effect). In a closed economy, the increased pollutant emissions due to an increase in economic activity would be offseted by an increase in pollution tax because the tax leads to abatement of pollutants. Using the language of a structural decompostion method, we arrive at the following insight: ”the scale and technique effect exactly offset each other, leaving the level of pollution unaffected by economic

[3]A similar theoretical model dealing with the same issues but for a global pollutant is offered in Copeland and Taylor (1995). We do not present the case of a global pollutant at this point. Some (empirical) problems of dealing with such a global externality are discussed in section III., subsection C.

growth. Note that there is no composition effect in autarky since tastes are homothetic" (Copeland and Taylor (1994), p. 774). Homotethic preferences mean that the increase in income leaves the relative demand for the different goods unaffected, only the absolut demand increases. By assuming that the different consumption goods are produced in their own industries this implies without any doubts that there is no composition effect because the composition of these industries remain the same. Clearly, this means that there is no structural change in autarky due to environmental policy which in turn was induced by rising income. In autarky, only changes in the demand structure or technological change can cause structural change, but not environmental policy is expected to play a minor role.

In the next step, we consider the case of an open economy. Now suppose that the North has a higher per capita income than the South and trade between the two countries is possible. Because of the higher income in the North, also the pollution tax must be higher in the North. This implies that pollution intensive production is more expensive in the North than in the South. In a situation where North and South only differs in their per capita income, trade between these countries is "driven entirely by income-induced international differences in pollution policy" (Copeland and Taylor (1994), p. 768). This is the case because pollution intensive production relocates to the South, so that trade makes the North cleaner and the South dirtier[4]. This effect is called the Pollution Haven Effect (PHE) (Copeland and Taylor (2004)).

But in contrast to the PHE, there is also another effect of international trade on the environment. To investigate this effect, we go back to the model in subsection A. where structural change occured because the North was the only country capable to innovate. As we have seen, structural change and trade forced capital to relocate into the North. And furthrmore, we assumed that capital intensive production is dirtier. If structural change forces capital to relocate to the North, international trade makes the North more dirty and the South cleaner. Obviously, the effect of trade and structural change on the environment is counter to the case where trade occured only because of cross-country differences in environmental policy which increased trade, as the PHE predicts.

Furthermore, if the North is specialized in capital intensive production for reasons discussed earlier, a reduction in trade barriers would result in more specialization since capital is abundant in the North and labor in the South. In other words, the North has a comparative advantage in capital intensive prodcution and the North in labor intensive production. So a reduction in trade barriers would make the North dirtier due to the specialization in capital inten-

[4] As we will se later in section C., trade increases economic welfare so that also the South will impose some environmental taxes which results in pollution abatement. But the net effect remains unclear at the moment since there are also more effects of trade we have to consider. Therfore, we address the overall effect of trade on the environment to the empirical estimation in section IV., subsectioneststrategy

sive production as the Heckscher-Ohlin-Model predicts. Antweiler et al. (2001) refers to this effect as the Factor Endownment Effect (FEH). In contrast to this, a reduction of trade frictions in the PHE case would make the North cleaner and the South dirtier.

As we have seen, the overall effect of trade and structural change on the environment is difficult to study. Therefore, we address these issues to the econometric sections that follows.

III. Trade, globalization and environmental indicators

A. Introductory comments

As mentioned in the introduction, this paper investigates how globalization and trade affect the environment by using environmental indicators. Even though there is a huge amount of literature on this question, the on-going debate whether free trade is good or bad for the environment still indicates further demand for economic and especially empirical research. Because "the vast majority of work in this area estimates specifications only loosely related to theory" (Levinson and Taylor (2008), p. 229) we want to discuss empirical problems based on the actual literature on trade and the environment in detail at this point.

In general, there are three major approaches for dealing with this question of interest (see Brunnermeier and Levinson (2004)). First: the effect of location choice and foreign direct investments on environmental issues[5]. Second: the impact of changes in national production output on shifts of industry composition and trade patterns which finally affect the location of pollution emissions. And third: a further approach deals with the question whether the movements of inputs are triggered by environmental policy. In this paper, the only interest will lie on the second approach, dealing with changes in national output - for instance triggered by environmental regulation - and its consequences for world trade patterns and global pollutant emissions locations[6].

A common held opinion is that tightening environmental regulations in a country results in decreasing economic activities of pollution-intensive production and increasing economic activities in countries with lax or even no environmental regulations, the so called "pollution havens". Using the terminology of Copeland and Taylor (2004), this effect is hereafter denoted as the "Pollution Haven Effect" (PHE). The assumption that tightening environmental regulations forces pollution-intensive production to relocate into countries with less stringent regulation, rather than only to decrease economic activities, needs the so called Pollution Haven Hypothesis (PHH) to be true.

[5]This strand of the literature often uses firm or plant level data. The number of observations on the plant level is typically small. Thus, other econometric approaches like a (conditional) Poisson model used in Becker and Henderson (2000) or the Propensity Score Matching Method used in List et al. (2003) are appropriate methods for dealing with plant level analyses. This is another reason why we will not discuss this strand of the literature at this point. The recent study uses country level data with a large number of observations and would make comparison to plant level studies difficult.

[6]A detailed survey of all three approaches is offered by Brunnermeier and Levinson (2004).

But in addition to these two effects with the same direction, dealing with environmental issues in a world of globalization and trade liberalization may create another effect. The direction of this effect is counter to the direction of the the PHE and PHH. This means that further trade liberalization can also result in more specialization with the effect that countries with comparative advantages in capital intensive dirty good production increase related economic activities regardless of the presence of stringent environmental regulation. Following Antweiler et al. (2001), in this context this effect is called the Factor Endowment Hypothesis (FEH). To include also this last effect requieres a little bit more complex econometric approach than an analysis on the pure PHE needs. The standard approach to investigate the overall effect of trade on the environment is using econometric structural decomposition analysis (SDA), presented in subsection C. The next subsection discovers the econometric literature dealing with the PHE effect. Both subsections will focus on econometric difficulties for the mentioned approaches. Subsection D. discusses problems arising if CO_2 or other greenhouse gases are used as environmental pressure indicators.

B. Measuring the Pollution Haven Effect

At first, we will have a look on the impact of differences in the stringency of regulation, for instance using the proxy pollutant abatement costs expenditure (PACE), on economic activity represented by trade flows. Or in other words: we ask whether cross-country differences in PACE cause the PHE.

To do so, several explanatory variables have to be regressed on imports. Levinson and Taylor (2008) use net imports, as the dependent variable. Net imports are scaled by the value of shipment of each sector because sectors may differ in size. In contrast, Grossman and Krueger (1991), and Ederington et al. (2004) use gross imports (imports scaled by the value of shipment for each industry). In the following, we use the world imports synonymously for net- or gross imports. As said, we are interested in the impact of changes in the cross-country enforcement of environmental regulation on domestic imports. A widely used proxy for the cost consequences associated with regulation is the PACE. Levinson and Taylor (2008) use PACE for each sector scaled again with the sector's value added. But as they mention, this proxy suffers from problems of unobserved heterogeneity in a case when variation in PACE across sectors is not due to differences in regulatory stringency. A second problem mentioned by Levinson and Taylor (2008) is that environmental regulation in the foreign country is not included in the model. Finally, in their model, using 3-digit level PACE data can cause an aggregation bias if PACE are heterogeneous on the 4-digit

[7] Such a problem does not exist in the analysis of Tang (2010) because he uses commodity-level data to proxy regulation stringency in an analysis on trade in toxic chemicals. As a measure for regulatory stringency he uses the Toxic Release Inventory (TRI) status of the U.S. Environmental Protection Agency for the chemicals of interest in two periods (1992 and 2008). In order to quantify the impact of changes in the TRI listing between 1992 and 2008 on net imports of toxic chemicals, he uses differences-in-differences estimation.

level[7]. Levinson and Taylor (2008) cope with these three problems by using instruments[8].

Furthermore, Ederington and Minier (2003) call into question that environmental policy can not be regarded to be strictly exogenous. Similar concerns were raised by Grossman and Krueger (1993) but without taking them into account in their econometric model. Ederington and Minier (2003) found that environmental policy could be seen as a secondary trade barrier. To be more precisely, the authors "[] predict that the stringency of environmental regulation will be decreasing in net imports." (Ederington and Minier (2003),p. 142). This means that policymakers tend to lower environmental regulation if net imports rise in order to protect domestic competitiveness. Therefore, Ederington and Minier (2003) use instruments to address the endogeneity of PACE, for instance unemployment rate, the percentage of union membership or the concentration ratio[9]. By using OLS estimation, they found domestic environmental regulation to have a significantly positive impact on net imports, which supports the evidence of a pollution haven effect. Testing for endogenous environmental regulation using 3SLS and instruments provides also significant evidence that regulation is dependent on net imports (see Ederington and Minier (2003)).

In addition to PACE, the main variable of interest, tariffs are used as a control variable in Levinson and Taylor (2008), Ederington et al. (2004), and Ederington et al. (2005). In the study of Ederington et al. (2004), more attention has been paid to tariffs. They divide the pollution haven effect into a direct and an indirect effect. The direct effect is the pollution haven effect itself, which means the impact of environmental regulation on net imports. However, the indirect effect is whether the pollution haven effect is sensitive to changes in

[8]The instruments in Levinson and Taylor (2008) create independent variation in PACE relying on characteristics which vary by regions rather than by sectors. These regional characteristics have to be transformed into an instrument which varies over time and sector. As such a regional characteristic, the authors use a measure of 14 pollutants emitted in each state by all sectors within the state as a first instrument. A second instrument uses state incomes per capita as regional characteristic. The first instrument reflects the pollution demand, the second focuses on the supply. But Levinson and Taylor (2008) argue that these instruments might not be strictly exogenous with respect to trade. For instance, trade agreements or falling transport costs are mentioned by them as factors leading to location choices by firms close to the common borders. If the 2SLS estimator is used in a case for more than one instrument, relying on first stage F statistics can offer good evidence whether an instrument is weak or not. This is just because "[] in applications of two-stage least squares (TSLS), it is common for the first stage F statistic, which tests the hypothesis that the instrument do not enter the first stage regression, to take on a value less than 10." (Staiger and Stock (1997), p.557). Thus, values of the F statistic exceeding 10 indicate evidence that the instruments are not weak. Following Stock et al. (2002), this rule of thumb is not independent of the number of instruments. The value of the F statistic must be the larger the more instruments are used, for more details, see Stock et al. (2002, p. 522). If only one instrument is employed, the t statistics can be used in a similar way than first stage F statistics (see Wooldridge (2002)).

[9]Treffler (1993) demonstrated that private interests or business variables like concentration, capital stock or scale of firms have a more important impact on trade policy than organized labor has.

[10]Let M be the net imports of a country and P a measure for regulation, say the PACE. Then, the direct effect - or pollution haven effect - would be $\frac{\partial M}{\partial P}$. The indirect effect would be $\frac{\partial^2 M}{\partial P \partial T}$

tariffs[10]. In the estimation equation, this effect is captured by using an interaction term of PACE and trade restrictions (tariffs). The interaction term uses average PACE over time for all sectors multiplied with tariffs for sectors and time. Consequently, the authors ask whether "[] tariff changes have a large effect on imports for industries whose average pollution abatement costs are larger." (Ederington et al. (2004), p. 9). Please note that using this interaction term should not be mistaken for a possibility of coping with the endogeneity of regulation (PACE) as discussed before.

Since almost all econometric studies on the pollution haven effect use panel data methods, only these methods have been discussed in this subsection. Kellenberg (2009) argues that his study is the only one which found evidence for a pollution haven effect using a cross-sectional analysis.

C. Econometric Structural Decomposition Analysis of Pollutant Emissions

In the previous subsection, approaches were presented, in which cross-country differences in the stringency of environmental regulation affects domestic imports. Thus, we asked whether increasing enforcement of regulation and trade liberalization shifts production in pollution intensive sectors into foreign countries. However, in this subsection, a slightly different question is of interest. We are now interested in the overall effect of further trade on environmental pressure. Thus, we have to take all impacts of trade on a country's economy into account which are relevant for changes in pollutant emissions. A good tool to reach this aim is the Structural Decomposition Analysis (SDA).

This approach decomposes the change in total pollutant emissions into three parts: The change in overall economic activity or the size of the whole economy, which we call the "scale effect". Second: within economy shifts in the relative share of the country's industries, which we will denote as the "composition effect". And finally we will ask whether a change in production technologies has an impact on total pollution. Hereafter, this effect is defined as the "technique effect". Since a major interest lies in the impact of trade liberalization on pollution migration, it is useful to employ a further effect, the so called "trade induced composition effect".

The (normal) composition effect describes the environmental consequences of a change in a country's industry composition holding scale and production technology constant. Antweiler et al. (2001) measure the composition effect using capital-to-labor ratios. The scale effect describes the environmental consequences of an increase in economic activity holding industry composition and production technology fixed. It is measured using GDP as an indicator of overall economic activity. Similar to the scale

[11]Cole and Elliott (2003) measure the technique effect by using GDP per capita. They notice that in this case, the measures of technique and scale effect are the same. Consequently, scale and technique effect cannot be separated. Antweiler et al. (2001) use one period lagged three-year moving average GNP per capita as a proxy for the technique effect. GNP is chosen because it measures the whole income of a country's citizens, regardless where it was generated, whereas GDP measures only the economic activity

effect, the technique effect can be measured using GNP (or per capita GNP) since GNP is a proxy for income[11]. It is proxied by per capita income and squared per capita income because of relying on the Environmental Kuznets Curve (EKC). At a certain threshold of income, environmental regulation will be enforced to force changes in production technologies in order to mitigate environmental damage. In general, the technique effect describes the environmental consequences of a change in production technology holding scale and composition effect fixed. Please note that the technique effect can be proxied by per capita income and squared per capita income only in a case of pollutants with strong local environmental damage, like for instance SO_2 as an environmental pressure indicator.

Why is SO_2 the most favored choice? A good indicator (or pollutant) should be a by-product of goods production and should be subject to regulation. Furthermore this by-product should vary across industries, have strong local effects and there should be well known abatement technologies for this special pollutant. "An almost perfect choice for this study is sulfur dioxide" (Antweiler et al. (2001), p. 889). Cole and Elliott (2003, p. 370) argue that NO_x and BOD (biochemical oxygen demand) also meet these requirements. CO_2 was formerly no subject to regulation and also does neihter have strong local nor transboundary effects (Cole and Elliott (2003), p. 370). Therefore CO_2 may not be a good choice for testing the pollution haven effect or hypothesis when very old observations are used[12]. Another argument for the use of SO_2 mentioned by Antweiler et al. (2001, p. 889) is that this gas is emitted in energy-intensive industries, which are also capital-intensive. Finally, using the measure of the technique effect described before for approaches on CO_2 causes some difficulties discussed in subsection D.

The base of the econometric point of view in this subsection will be the pioneering work of Antweiler et al. (2001), where we will discuss some extensions made by recent literature, especially with respect to econometric challenges. Econometrically challenging are especially the trade induced composition effect and the technique effect. First, we will have a look on the trade induced composition effect. In the previous subsection we discussed the use of instrument variables in order to solve endogeneity problems of environmental regulation. Thus we shed light on the impact of environmental policy on trade flows, measured with (net or gross) imports.

In this part, trade flows are not our dependent variable but a regressor. In the paper of Antweiler et al. (2001), the impact of trade on the environment is implemented using interaction terms of trade openness (Exports plus Imports divided by GDP) and country characteris-

or the income generated within the country. "This cross-country variation will be useful in separating scale from technique" (Antweiler et al. (2001), p. 890).

[12]Cole and Elliott (2003, p. 374) argue that the lack of regulation of CO_2 emissions in former times has accounted for their finding of only weak support for an effect of environmental regulation on CO_2 emissions.

tics that influence changes in total pollution through their impact on trade. These country characteristics are relative factor endowments and relative income. Relative factor endowments measured using relative capital-to-labor ratios are applied because an increase in trade openness is expected to shift production in direction of the relative abundant factor. In other words, capital abundant or dirty countries are expected to become even dirtier if trade openness increases, like the Heckscher-Ohlin-Model suggests. As already mentioned, this effect is called the factor endowment hypothesis.

In addition to relative factor endowments, trade openness also directly interacts with relative income (and relative squared income as a measure of the EKC). This interactive term accounts for the influence of trade on the environment only through its influence on income. In other words: Trade increases income and because higher income is associated with more stringent regulation (technique effect), trade also affects the environment via its influence on income. The two effects of an increase in trade openness on the environment are diametrically opposed. In addition to these two effects, an increase in trade openness may affect the environment also via its impact on income caused by an increase in capital accumulation. Antweiler et al. (2001) implement this effect by interacting trade openness with the relative capital-to-labor-ratio and relative income. In summary, the overall effect of an increase in trade openess on the environment depends on the country characteristics (capital abundance and income level). This approach of interacting trade openess with relative capital-to-labor ratio and relative income is adopted by many other authors, for instance Cole and Elliott (2003), Cole (2006), and most recently Managi et al. (2009). But in order to anticipate the main findings in this subsection, trade openness is not strictly exogenous. Therefore, we have to introduce further instruments to address this endogeneity problem.

A first approach on this problem was done by Frankel and Rose (2005). They used instruments borrowed from gravity models, like for instance geographic distance and land area. But the endogeneity problem does not only arise with regard to trade flows but also in view of income as it is affected by trade flows and also by the stringency of environmental regulation. Frankel and Rose (2005) therefore use further instruments like for instance lagged income, population size, or human capital formation to address the endogeneity of income.

D. Trade and other environmental indicators

In the previous section we only took local pollutants like for instance SO_2 into account. Why not greenhouse gas (GHG) emissions like CO_2? If we want to employ the methods described above we are confronted with one important problem. GHG emissions, especially CO_2, are a purely global externality. Thus, it is unlikely that a country will enforce GHG emission regulation without international cooperation. This may be a reason why Frankel and Rose (2005) find no significant impact of trade openess on CO_2 emissions. Furthermore, the analysis of Frankel and Rose (2005) finds no evidence for an environmental Kuznets Curve relationship for CO_2. The simple consequence of this finding is that the EKC relationship measure using income and squared income cannot be used as a proxy for the technique effect in an approach focusing on CO_2 emissions.

Nevertheless, Managi et al. (2009) use a structural decomposition approach based on Antweiler et al. (2001), where scale- and technique effect are measured using income and squared income. Consequently, the technique effect cannot be separated from scale effect. As mentioned, the use of CO_2 is problematic because the EKC relationship is no longer a good proxy for the technique effect. Managi et al. (2009, p. 348) introduce a dummy for the Kyoto protocol (and some more protocol dummies) as "additional technique effects". Furthermore they employ a lagged term of the dependent variable to control for dynamic effects. Such dynamic effects are also addressed by the authors using differenced GMM estimation.

Using econometric panal data methods, it is also possible to employ indicators different from SO_2 or other gases for dealing with trade and the environment. For instance, Cole (2006) asked for the impact of international trade liberalization on national energy use. He uses total energy use of a country in the years 1975-1995. Furthermore he provides results for energy use per capita and energy intensity. For this analysis, he employs the empirical model developed by Antweiler et al. (2001), which will be discussed at a later point in detail. As we will see later, in the analysis of the impact of trade and globalization on environmental issues it is common to focus on pressure indicators, like SO_2 concentrations, emissions, or other local pollutant emissions. Frankel and Rose (2005) provide estimation results for the impact of trade openess on NO_2, SO_2, and suspended particulate matter (PM) pollutant concentrations as well as for four other environmental indicators. The additional indicators are: CO_2 emissions, deforestration, energy depletion, and rural clean water access.

E. Summary

As it is obvious, all these authors who analyzed the impact of structural change and globalization on environmental pressure or state indicators only used very simple consumption based indicators. More sophisticated and consumption based indicators are hard or even impossible to decompose in their consisting parts. For pointing out the impact of globalization on environmental problems, we need to know whether structural shifts in a country's composition of different industries causes "outsourcing" of pollutant emissions. Consequently, we need detailed information on the causes of the change of each economy's pollution emissions. For this reason, a general (or rough) indicator is needed, which can be decomposed into its influence variables (or influence indicators) using structural decomposition analysis within a panel econometric framework. That's why we want to use only emissions of some special pollutants in our analysis, like for instance SO_2, NO_x, and furthermore as environmental indicators or dependent variables.

In general, most of the cited studies find that international trade has a positive influence on environmental issues. This is in contrast to the conventional wisdom that trade spurs structural change and shifts pollution into less developed countries with less stringent environmental standards. Levinson and Taylor (2008) find no evidence for the PHE to be true. Rather, they find that the opposite is the case. For the example of the United States, they provide evidence that the U.S. imports relatively pollution-intensive goods from other rich and high-developled countries and relatively clean goods from less-developed countries which have a comparative advantage in labor-intensive and consequently clean production. This means that the FEH seems to be more relevant than the PHE. Studies like Ederington et al. (2004) also find no evidence that increasing regulatory stringency measured by increase in PACE leads to a shift of dirty goods production into other countries. Levinson and Taylor (2008) still find evidence for a PHE, as well[13]. To be more precise, they find that an increase in U.S. PACE leads to an increase in net imports from both developed and less developed countries. But the question wether the overall effect of trade and globalization is good or bad for the environment remains unobserved in this strand of literature. Such a question is answered by the literature strand using SDA approaches to investigate in the overall effect of trade, globalization and structural change on the environment, like Antweiler et al. (2001) have done.

For instance, Antweiler et al. (2001) found that the scale effect is positive significant which means that an increase in GDP increases pollution. An 1 per cent increase in scale forces pollution to increase by around 0.3 per cent. Similar results were found for the case of the composition effect. Here, a 1 per cent increase in the capital-to-labor ratio causes nearly an 1 per cent increase in pollution (see Antweiler et al. (2001), p. 893f). Furthermore, Antweiler et al. (2001, p. 895) argue that the positive scale effect and the positive composition effect are dominated by the negative technique effect and the negative trade effect. More precisely, a 1 per cent increase in lagged per capita income and capital-to-labor ratio times the income (which in sum represents the technique elasticity) decreases pollution by around 1,6 per cent. Furthermore, an 1 per cent increase in trade intensity decreases pollution by around 0.39 per cent (Antweiler et al. (2001), p. 893). In summary, the analysis of Antweiler et al. (2001) provided robust empirical evidence that free trade is good for the environment.

[13] Henderson (1996), Becker and Henderson (2000), and List et al. (2003) found evidence for pollution havens within the U.S. between different counties with differences in the stringency of environmental regulation. However, they do not deal with international trade und the question whether increasing trade openess has some influence on the PHE like it is done in the standard literature on the PHE.

IV. Econometric Approach: A reference model from the literature

After having discussed econometric approaches to deal with structural change and international trade in the previous section, this section implements these approaches using the WIOD data. As said, our primary interest lies in the impact of structural change on the environment, or to be more precisely, the impact of structural change on trade issues affecting the environment. For this aim, this paper adopts following key approaches by Antweiler et al. (2001) and Cole and Elliott (2003) to the whole country sample of the WIOD data.

A. Data issues

Without any doubts, structural change is only relevant for environmental issues if it is associated with a change in industry compostion and if industries differ in emission intensities. By assuming that the more capital-intensive an industry is the more pollution-intensive its production process is, structural change's impact on the environment can be measured using the capital-to-labor ratio of the whole economy. Thus, if structural change exists but does not alter the capital-to-labor ratio (for instance because of a shift from one service sector to another) there is no effect on the environment. Therefore, the capital-to-labor ratio is a good indicator to proxy the impact of structural change on the environment. Since the WIOD data only offer data on the capital compensation rather than data on the capital stock, we use the capital-to-labor ratio provided by the Extended Penn World Tables 3.0 (EPWT 3.0). Please note that the EPWT 3.0 only cover the years until 2003 so that the the time series used for the model is reduced from 12 to 9 periods. In general, the database used to run the regressions in this section covers 19 countries, listed in the appendix A. Taking also the remaining 9 time periods into account, we are left with 171 observations.

To investigate the impact of structural change on the environment, the model presented in this paper uses environmental data from the WIOD Air Emission Files as dependend variables. However, we restrict the analysis to SO_2 for reasons already discussed in the previous section. In section C., we presented the structural decomposition method with which environmental pressure is decomposed into scale, composition, and technique effect. This is important to isolate the impact of structural change from the other forces relevant for changes in total emissions of pollutants. But the composition effect is associated with changes in international trade patterns. Therefore, we use bilateral WIOD trade data to control for the impact of international trade. To forecast some major findings of this section, trade is endogenous. For this reason several instruments have to be constructed using data from the Penn World Tables 6.3 (PWT 6.3) and the EPWT 3.0. Other instrumental variables like the common border dummy are constructed using the CIA World Factbook. But this is not the only problem of endogeneity as the measure for income is endogenous, too.

B. Addressing the endogeneity problems

For these reasons, it seems to be necessary to construct instruments for both trade openess and also income before running an econometric structural decomposition analysis. This subsection provides information of how instruments for the later approach are calculated.

The endogeneity of trade The trade openess regressors in our model may cause a serious problem as they are not exogenous as Frankel and Rose (2005) firstly notice. Countries which typically have high pollutant emissions are industrialized countries. Clearly, those countries play the most important role in international trade. Treating trade flows as exogenous would mean that these countries emit more pollutants just because they engage more in international trade than others. But it would be more realistic to argue that those countries which engage more in international trade emit more pollutants for other reasons than trade. Put it otherwise: Trade is endogenous. Endogeneity means that the regressor (trade openess in this case) is correlated with the error term [14]. To solve this problem an instrument for trade openess has to be used. An good instrument should be highly correlated with trade openess but uncorrelated with the error term, which also means that it must be uncorrelated with pollutant emissions.

Frankel and Romer (1999) suggest to use instrument variables borrowed from gravity models of international trade. Such instruments are for instance geographical distance and common boarders. Clearly, geographic distance is highly correlated with trade flows but uncorrelated with pollutant emissions. In an analysis that is similar to the one in this paper, Frankel and Rose (2005) use geographic distance between trade partners, land area, population, a common language dummy, a common land border dummy, and finally, a dummy for a countries land locked status as instruments for trade endogeneity. Land area as well as population size have strong impact on a country's foreign trade. This is because "residents of larger countries tend to engage in more trade with their fellow citizens simply because there

[14] Following Kennedy (2008) econometric analysis, endogeneity may arise due to the following problems: First, endogeneity is caused by measurement errors in explanatory variables. A measurement error in determining the explanatory variable does not only affect the values of the regressor but also the values of the error term. Consequently, regressor and error term are not independent. A second reason for endogeneity is autoregression with autocorrelated errors. If a lagged value of the dependent variable appears as a regressor, an endogeneity problem can arise if the errors are autocorrelated. The reason for this is that the lagged value of the dependent variable depends on the error term of the corresponding period. If now the comtemporaneous error term hinges on the former error terms, it is in this way correlated with the lagged value of the depend variable. Such a problem is often adressed by employing a differenced-GMM estimator (the Arellano and Bond (1991) approach). A further reason for endogeneity is simultaneity. Endogeneity occurs as well if there is a reverse causation between a dependent and an independent variable. Fourth, there may be a problem due to omitted explanatory variables. When an important explanatory variable is omitted in the estimation equation, its influence is contained in the error term. If this omitted variable is in addition correlated with any of the included explanatory variables, they will be correlated with the error term. This is the reason why trade openness is endogenous in the present paper. A last reason for endogeneity is sample selection. A difficulty that is similar to the omitted variable problem is that the chosen sample can be influenced by some unmeasured characteristics. The regressors are consequently not independent from the error term.

are more fellow citizens to trade with" Frankel and Romer (1999, p. 380). For trade openess this implies that larger countries in terms of land area and population size have higher within country trade flows and a smaller trade openess (foreign trade) compared to smaller countries.

Using instruments to adress the problem of endogeneity of trade openess allows us to isolate the effect of trade on the environment by trade's impact on income, industry composition (structural change) and industry composition due to changes in income. These effects are modelled by using interaction terms as described before.

Please note that the instruments borrowed from the gravity model need to calculate a model of bilateral trade flows for the first stage regression. Clearly, this is because distance, common border, and common language between two countries need a bilateral model. Thus, the measure of trade openess for country i to country j becomes:

$$Openess_{ijt} = \frac{X_{ijt} + M_{ijt}}{GO_{it}}; \qquad i \neq j \qquad (1)$$

We introduce the variables mentioned before into the model by running a two-step procedure. The first stage regression is (Model 6):

$$\begin{aligned} \ln Openess_{ijt} \;=\; & \gamma_0 + \gamma_1 \ln Distance_{ijt} \\ & + \gamma_2 \ln ActPop_{it} \\ & + \gamma_3 \ln ActPop_{jt} \\ & + \gamma_4 \ln(Area_{it} x Area_{jt}) \\ & + \gamma_5 (LL_{it} + LL_{jt}) \\ & + \gamma_6 CB_{ijt} \\ & + \gamma_7 CC_{ijt} \\ & + \gamma_8 CB_{ijt}(LL_{it} + LL_{jt}) \\ & + \varepsilon_{ijt} \qquad (2) \end{aligned}$$

The regressor D_{ijt} represents the geographic distance between the capitals of the two trade partners i and j. $ActPop_{it}$ and $ActPop_{jt}$ measure the economically active population of country i and j, respectively. In addition to this, $(Area_{it} x Area_{jt})$ is the product of the land area of the two countries, whereas LL_{it} and LL_{jt} are dummies measuring whether the countries are land locked. $(LL_{it} + LL_{jt}$ is the common landlocked dummy. This means that the dummies representing the countries' land locked status are summed up. The variable CB_{ijt} represents a dummy taking the value of one if trade partners share a common border.

In addition to the model of Frankel and Romer (1999) we include also a dummy for commom currency between country i and j which is defined as CC_{ijt}. It takes the value one if both trade partners share a common currency, and zero otherwise. This regressor is expected to be of considerable importance because "currency union seems to have a large effect in creating trade" Frankel and Rose (2002, p. 444). To be more precise, they find that being member in a currency union triples trade relations with other members. Frankel and Rose (2002) also find that this effect does not come at the expense of trade relations with nonmember countries.

The estimation results of constructed trade openess appear in table 1. The reference model of Frankel and Romer (1999) is labeled as model 3. Model 4 is similar to model 3 but includes the common currency dummy (CC) as an additional regressor. The first estimated model (model 1) is the instrument for trade openess which is used in Managi et al. (2009). This model is augmented by the common currency dummy (CC) and hereafter labeled as model 2. The model 5 is similar to model 2 but includes also interaction terms of the common border dummy and all other regressors used in model 2.

Finally, model 6 is a mixture of the model of Managi et al. (2009) and Frankel and Romer (1999). It includes the populations in both countries like the model of Frankel and Romer (1999) but in contrast to this model, it includes the geographic areas not for both countries but as the product of their sizes as in Managi et al. (2009). Furthermore, model 6 abandons the use of the many interaction variables of Frankel and Romer (1999). This is expected to be useful in order not to lose to much degrees of freedom since the database only covers 19 countries and 9 periods. Our estimation results are presented in table 1 below.

Table 1: Estimation results of intruments for trade openess

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
log_Distance	-0.847***	-0.819***	-0.829***	-0.804***	-0.811***	-0.804***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
log_ActPop_j	0.865***	0.872***	0.787***	0.798***	0.881***	0.798***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
log_A_x_A	-0.035***	-0.027**			-0.027**	0.040***
	(0.01)	(0.01)			(0.01)	(0.01)
LL_i + LL_j	-0.249***	-0.217***	-0.440***	-0.408***	-0.269***	-0.418***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
CB	0.489***	0.447***	2.642**	3.986***	3.053**	0.446***
	(0.06)	(0.06)	(0.94)	(0.98)	(1.15)	(0.05)
CC		0.274***		0.226***	0.320***	0.216***
		(0.03)		(0.03)	(0.03)	(0.03)
log_ActPop_i			-0.263***	-0.251***		-0.271***
			(0.02)	(0.02)		(0.01)
log_Area_i			0.020	0.023		
			(0.02)	(0.02)		
log_Area_j			0.049***	0.052***		
			(0.01)	(0.01)		
CB_Dist			0.968***	0.668**	-0.547***	
			(0.21)	(0.21)	(0.15)	
CB_Pop_i			-0.446***	-0.455***		
			(0.07)	(0.07)		
CB_Area_i			0.090	0.120		
			(0.08)	(0.08)		
CB_Pop_j			-0.087	-0.099	-0.073	
			(0.07)	(0.08)	(0.05)	
CB_Area_j			-0.354***	-0.324***		
			(0.06)	(0.06)		
CB_LL			0.429***	0.340***	0.216*	0.445***
			(0.09)	(0.09)	(0.11)	(0.09)
CB_A_x_A					0.059	
					(0.06)	
constant	-5.910***	-6.472***	-4.579***	-5.130***	-6.615***	-5.007***
	(0.21)	(0.23)	(0.22)	(0.24)	(0.23)	(0.23)
Observations	3078	3078	3078	3078	3078	3078
R squared	0.688	0.693	0.728	0.731	0.696	0.728
Adjusted R squared	0.688	0.693	0.727	0.730	0.695	0.728
Root MSE	0.857	0.850	0.801	0.797	0.846	0.800

* p¡0.05, ** p¡0.01, *** p¡0.001

First of all, most of the estimated coefficients in the different models have the expected signs. Most important, the distance between the trade partners appears to have a strong negative impact as the gravity model predicts. Furthermore, population size of the partner country ($ActPop_j$) is also in line with the prediction of the gravity model. The larger the size of population of the partner country is, the larger trade flows between the two trade partners. This is reasonable because there are more people in the partner country to trade with. The coefficients of a country's own population size in the models 3 and 4 have the expected negative sign. As mentioned before, the reason for this finding is that a larger population size leads to more within country trade, see Frankel and Romer (1999). Being landlocked also appears to be bad for a country's trade openess as it was expected. In the models 2, 4, and 5, the common currency dummy also performs well which means that a common currency has a positive effect on bilateral trade flows for countries in a currency union. Finally, countries sharing a common border (CB) are those ones with higher bilateral trade flows as the respective coefficients indicate.

In the models 3 and 4, the coefficients of the area variables of both trade partners are of counter direction than it was expected on the base of the model of Frankel and Romer (1999). Both coefficients are expected to be negative since countries with larger geographic size are expected to engage more in within and less in foreign trade. A reason for this outcome could be the very small sample size of 19 countries and 9 periods.

Finally, in the models 3 and 4, the coefficents of the interaction terms of the common border dummy and all other regressors are of the expected sign except of the coefficient of common border and land area of country i. We think that model 4, which is the Model of Frankel and Romer (1999) augmented by the common currency dummy (suggested by Frankel and Rose (2002) for reasons mentioned before) fits the data well and also model 6. For the instrument of trade openess, model 6 is chosen. One reason is that this model has nearly the same model fit than model 4 by using less variables. But the more important reason is that after having calculated the variance inflation factor[15] of model 4, the interaction terms performed very bad. The VIF value was for some of the interaction terms of more than 400. Using model 4 as instrument for trade openess in the second stage will cause serious problems because of the large variance of the estimators/coefficients. The VIFs for all coefficients in model 6 are close to one, indicating no problem of multicollinearity. For this reason, we chose model 6 as the instrument for trade openess for any further analysis.

After having estimated the (first stage) regressions in table 1 to construct a reliable instrument for trade openess, the fitted values have to be aggregated across all bilateral trade partners. This is because the second stage regression of the reference model (see equation 10) uses only trade openess for every country but no bilateral trade flows. The aggregation yields trade openess for a respective country. The aggregation method used here is borrowed from Frankel and Romer (1999) and is presented in equation 3 below:

$$\hat{Openess}_{it} = \sum_{i \neq j} e^{\hat{\gamma}' \boldsymbol{X}_{ijt}} \quad (3)$$

[15]The variance inflation factor (VIF) is a statistic for individual coefficients and calculated as $VIF_j = 1/(1-R_j^2)$. It is a useful tool to identify multicollinearity. Following Wooldridge (2009, p. 99), "VIF$_j$ is the factor by which Var($\hat{\beta}_j$) is higher because x_j is not uncorrelated with all the explanatory variables." Thus, having a very high VIF_j for the regressors j indicated multicollinearity of these regressors with other regressors which mighty be a serious problem.

The vector γ represents the coefficients in equation 2 whereas the vector $\boldsymbol{X}_{ijt}$ stands for the right-hand side variables in equation 2.

From the first stage regression, fitted values where used to predict trade openess. Table 2 plots these predicted values of trade openess from the estimations presented in table 1 against the true values of openess.

Table 2: Estimation results for actual trade openess vs. predicted openess

Openess (actual and aggregated)	(1)	(2)	(3)	(4)	(5)	(6)
Predicted agg. openess (Model 1)	.8980213					
Predicted agg. openess (Model 2)		.8833753				
Predicted agg. openess (Model 3)			.9637727			
Predicted agg. openess (Model 4)				.9676857		
Predicted agg. openess (Model 5)					1.011091	
Predicted agg. openess (Model 6)						.9955922
constant	.0662908	.0686355	.0479355	.0474026	.049046	.0442622
Observations	171	171	171	171	171	171
R squared	.2175351	.20762	.4225824	.4157018	.2507973	.3788665
Adjusted R squared	.2129052	.2029314	.4191657	.4122444	.2463642	.3751911
Root MSE	.1281827	.1289923	.1101139	.110768	.1254286	.1142062

Obviously, the resulting coefficients are close to one. Especially for model 6 this is the case. The coefficient of 0.99 indicates the good quality of the instrument. This means that an increase in the actual (and aggregated) trade openess of one percent is associated with an almost one percent increase in the predicted trade openess using our instruments. Thus, the correlation of the actual and the constructed trade share is very high (almost 0.8). As we think that model 6 fits the data best, the predicted values of the trade openess from this model are used to instrument trade openess in the further analysis. Figure 1 presents the plot of actual vs. constructed trade shares for model 6.

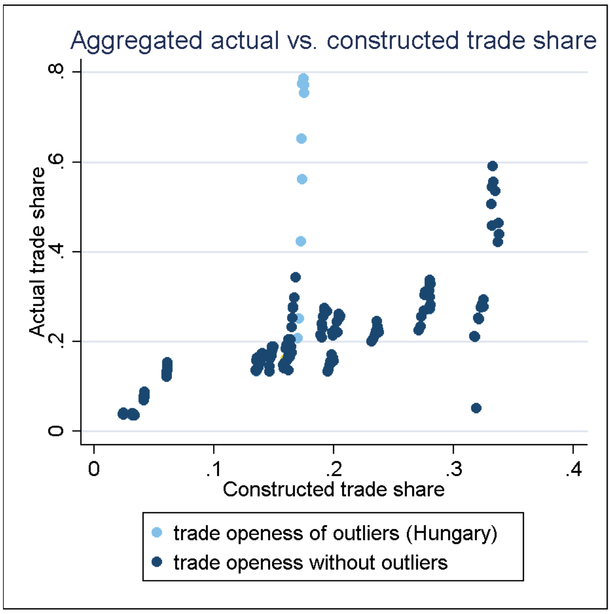

Figure 1: Actual vs. constructed trade openess

The endogeneity of income In addition to the endogeneity problem of trade openess, income is endogenous as well. Similar to the problem of trade openess, countries which typically emit large quantities of pollutants are industrialized nations. Without any doubts, highly industrialized nations are those with the highest per capita income. Once again, treating income as exogenous would mean that rich countries emit more pollutants just because they are rich. Needless to say that this relation neglects the fact that rich countries typically are capital abundant and use more pollution intensive production techniques. In order to cope with this further endogeneity problem we have to introduce instruments for income like Frankel and Rose (2005) have done. The instruments they use are: lagged income, population size, investment rates, and human capital formation. By doing so, the authors rely on instruments from the growth literature, or more precisely, from the Conditional Convergence Hypothesis.

The Conditional Convergence Hypothesis can be seen as an extention of the standard model of the growth theory, the model of Solow (1956). Mankiw et al. (1992, p. 422) explain very succinctly what the hypothesis is: "[...] the Solow model does not predict convergence; it predicts only that income per capita in a given country converges to that country's steady-state value. In other words, the Solow model predicts convergence only after controlling for the determinants of the steady state, a phenomenon that might be called 'conditional convergence'". What we will do in this section is to construct an instrument for income in order to deal with the endogeneity of income in the second stage, the estimation of the reference model of Antweiler et al. (2001). To do so, we closely rely on growth literature, or more precisely, on the Conditional Convergence Hypothesis.

Normal convergence means that the income at the end of a given period t depends on the income at the begining of the periods which, of course, corresponds to the income at the end of the period before $(t-1)$. Following the Solow growth model, income converges against a certain long-run steady state. To go back to the Conditional Convergence Hypothesis, this "[...] Convergence is conditional if it is present only after conditioning on variables such as factor accumulation" (Frankel and Rose (2002), p. 446). Thus, taking the natural logarithm , the estimation equation for the instrument of income becomes:

$$\ln\left(\frac{GDP}{Pop}\right)_{it} = \alpha\left(\frac{GDP}{Pop}\right)_{it-1} + \boldsymbol{\beta}'\boldsymbol{C} \quad (4)$$

$\boldsymbol{C}$ covers all influences forcing income to grow from the level in $t-1$ to its level in t we want to condition for. Such influence factors are for instance factor accumulation as modeled in the Solow Model. By modelling these conditions, we follow Mankiw et al. (1992) and Frankel and Rose (2002). We also follow them by taking accumulation of two factors into account: physical capital K and human capital H. The relevant literature (Mankiw et al. (1992), Frankel and Rose (2002), and many others) proxies human capital with the fraction of the population enrolled in secondary school. In the present approach, human capital is however proxied by the share of high-skilled worker compensation in total worker compensation ($labhs$) offered in the WIOD output and labor files. But a problem which may arise out of using this human capital measure is that high-skilled labor employment is an investment into human capital or new technology, respectively. To be more precise, it is an insecure investment since generating new technologies and innovations is by itself an uncertain process. To cope with this problem, we also test models where human capital is proxied with the output of innovation processes measured by using patent data[16]. In the estimation equation, U.S. patent applications are labeld as $patents$.

For all other components of $\boldsymbol{C}$ in equation 4, we directly follow Mankiw et al. (1992). First of all, investment clearly is the change of the capital stock over time from period t to $t+1$. Since the identity of savings and investment has to be considered, we can measure (net) investments (the change of capital stock over time) as the fraction of GDP which has been saved. The Penn World Tables 6.3 offer this data. Hereafter we define investments (equally to savings) As I/GDP. Furthermore, the growth of per capita income depends not only on investment into physical capital but also on its depreciation (δ). Other factors which negatively affect capital accumulation are the rate of growth of the population (n) and the rate of growth of labor productivity (g). The variables n, g, and δ

[16]The patent data we used are offered by the U.S. Patent and Trademark Office. Thus, we use the patent applications of all 19 countries in the U.S. This is important in order not to be left with problems of having different national patent right systems which may bias the results.

are taken from the PWT 6.3 and are expected to have a negative impact on income per capita. By taking all these factors into account we want to condition for, per capita income can by estimated by:

$$\ln\left(\frac{Inc}{Pop}\right)_{it} = \alpha_0 + \alpha_1 \left(\frac{Inc}{Pop}\right)_{it-1} + \alpha_2 \ln\left(\frac{I}{GDP}\right)_{it} - \alpha_3 \ln(n+g+\delta)_{it} + \alpha_4 HK_{it} + \varepsilon_{it} \quad (5)$$

We proxy income or GDP per capita with the WIOD gross output data divided by population taken from the PWT 6.3. Estimation equation 5 is similar to the one used by Mankiw et al. (1992)[17]. In addition to these factors Frankel and Rose (2002) and Frankel and Rose (2005) use trade openess as a further regressor. Our measure for per capita income (Inc/Pop) is the WIOD gross output in U.S. Dollars (using PWT 6.3. exchange rates) and in 1995 prices (deflated by WIOD output price index) scaled with PWT 6.3 population data. Since the WIOD data offers only data from 1995, we do not follow Mankiw et al. (1992) and Frankel and Rose (2002) regarding the use of a start point of per capita income (like 1970 in the case of Frankel and Rose (2002)). Instead, the present approach uses one period lagged income per capita and conditions for factors explaining its growth to its value in period t like for instance Managi et al. (2009) have done.

Equation 5 is estimated in table 3 using the share of high skilled worker compensation in total worker compensation ($labhs$) as a proxy for human capital (HK) in the models A and C. In contrast to this, HK is proxied by patents in the models B and D. Furthermore, a fixed effects panel estimation as well as a first difference Generalized Methode of Moments (GMM) estimation[18] are used. The estimation results for the first stage regressions for per capita income are presented in table 3.

[17]The variables n, g, and δ are estimated altogether in one term because this term is directly derived from the Solow textbook model as described by Mankiw et al. (1992). In this model, the evolution of capital formation (the factor we want to condition for) is of the form: $\dot{k} = s \cdot GDP/Pop - (n+g+\delta) \cdot k$, where s is the the rate of savings which is equal to the share of income invested into capital (I/GDP). The accumulation of human capital is of the same form but the $s \cdot GDP/Pop$ is replaced by the share of investment into human capital (for instance the share of population enrolled in secondary school). We do not go into further detail and refer to Solow (1956) for the standard model and to Mankiw et al. (1992) for the model augmented with human capital formation as it is used here.

[18]The difference-GMM estimator is described in Arellano and Bond (1991) and is a usefull method for adressing endogeneity problems by introducing lagged values as instruments. But the reason why it is also used in the present approach is another. The fixed effects estimation may be inconsistent for running a short panel estimation if the explanatory variables are supposed to be strictly exogenous as it is done in the present approach.

Table 3: Estimation results of intruments for income

log_Inc/Pop	FE_LABHS (Model A)	FE_Patents (Model B)	GMM_LABHS (Model C)	GMM_Patents (Model D)
one period lagged log_Inc/Pop	0.561***	0.510***	0.598***	0.395***
	(0.05)	(0.07)	(0.10)	(0.10)
log_I/GDP	-0.115	-0.085	-0.226	-0.092
	(0.10)	(0.13)	(0.14)	(0.14)
log_(n+g+δ)	0.143**	0.136**	0.164***	0.136***
	(0.04)	(0.05)	(0.03)	(0.03)
log_labhs	0.336**		0.448***	
	(0.10)		(0.09)	
log_patents		0.060		0.038
		(0.04)		(0.03)
constant	1.107*	1.853**	1.028	2.411***
	(0.50)	(0.58)	(0.66)	(0.61)
Observations	152	152	133	133
R squared	0.333	0.279		
Adjusted R squared	0.315	0.260		
Root MSE	0.074	0.077		

* p¡0.05, ** p¡0.01, *** p¡0.001

Obviously, the coefficients of I/GDP and $(n + g + \delta)$ are counter to their expected sign. We think this shortcoming is due to the use of gross output as a proxy for income and the use of the PWT 6.3 share of saved GDP for investments in one regression instead of the use of a respective share gross output invested. An alternative estimation using PWT 6.3 GDP data to proxy income is presented in table 11 in appendix C. In this estimation, all coefficients are of the expected signs and also in terms of the adjusted R^2 the model fit is much better.

Nevertheless, the aim of running this income estimation is to construct an instrument for endogenous gross output as a measure of both scale and income. For this reason, the predicted income per capita from the models in table 3 are regressed against the actual gross output per capita. The results can be seen in table 4.

Table 4: Estimation results for actual income vs. predicted income

Actual income (Gross output)	(A)	(B)	(C)	(D)
predicted income from Model A (FE_LABHS)	1.351***			
	(0.06)			
predicted income from Model B (FE_Patents)		1.246***		
		(0.04)		
predicted income from Model C (GMM_LABHS)			1.125***	
			(0.06)	
predicted income from Model D (GMM_Patents)				1.694***
				(0.04)
constant	-7.947***	-5.543***	-0.960	-18.634***
	(2.17)	(1.27)	(2.27)	(1.42)
Observations	152	152	152	152
R squared	0.757	0.894	0.675	0.916
Adjusted R squared	0.755	0.893	0.672	0.915
Root MSE	8.072	5.328	9.334	4.748
* p¡0.05, ** p¡0.01, *** p¡0.001				

Table 4 shows that the predicted coefficients are a little bit larger than one (for the alternative approach in appendix C they are smaller than one). Thus, the income instrument performs not as good as the instrument for trade openness. If we rely on table 4, we suppose that model B fits the data best. For this reason, model B is chosen as our instrument for the endogeneity of income. Figure 2 plots the constructed income against the actual WIOD gross output per capita (using PWT population data). Obviously, the regressors used to construct the instrument for income or gross output acount for the major part of the variation in the actual gross output. Thus, we think that model B serves as a good instrument to adress the engogeneity of income proxied by gross output in the final analysis.

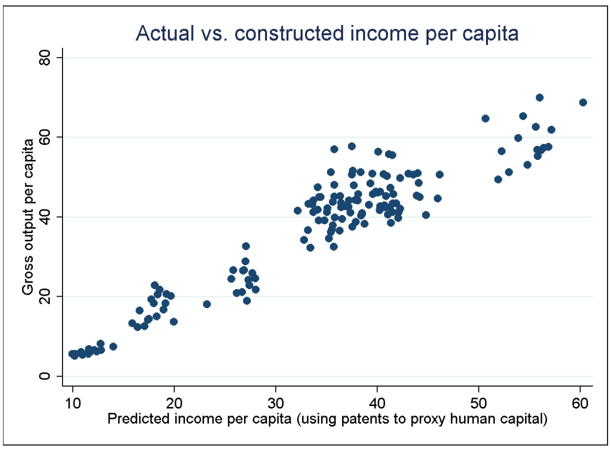

Figure 2: Actual vs. predicted income per capita

C. Estimation strategy

Having calculated the instruments for trade openess and income, these instruments can be used in the second stage regression. The second stage regression investigates the impact of structural change and international trade on the environment. This is the key interest of this paper. Without any doubts, a useful approach to shed light on this question is to run an econometric structural decomposition like for instance Grossman and Krueger (1991) Antweiler et al. (2001), or Cole and Elliott (2003) have done. A very simple decomposition would look like as follows:

$$\begin{aligned} P_{it} &= \alpha_0 + \alpha_1 INC_{it} + \alpha_2 (INC_{it})^2 \\ &\quad + \alpha_3 KL_{it} + \varepsilon_{it} \end{aligned} \quad (6)$$

P_{it} is environmental pressure of country i at time t. These data is taken from the WIOD database which includes data on environmental pressure for eight different air pollutants (CO_2, N_2O. CH_4, NO_x, SO_x, NH_3, NMVOC, and CO). The analysis which will be presented in this section is done only for SO_x for reasons discussed in the previous section. This is because for global pollutants like CO_2, some problems arise using the standard methodology of Antweiler et al. (2001). Our messure of scale, INC_{it}, is a country's gross output at time t which is a proxy for a country's income. Since gross output data taken from the WIOD output and labor files is in local currency, yearly exchange rates provided by the Penn World Tables 6.3 are used to convert local currencies into U.S. Dollars. Furthermore, gross output was deflated to 1995 prices using the WIOD gross output price index. By relying on the EKC relationship, we include also $(INC_{it})^2$ to allow for an inverted U-shaped relationship, where α_2 is expected to be negative and α_1 is expected to be positive for the EKC relationship to hold. Thus, be relying on the EKC, we measure the technique effect using INC_{it} and $(INC_{it})^2$. However, this appraoch implies that our measure for scale and technique effect are the same, or in other words: we can not distinguish between the two effects. This problem is also mentioned by Cole and Elliott (2003). It would be possible to use the WIOD gross output data to measure the scale of the economy and to employ further data from other sources like the PWT 6.3 to proxy income, for instance using gross national product (GNP). But since the aim of this paper is to employ WIOD data to shed light on the impact of structural change and trade on the environment, we decided to follow Cole and Elliott (2003) and Managi et al. (2009) by not distinguishing between scale and technique effect explicitely. Finally, the capital-to-labor ratio KL_{it} for the respective industries represents our proxy of the composition effect.

The simple estimation equation for a decomposition of P_{it} suits obviously just for a closed economy since there are no trade relations included. As Copeland and Taylor (1994, p. 774) argue, "there is no composition effect in autarky since tastes are homothetic". This means the only source of structural change affecting the environment in a closed economy is that increasing income shifts demand to commodities produced in less pollution intensive industries (non-homothetic preferences). But the aim of the paper is to investigate the impact of structural change in general on environmental issues. Therefore it is necessary to introduce international trade since it is a crucial driver of structural change like already argued in section A. Thus, equation 6 has to be augmented by international trade relations. To achieve that aim, we have to ask for all the effects international trade has on changes in environmental pressure P. In this paper, international trade is introduced in the model as trade openess, which is defined as:

$$TI_{it} = \frac{X_{it} + M_{it}}{GO_{it}} \quad (7)$$

where X_{it} represents a country's exports and M_{it} measures it's imports.

First of all, international trade leads to international specilization. This means that an increase in trade openess has some impact on capital-to-labor ratio. Relatively capital-abundant countries may specialize in the more capital-intensive production due to an increase in trade openess. This effect can be modelled by the interaction of trade openess TI with capital-to-labor ratio relative to the world's average ($REL.KL$) like it is done by Antweiler et al. (2001) or Cole and Elliott (2003). An increase in trade openess for capital-abundant countries is expected to rise enviromental pressure P because these countries will specialize in more capital-intensive and pollution-intensive production, and vice versa for the relatively labor abundant country. Antweiler et al. (2001) refers to this effect as the Factor Endowment Hypothesis (FEH) which obviously is based on the standard Heckscher-Ohlin Model of internation trade. To allow for non-linear relationships, the estimation equation also includes a squared interaction term of relative capital-to-labor ratio and trade openess. By doing so, equation 6 becomes:

$$\begin{aligned} P_{it} &= \alpha_0 + \alpha_1 INC_{it} + \alpha_2 (INC_{it})^2 \\ &\quad + \alpha_3 KL_{it} \\ &\quad + \beta_1 TI_{it} REL.KL_{it} \\ &\quad + \beta_2 TI_{it} (REL.KL_{it})^2 + \varepsilon_{it} \quad (8) \end{aligned}$$

The increased specilization due to an increase in trade openess causes welfare gains in the respective countries. These welfare gains increase citizens desire for more environmental quality as the EKC relationship indicates. But this is only the case in relatively rich countries. In relatively poor countries, where relative income ($REL.INC$) is below the world's average, trade-induced income gains increases pollution. Thus, the effect of income gains brought by free trade differs by countries with regard to their income relative to the world's average. Following Antweiler et al. (2001), equation 8 can be augmented by this effect of trade-induced changes in income on the environment as follows:

$$
\begin{aligned}
P_{it} = & \alpha_0 + \alpha_1 INC_{it} + \alpha_2 (INC_{it})^2 \\
& + \alpha_3 KL_{it} \\
& + \beta_1 TI_{it} REL.KL_{it} \\
& + \beta_2 TI_{it} (REL.KL_{it})^2 \\
& + \beta_3 TI_{it} REL.INC_{it} \\
& + \beta_4 TI_{it} (REL.INC_{it})^2 + \varepsilon_{it} \quad (9)
\end{aligned}
$$

Finally, we have to keep in mind that the income gains caused by an increase in trade openess may affect the relative capital-to-labor ratio. This is because higher income increases the demand for a higher environmental quality which can be achieved by implementing a more stringent regulation which in turn forces pollution-intensive production to relocate into countries with less stringent regulation. This effect of international trade on the environment is known as the PHH. Clearly, pollution havens are countries with lower income than the world's average and also low capital-to-labor ratio. Thus, an increase in trade openess is expected to increase environmental pressure in these countries. For countries with both, capital-to-labor ratio and income above the world's average, the effect of the PHH is expected to decrease environmental pressure. As first shown by Antweiler et al. (2001), this third effect of an change in trade openess can be modeled by using an interaction term of trade openess, relative capital-to-labor ratio and relative income. A similar expression is presented in equation 10 below.

$$
\begin{aligned}
P_{it} = & \alpha_0 + \alpha_1 INC_{it} + \alpha_2 (INC_{it})^2 \\
& + \alpha_3 KL_{it} \\
& + \beta_1 TI_{it} REL.KL_{it} \\
& + \beta_2 TI_{it} (REL.KL_{it})^2 \\
& + \beta_3 TI_{it} REL.INC_{it} \\
& + \beta_4 TI_{it} (REL.INC_{it})^2 \\
& + \beta_5 TI_{it} REL.KL_{it} REL.INC_{it} \\
& + \gamma_6 Helsinki_{it} \\
& + \gamma_7 Oslo_{it} \\
& + \varepsilon_{it} \quad (10)
\end{aligned}
$$

Please note that this estimation equation is a simplified version of Antweiler et al. (2001). These authors use SO_2 concentrations as the dependend variable (P_{it}). The similar version of Cole and Elliott (2003) provides estimation results also for SO_2 emissions. Please note that this model additionally includes a squared term of the capital-to-labor ratio (KL^2_{it}) and an interaction term of capital-to-labor ratio and income ($KL_{it}INC_{it}$). Cole and Elliott (2003, p.367) argue that squared capital-to-labor ratio is included "to allow capital accumulation to have a diminishing effect at the margin [...]"; the interaction term of capital-to-labor ratio and income "captures the fact that the effect of income on pollution is likely to depend on the existing level of KL, and vice versa". In this paper, however, we do not take these effects into account and estimate equation 10 as the reference model taken from the literature.

We finally add two control variables for the effect of environmental regulation: the Helsinki-Protocol and the Oslo-Protocol dummies (a dummy is 1 in year

t if country i has ratified the particular agreement and 0 otherwise). The Helsinki-Protocol had been a first step towards a regulation of SO_X-emissions and entered into force in 1987. This dummy is eliminated in the Fixed-Effects and Arellano-Bond estimations. The Oslo-Protocol entered into force in 1998 and so this dummy remains in the Fixed-Effects and Arellano-Bond estimations. A negative sign for both coefficients is expected, with a larger magnitude for the Oslo-Dummy since this is the more actual and more stringent regulatory framework. We develop our final equation 10 in three steps: First, we estimate a strictly linear linear relationship without any quadratic terms (Model 0). Then we add the KL_{it}^2 in Model 1. Finally we estimate equation 10 and refer to it as Model 2. Due to space constraints we limit our analysis to SO_2 in order to compare the results using WIOD data with the results of previous research.

D. Empirical results

First of all, some words of caution must be adressed at this point. Please note that these results are very preliminary because of having only considered 19 countries over 9 periods. Furthermore, the country sample is not meaningful for doing such an analysis. The 19 countries can be found in Appendix A. It can be easily seen, that our sample is currently dominated by industrialized countries and hence a strong sample selection bias can be assumed. Combined with the limitations regarding our shortened observation period, panel econometrics provides currently weak results and we expect an enormous improvement, when more countries will be completely included in the WIOD-database. For all of these reasons, conclusions drawn from the results of our regressions are NOT APPROPRIATE for policy advice!

Endogenous cross-section regressions
Before we use our constructed instruments for trade-intensity and income in the context of Two-stage least squares (2SLS), Instrumental Variables (IV) and Panel estimations, we first employ our approach with simple cross-section ordinary least squares (OLS). We are fully aware of the endogenity problems, nevertheless we want to present the results from OLS for the sake of completness and for reasons of comparebility. Table 5 summarizes the estimation results for Model 0 (without non-linearities), Model 1 (with KL_{it}^2) and Model 2 (based on our equation 10).

Because our models are nested, we can compare them using a likelihood ratio (LR) test. The results indicate, that the gain from using Model 1 instead of Model 0 is quite imposing and that using Model 1 instead of Model 2 is still beneficial, although not as much as using Model 1 instead of Model 0. It appears, that the non-linearity restrictions within Model 0 are too tight. The results are in line with previous studies. Our control for environmental regulation manifests the expected results. Both, the Helsinki as well as the Oslo dummy tend to have a negative and significant impact on SO_X-emissions.

Table 5: Estimation results for the endogenous OLS-regression

Log of SO_X-Emissions	M0 (Endogen, OLS)	M1 (Endogen, OLS)	M2 (Endogen, OLS)
INC (from WIOD)	-0.029*	-0.048**	0.072
	(0.01)	(0.01)	(0.04)
KL	0.082	0.741***	0.058
	(0.09)	(0.20)	(0.31)
TI (from WIOD)	-0.807	-1.292	-2.107*
	(0.55)	(0.72)	(0.97)
TI.REL.KL	-0.007	0.014	0.041**
	(0.00)	(0.01)	(0.01)
TI.REL.INC	0.044***	-0.041**	-0.108***
	(0.01)	(0.02)	(0.03)
TI.REL.INC.REL.KL	-0.010***	0.027**	0.024*
	(0.00)	(0.01)	(0.01)
Oslo	-0.405***	-0.510***	-0.498***
	(0.11)	(0.11)	(0.12)
Helsinki	-0.075	-0.154	-0.246
	(0.11)	(0.10)	(0.13)
$(KL)^2$		-0.046**	-0.006
		(0.01)	(0.02)
$(TI.REL.KL)^2$		-0.010***	-0.014***
		(0.00)	(0.00)
$(TI.REL.INC)^2$		0.002	0.033
		(0.01)	(0.02)
INC^2			-0.001**
			(0.00)
constant	-0.339	-1.636***	-1.370**
	(0.22)	(0.31)	(0.42)
Observations	171	171	171
R squared	0.464	0.567	0.588
Adjusted R squared	0.437	0.537	0.557
Root MSE	0.674	0.611	0.598
F-Statistic	27.529	28.383	18.789
LR-Test	45.14***	8.33**	
Scale + Technique Elasticity	- 1.072	- 1.793	0.469
Composition Elasticity	0.602	2.739	0.097
Trade Intensity Elasticity	- 0.413	- 0.447	- 2.143

* p¡0.05, ** p¡0.01, *** p¡0.001

To quantify the effects of trade on the environment we estimate the relevant elasticities at the sample means using the standard Delta method. We are measuring three different effects: First, the combined scale and technique-effect. The relevant variables herefore are INC_{it} and INC_{it}^2. While Model 0 and Model 1 both result in a stronger technique than scale-effect, the more appropriate Model 2 indicates that the Scale-and-Technique Elasticity is positive, an indicator for the hypothesis that the scale effect, an increase in economic activity measured by an increase in output, rules out the technique effect. The second effect is the composition effect, represented by a nations capital to labor ratio (and in Model 2 its squared term). In all models we find a positive composition effect due to an increasing capital to labor ratio. The estimated elasticities vary between almost 0.1 in Model 2 up to 2.7 in Model 1. Finally, we provide estimates for the impact of a changing trade-intensity on the SO_X-emissions. Our results indicate a strong negative impact, ranging from - 0.4 (Models 0 and 1) up to - 2.1 (Model 2). The results are significant for all Models since we could reject the hypothesis that the relevant terms reflecting our trade-intensity elasticity are jointly equal to zero. Put it otherwise, for an average country the trade-induced composition effect is negative. Put it otherwise, free trade tends to have positive impacts on the environment.

IV cross-section regressions The next step in our estimation are IV-regressions using our constructed instruments. Our results are summarized in table 6. We estimate all three possible combinations: A model with only the trade instrument (labeled with a TI), a model with the income instrument (labeled with INC) and finally a model with both instruments (called BOTH). Are the instruments valid and appropriate? With reference to the rule of thumb from Staiger and Stock (1997), which mentions the criterion of a F-Statistic from the first-stage regression greater than 10, we can accept the instruments. The F-Statistic for Model 0 (TI) is e.g. 28.38 and the adjusted R squared 0.5919. For Model 1 (TI) the values are 25.63 and 0.6421. And finally for Model 2 (TI) 23.35 and 0.6398. Similar results occur for the other instrument combinations. With regard to the elasticities the results are akin to the endogenous regressions in the previous section. The main difference is the negative scale-and-technique effects. The range is between - 0.2 and - 3.2 for the scale-and-technique effect. The composition elasticity is in the most regressions positive with a range of - 0.37 (Model 1 TI) and 3.9 (Model 2 TI). Since our interest lies mainly on the trade-intensity elasticity, we can confirm that the results of the endogenous regressions hold: all results are negative within a range of - 0.17 (Model 0 INC) and - 0.59 (Model 2 INC). And again, free trade tends to have positive impacts on the environment.

Table 6: Estimation results for IV-regressions

Log of SO_X-Emissions	M0 (TI)	M0 (INC)	M0 (BOTH)	M1 (TI)	M1 (INC)	M1 (BOTH)	M2 (TI)	M2 (INC)	M2 (BOTH)
TI (IV)	-3.255*		-2.823*	-0.924		-0.996	-1.928		-0.953
	(1.34)		(1.32)	(0.97)		(1.03)	(1.36)		(1.04)
INC (2SLS)	-0.029			-0.006			-0.170		
	(0.02)			(0.02)			(0.12)		
KL	0.076	0.030	0.124	0.501*	0.050	0.490*	1.135**	0.586	1.021*
	(0.10)	(0.15)	(0.13)	(0.20)	(0.62)	(0.20)	(0.43)	(0.77)	(0.45)
TI.REL.KL	0.009	0.030	0.009	-0.056	0.020	-0.054	-0.161*	-0.055	-0.126
	(0.02)	(0.02)	(0.02)	(0.06)	(0.12)	(0.05)	(0.07)	(0.13)	(0.06)
TI.REL.INC	0.208***	0.264***	0.232***	0.298*	0.338*	0.305*	0.605**	0.523***	0.496**
	(0.04)	(0.05)	(0.05)	(0.13)	(0.13)	(0.14)	(0.22)	(0.15)	(0.15)
TI.REL.INC.REL.KL	-0.076***	-0.084***	-0.082***	0.188***	0.182***	0.183***	0.190***	0.189***	0.191***
	(0.01)	(0.01)	(0.01)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Oslo	-0.349**	-0.466**	-0.414**	-0.283*	-0.315*	-0.296*	-0.249	-0.267	-0.247
	(0.12)	(0.14)	(0.15)	(0.12)	(0.14)	(0.14)	(0.13)	(0.16)	(0.16)
Helsinki	0.131	-0.069	0.106	0.023	-0.026	0.028	0.090	-0.064	-0.014
	(0.16)	(0.10)	(0.15)	(0.13)	(0.11)	(0.13)	(0.15)	(0.10)	(0.13)
INC (IV)		-0.023	-0.026		-0.006	-0.006		-0.076	-0.078
		(0.02)	(0.02)		(0.02)	(0.02)		(0.06)	(0.06)
TI (2SLS)		-0.113*			-0.148			-0.142	
		(0.05)			(0.15)			(0.16)	
$(KL)^2$				-0.038*	-0.012	-0.036*	-0.075**	-0.049	-0.072
				(0.01)	(0.04)	(0.02)	(0.03)	(0.05)	(0.04)
$(TI.REL.KL)^2$				-0.033**	-0.044*	-0.033**	-0.017	-0.031	-0.021
				(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
$(TI.REL.INC)^2$				-0.415***	-0.423***	-0.411***	-0.546***	-0.523***	-0.514***
				(0.09)	(0.09)	(0.09)	(0.12)	(0.11)	(0.12)
INC^2 (2SLS)							0.002		
							(0.00)		
INC^2 (IV)								0.001	0.001
								(0.00)	(0.00)
constant	-0.500	-0.408	-1.060	-2.064***	-0.154	-2.114***	-1.544*	-0.878	-2.771***
	(0.49)	(0.78)	(0.56)	(0.59)	(2.53)	(0.58)	(0.77)	(2.62)	(0.71)
Observations	152.000	152.000	152.000	152.000	152.000	152.000	152.000	152.000	152.000
R squared	0.412	0.461	0.420	0.564	0.557	0.559	0.558	0.548	0.555
Adjusted R squared	0.379	0.430	0.387	0.530	0.523	0.524	0.520	0.509	0.516
Root MSE	0.713	0.682	0.708	0.620	0.625	0.624	0.627	0.633	0.629
F-Statistic	22.566	25.999	22.360	34.323	38.914	34.053	31.489	38.188	34.713
Scale + Technique Elasticity	- 0.968	- 0.844	- 0.947	- 0.207	- 0.202	- 0.219	- 3.185	- 1.266	- 1.309
Composition Elasticity	0.565	0.225	0.918	1.442	- 0.375	1.465	3.924	1.424	3.229
Trade Intensity Elasticity	- 0.439	- 0.167	- 0.207	- 0.504	- 0.563	- 0.460	- 0.575	- 0.585	- 0.487

* p¡0.05, ** p¡0.01, *** p¡0.001

Endogenous panel estimates The next estimations we carry out are using panel econometrics. Before we interpret the results we want to remind the reader of the preliminary status of the used database. The relatively short period and the biased sample towards industrialized countries do currently **NOT** allow better estimations. For sake of completeness we have included the results in order to give an outlook which calculations can be performed using the WIOD database. In 7 the estimation results for Fixed- (labeled in the tables as FE), Random-Effects (RE) and Arellano-Bond GMM (AB) estimations are presented. A Hausman-test suggests evidence for the random effects estimation. Just like in the cross section IV estimations in the previous section the scale-and-technique elasticity is negative (from - 0.2 to - 0.9). The composition elasticity is, not like in previous results, negative. We guess, that this is a consequence of the biased sample. Nevertheless the trade-intensity elasticity remains negative (- 0.2 to - 0.3). With regard to the estimation problems, we do not conclude anything from these estimations.

Panel estimates using Instruments Finally we employ the fitted values of our instruments and include them in our panel estimations. The obtained estimates for the elasticities of interest are now more in line with the results from the previous section. In most cases we find a positive scale-and-technique elasticity, despite in Model 2 (RE). The composition elasticity is heterogenous and lies between - 1.4 and 0.35. And finally the trade-intensity elasticity is again negative all estimations (ranging from - 0.21 to - 0.31). Again we have to warn the reader to draw conclusion from the panel-estimations.

Table 7: Estimation results for endogenous Panel-regressions

Log of SO_X-Emissions	M0(FE)	M0(RE)	M0(AB)	M1(FE)	M1(RE)	M1(AB)	M2(FE)	M2(RE)	M2(AB)
INC (from WIOD)	-0.009*	-0.009*	-0.000	-0.006	-0.008	0.000	-0.036*	-0.037*	-0.037***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.02)	(0.01)
KL	-0.078*	-0.082*	-0.007	0.018	-0.048	-0.012	0.049	0.022	0.115
	(0.04)	(0.04)	(0.04)	(0.14)	(0.12)	(0.11)	(0.14)	(0.13)	(0.12)
TI (from WIOD)	-0.116	-0.139	0.647*	0.690	0.443	1.151***	0.769	0.542	1.111***
	(0.32)	(0.32)	(0.29)	(0.43)	(0.44)	(0.32)	(0.43)	(0.44)	(0.32)
TI.REL.KL	-0.004	-0.004	-0.004**	-0.019**	-0.014*	-0.016***	-0.022**	-0.018**	-0.022***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
TI.REL.INC	-0.004	-0.002	0.014**	0.027*	0.021	0.038***	0.038**	0.033*	0.057***
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
TI.REL.INC.REL.KL	0.003	0.003	-0.001	-0.001	0.001	0.000	0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Oslo	-0.178***	-0.182***	-0.047	-0.176***	-0.181***	-0.042	-0.188***	-0.193***	-0.049
	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.03)	(0.05)	(0.05)	(0.03)
Helsinki		-0.411			-0.494			-0.458	
		(0.39)			(0.32)			(0.31)	
Lagged Log SO_X capita			0.800***			0.761***			0.798***
			(0.09)			(0.08)			(0.08)
$(KL)^2$				-0.006	-0.003	-0.001	-0.008	-0.006	-0.007
				(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$(TI.REL.KL)^2$				0.004	0.002	0.002	0.004	0.003	0.003
				(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$(TI.REL.INC)^2$				-0.009	-0.007	-0.012**	-0.016*	-0.014	-0.021***
				(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
INC^2							.	0.000	0.000***
							.	(0.00)	(0.00)
constant	-0.147	0.013	-0.385	-0.621	-0.151	-0.390	-0.212	0.073	-0.200
	(0.28)	(0.36)	(0.20)	(0.52)	(0.47)	(0.41)	(0.56)	(0.48)	(0.41)
Observations	171	171	133	171	171	133	171	171	133
R squared (overall)	0.272	0.329		0.107	0.268		0.139	0.259	
Root MSE	0.163	0.161		0.159	0.164		0.158	0.163	
F-Statistic	14.877			11.681			11.155		
χ^2		112.419	359.853		117.167	417.572		122.474	437.449
Scale + Technique Elasticity	- 0.336	- 0.350	—	- 0.229	- 0.302	—	- 0.813	- 0.877	—
Composition Elasticity	- 0.570	- 0.584	—	- 0.245	- 0.522	—	- 0.103	- 0.199	—
Trade Intensity Elasticity	- 0.313	- 0.276	—	- 0.270	- 0.234	—	- 0.232	- 0.215	—

* p¡0.05, ** p¡0.01, *** p¡0.001

Table 8: Estimation results for instrumented Panel-regressions

Log of SO_X-Emissions	M0(FE)	M0(RE)	M0(AB)	M1(FE)	M1(RE)	M1(AB)	M2(FE)	M2(RE)	M2(AB)
INC (2SLS)	0.005	0.003	0.008	0.005	0.004	0.005	0.025	-0.014	-0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)	(0.05)	(0.04)
KL	-0.076	-0.135***	-0.021	0.151	-0.244	0.179	0.158	-0.233	0.168
	(0.04)	(0.04)	(0.04)	(0.26)	(0.23)	(0.25)	(0.27)	(0.23)	(0.25)
TI (2SLS)	-0.202	0.021	0.117	-0.199	-0.038	0.113	-0.173	-0.060	0.099
	(0.14)	(0.07)	(0.13)	(0.14)	(0.09)	(0.12)	(0.16)	(0.12)	(0.13)
TI.REL.KL	-0.036	-0.009	-0.007	-0.125	-0.022	-0.045	-0.127	-0.026	-0.042
	(0.03)	(0.03)	(0.03)	(0.07)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
TI.REL.INC	-0.140	-0.048	-0.039	0.011	0.101	0.253*	-0.053	0.149	0.292
	(0.09)	(0.07)	(0.07)	(0.13)	(0.10)	(0.11)	(0.21)	(0.17)	(0.17)
TI.REL.INC.REL.KL	0.031	0.009	0.001	-0.009	-0.002	0.044	-0.008	-0.002	0.044
	(0.03)	(0.02)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Oslo	-0.130*	-0.167***	-0.031	-0.131*	-0.163***	-0.038	-0.127*	-0.165***	-0.039
	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)
Helsinki		-0.194			-0.268			-0.256	
		(0.48)			(0.49)			(0.52)	
Lagged Log SO_X capita			0.853***			0.910***			0.915***
			(0.14)			(0.14)			(0.14)
$(KL)^2$				-0.013	0.007	-0.012	-0.014	0.006	-0.011
				(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$(TI.REL.KL)^2$				0.024	0.005	-0.001	0.024	0.006	-0.001
				(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$(TI.REL.INC)^2$				-0.017	-0.059	-0.190***	0.011	-0.079	-0.207**
				(0.07)	(0.06)	(0.06)	(0.09)	(0.09)	(0.08)
INC^2							-0.000	0.000	0.000
							(0.00)	(0.00)	(0.00)
constant	5.011*	-0.042	-1.472	4.704*	0.438	-3.656	4.465*	0.789	-3.570
	(2.01)	(0.72)	(2.25)	(2.04)	(1.12)	(2.27)	(2.13)	(1.48)	(2.28)
Observations	152	152	133	152	152	133	152	152	133
R squared (Overall)	0.088	0.291		0.072	0.268		0.071	0.264	
Root MSE	0.153	0.157		0.152	0.155		0.152	0.154	
F-Statistic	12.555			9.526			8.616		
χ^2		81.601	294.889		89.026	312.106		89.168	309.120
SARGAN-Test			0.006**			0.0363*			0.0413*
Scale + Technique Elasticity	0.175	0.113	—	0.159	0.142	—	0.530	- 0.211	—
Composition Elasticity	- 0.561	- 0.996	—	0.309	- 1.443	—	0.351	- 1.409	—
Trade Intensity Elasticity	- 6.032	- 0.460	—	- 6.580	- 0.553	—	- 6.755	- 0.594	—

* p¡0.05, ** p¡0.01, *** p¡0.001

V. Concluding remarks

Traditionally, the conventional wisdom about structural change and its simultaneous relations to international trade draws a dark picture on these forces, especially with respect to their impacts on the environment. There is a widely held opinion by the opponents of free trade, that international trade due to structural change relocates dirty production into countries with less stringent environmental protection. In the absence of trade protection, especially environmental regulation in the industrialized nations is supposed to cause such a development, which is well known as the Pollution Haven Effect. Despite all these concerns, recent empirical research identified trade liberalization to be good for the environment. Also our approach using the WIOD database for a sample of 19 countries confirms these prior findings. The empirical results point out that trade has a beneficial effect on the emission of SOx pollutants. As it was argued in the very beginning of this paper, structural change and trade cannot be treated isolated from each other. By relying on the literature, the connection of these forces was discussed using very simple considerations. In the following econometric analysis, these interrelated influences of structural change and trade were modeled by following the pioneering work of Antweiler et al. (2001) who interacted the respective measures for trade, structural change, and also income in an econometric structural decomposition approach. By relying on this guideline, we are aware of the problem that some of these variables can not be considered as being strictly exogenous. This is the case for trade and income as is was pointed out. To cope with the problem of endogenous regressors, we construct instruments for trade and income. In the end, our models, at least our cross-section analysis, indicate strong support for the evidence that globalization has no harmful effects on the environment.

Appendix A: List of countries included in the regression

Table 9: Countries used for the estimation

Country code	Country name	Country code	Country name
AUS	Australia	JPN	Japan
AUT	Austria	KOR	Korea
DNK	Denmark	NLD	Netherlands
FIN	Finland	POL	Poland
FRA	France	PRT	Portugal
GER	Germany	ESP	Spain
GRC	Greece	SWE	Sweden
HUN	Hungary	GBR	United Kingdom
IRL	Ireland	USA	United States
ITA	Italy		

Appendix B: Descriptive Statistics

Table 10: Descriptive Statistics of used Variables

Variable	**Dimension**	**Mean**	**SD**	**Min**	**Max**
Log of SO_X per Capita	Logarithmic	-1.45	0.89	-3.55	0.33
Capital-Labor Ratio	$ 10k/worker	7.33	2.29	1.54	11.24
Relative KL	World = 1.00	2.67	0.81	0.61	4.08
Openess	in %	62.96	28.57	18.70	158.84
Income	GO/Capita in 1000 $	33.93	12.37	9.98	60.28
Relative I	SampleMean = 1.00	1	0.36	0.29	1.74
Population	in 1000	46689.29	63265.72	3613.89	289985.80
Area	in km2	1142189	2639617	41526	9826630
Distance	in km	4784.58	4880.54	218.94	18040.40
Common Currency	(dimensionless)	0.26	0.44	0	1
Landlocked	(dimensionless)	0.21	0.42	0	2
Common Border	(dimensionless)	0.06	0.25	0	1

Appendix C: Alternative income estimation

Table 11: Alternative income estimation using PWT 6.3 GDP data

log_GDP/Pop	FE_LABHS (Model A)	FE_Patents (Model B)	GMM_LABHS (Model C)	GMM_Patents (Model D)
L1.log_GDP/Pop	0.760***	0.656***	0.731***	0.652***
	(0.06)	(0.05)	(0.06)	(0.04)
log_I/GDP	0.359**	0.333**	0.568***	0.410***
	(0.12)	(0.11)	(0.13)	(0.12)
log_(n+g+δ)	-0.054	-0.040	-0.079*	-0.053
	(0.04)	(0.03)	(0.03)	(0.03)
log_labhs	0.159		0.188	
	(0.13)		(0.14)	
log_patents		0.152***		0.159***
		(0.04)		(0.03)
constant	-0.466	-0.266	-1.143**	-0.569
	(0.44)	(0.38)	(0.43)	(0.36)
Observations	171	171	152	171
R squared	0.822	0.840		
Adjusted R squared	0.796	0.816		
Root MSE	0.091	0.087		

* p¡0.05, ** p¡0.01, *** p¡0.001

Table 12: Actual PWT 6.3 income vs. predicted income

Actual income (PWT 6.3 GDP per capita)	(A)	(B)	(C)	(D)
predicted income from Model A (FE_LABHS)	0.849***			
	(0.04)			
predicted income from Model B (FE_Patents)		0.300***		
		(0.03)		
predicted income from Model C (GMM_LABHS)			0.723***	
			(0.04)	
predicted income from Model D (GMM_Patents)				0.282***
				(0.03)
constant	35.185***	158.509***	63.683***	162.587***
	(9.18)	(8.64)	(9.92)	(8.46)
Observations	171	171	171	171
R squared	0.747	0.354	0.652	0.341
Adjusted R squared	0.746	0.350	0.650	0.337
Root MSE	29.919	47.832	35.094	48.306

* p¡0.05, ** p¡0.01, *** p¡0.001

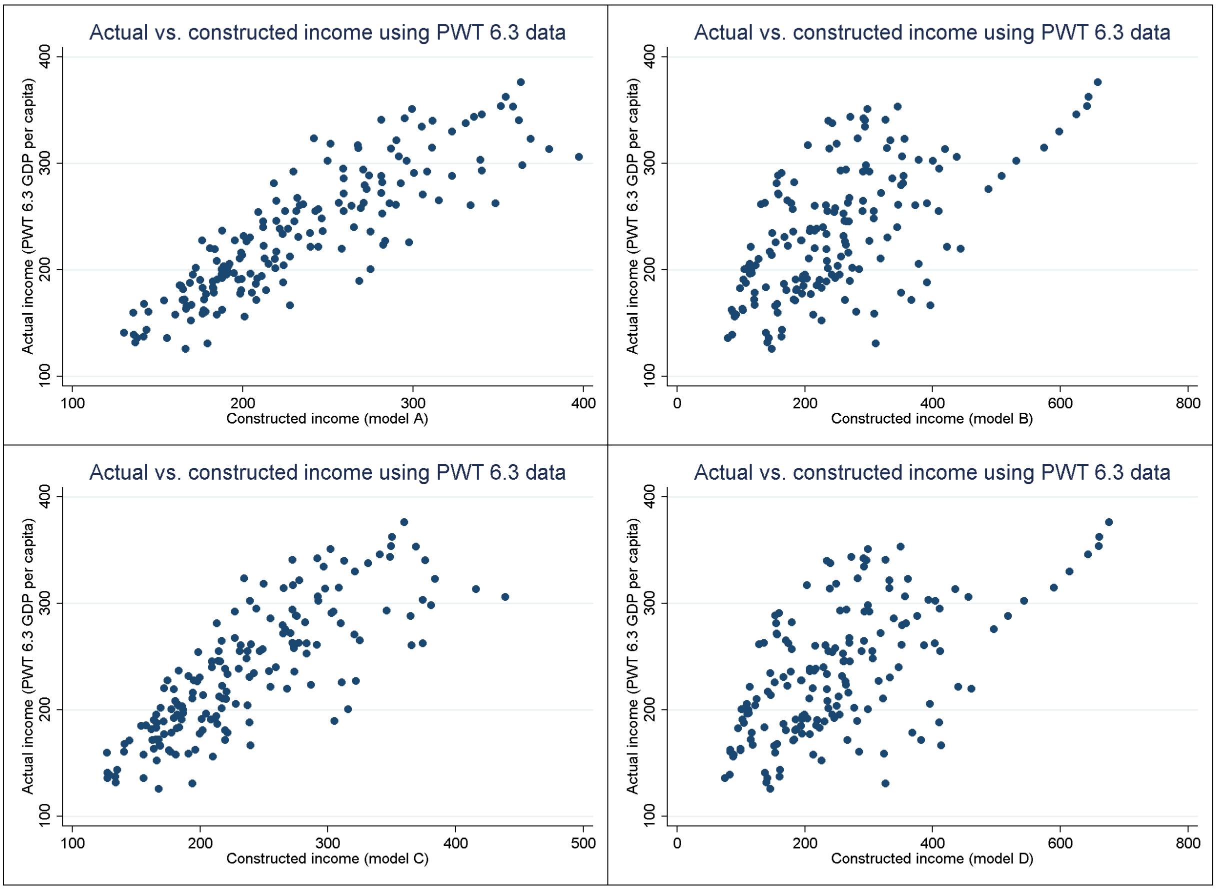

Figure 3: xxx

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