Revisiting the Environmental Kuznets Curve

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Abstract

The view that human released CO_2 emissions are one of the main causes of anthorpogenic global warming is now widespread among the scientific community. Ranging from rising sea levels to land and water shortages the effects of climate change on the global ecosystem and the world economy will be severe. This makes the existence of a U-shaped relationship between economic development and pollution the Holy Grail of environmental economics. While there is theoretical support for this so called Environmental Kuznets Curve (EKC), epirical evidence is far from robust, sometimes even contradicting theoretical suggestions. Here we test for the existence of an inverted U-shaped relationship between carbon dioxide emissions and real income for a panel of 78 individuals (66 countries and 12 composite regions) for the years 1997, 2001, 2004 and 2007. We contribute to the literature in two ways. First, by applying multi-region input output (MRIO) methodology on the GTAP database we can also take CO_2 consumption into account besides established production-based measures. Secondly, we also apply a threshold model alongside conventional lniear models on our dataset. The existence or non-existence of an EKC for CO_2 is of considerable importance of the design of global mitigation mechanisms and agreements on climate change.

JEL classification:
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1 Introduction

Global warming is a fact. That human activities are one of main the causes of global warming is an statement that starts settling down in the scientific community. That being so, the existence of an inverted U-shaped relationship between pollution and economic development constitutes the Holy Grial of environmental economics; and what's more, the hope of the economic system as we know it. There is theoretical support for the existence of an inverted U-shaped relationship between pollution and economic growth. However, the empirical evidence is far from being robust, when not contradicting the theory (Dasgupta et al., 2001, or Stern, 2004).

The development and design of climate mitigation and abatement policies and international agreements on climate change has much to do with the existence of an EKC. For local pollutants, coincidence of the place where pollution is originated and its effects are noticed favours the conception of correct environmental regulation. This is much more difficult for the case of global pollutants, like greenhouse gasses, since their effects are noticed at a global scale.

Climate change is the persistent variation in mean weather conditions and their variability, including natural and anthropogenic global warming and their effects. Other impacts of climate change include glaciers and Arctic sea ice retreat, and ice-loss from the ice sheets in Greenland and Antarctica; the rise of the sea-level due to combined effect of ice melting and ocean thermal expansion; the increase in the acidification of oceans. It will also be associated with changes in precipitation patterns with an increase of the duration of the dry-season and a reduction of rainfall during dry-seasons, or higher probabilities of floods, hurricanes and catastrophes. Moreover, climate change will deteriorate air and water quality, and reduce water availability too. It is thus expected to have dramatic effects on the ecosystems, on many plant and animal species; and on the economic system, on agriculture and tourism; and to have adverse consequences for human health, from heat stress and flooding, or by exhacerbating disease transmition and malnutrition resulting from increased competition for crops and water resources (see Parry et al., 2007, for a complete review of climate impacts).

Greenhouse effect is one of the forcing mechanisms of climate change. Greenhouse gasses such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) are responsible of greenhouse effect and anthropogenic global warming. Amongst them, CO_2 emissions caused by human activities are the major contributor to anthropogenic global warming. Although carbon dioxide has a lower global warming potential per mole than the other greenhouse gasses above mentioned, it represents a larger proportion of total concentrations relative to the others, and it has a much longer atmospheric lifetime. Indeed, CO_2 perturbations present a very long atmospheric lifetime. As a result, its warming potential takes a long period of time to fall off, being the climate change effects associated with carbon dioxide concentration estimated to be largely irreversible for 1,000 years after emissions stop (Solomon et al., 2009). In consequence, carbon dioxide is responsible for the major percentage of radiative forcing and warming potential. In addition, the recent trends CO_2 emissions are far from being positive news. The rates of growth of CO_2 emissions from fossil fuel and industrial processes have shown an acceleration at a global scale, increasing from 1.1% per year for the period 1990-1999 to more than 3% per year for the period 2000-2004 (Raupach et al., 2007). Fossil fuel combustion processes constitute the main source of anthropogenic CO_2 emissions. For example, the Intergovernmental Panel on Climate Change (IPCC) estimates in about 2/3rds the proportion of anthropogenic CO_2 coming fossil fuels since 1750 (Solomon et al., 2007). All this emphasizes the importance of understanding the connection between CO_2 emissions and economic development.

We test for the existence of an inverted U-shaped relationship between Carbon Dioxide (CO_2) emissions and real Gross Domestic Product (GDP) for a panel of 78 individuals (66 countries and 12 composite regions) for the years 1997, 2001, 2004 and 2007 (312 observations). We compute two measures of CO_2 emissions from fossil fuels, production-based and consumption-based emissions, based on the Global Trade Analysis Project (GTAP) dataset by using trade-linked multiregion input-output (MRIO) framework. Afterwards, we test for the existence of an EKC for both measurements of CO_2 emissions. Our results show...

Our research contribution stems from three aspects. First of all, international trade can be of importance in global pollutants such as greenhouse gasses, as shown, by Peters and Hertwich (2007), for example. We focus on CO_2 emissions, considered the most relevant source of anthropogenic global warming. Our measurements of production-based and consumption-based CO_2 emissions allow us to take into account CO_2 emissions embodied in international trade. Moreover, the number of countries and years that our sample covers makes it, to the best of our knowledge, the biggest account for those measurements. Secondly, given the distinction between those two measures of CO_2 emissions, the EKC has two different meanings, helping unveiling what drives the actual tendency to increase CO_2 emissions. We are not aware of any research that tests the existence of an inverted U-shaped relationship between CO_2 emissions and economic development for both types of measurements. Finally, understanding the form of the relationship between CO_2 emissions and income by using both production-based and consumption-based accountancies may help recognize the urge for a serious adjustment of emission inventories for trade to feed rigorous information that may improve the framework of mitigation policies and international agreements such as Kyoto Protocol.

This article is structured as follows. In section 2 we revise the theoretical underpinnings underlying the EKC and the previous empirical evidence. We explain the data in detail in section 4. The econometric model and the results are presented in section 5 . Section 6 concludes.

2 Theoretical foundations and previous evidence

Interest in the relationship between economic growth and environmental quality began in the early 1990s with the seminal work of Grossman and Kruger (1991). Using a cross section of urban areas in about 42 countries they estimated the effect of income on two indicators of environmental quality (SO_2 and suspended particular matter). Per capita pollution along the path of development was intensively thematized in the 1992 World Development Report. Shafik and Bandyopadhyay (1992) provided a background study to this report testing its assumptions econometrically on a number of indicators for environmental quality, profiting from improving data availability. Besides from contributing to the econometric analysis of the phenomenon, Panayotou (1993) was the first calling the assumed inverted U-shape of the relationship between per capita pollution and devlopment „Environmental Kuznets Curve“ (EKC) after Simon Kuznets results on inequality and income. Being an empirical phenomenon only at the beginning, these early contributions to the field found cautious support for the existence of an EKC for local pollutants with high personal costs for the affected population (SO_2, suspended particular matter, sanitation quality). In this respect the results of these early studies seem fairly robust, since methods and results were highly comparable.

The literature discusses in general three effects that are characterizing the income-pollution path knwon as Environmental Kuznets Curve (Kaika and Zervas 2013, and Stern 2004). As income rises at the early stages of development increasing production leads to a deterioration of environmental quality due to the increasing use of resources (scale effect). As income grows demand for a cleaner environment shifts the economy to less polluting service sectors (composition effect) and supports introduction of less pollution-intensive production technologies (technique effect). Those factors work against and may dominate the scale effect (Smulders et al. 2011). The focus of these early studies was to assess the role of the composition and technology effects during economic development compared to the scale effect of economic growth on environmental quality. Grossman and Krueger (1995) again contributed to the field by updating their methods to the fast established level and increasing data range, confirming previous results in the field. The fast emerging literature on the EKC, however, lacks a sound decomposition of the three mentioned effects, as it is critizised by Antweiler et al. (2001). So those authors were the first to do this decomposition, although for the effect of trade on the environment, in a theoretical and also an empirical setting.

Dominated by empirical applications the work on the EKC was soon complemented by theoretical foundations, first based on adapted versions of standard macroeconomic growth models, looking at the production-side of pollution. Applying a simplified neoclassical growth model, Selden and Song (1995) demonstrated a theoretical foundation for the empirically observed inverted U shape for pollutants. Intertemporal issues were only discussed marginally in this model, so the next important step followed by the work of John and Pecchenino (1994) who applied an overlapping generations framework on pollution and development, allowing for intergenerational maximization problems. Depending of the returns of maintainance an inverted U shape can be seen for some pollutants while not for others. Focusing on the role of the governmental decision-making and the interaction of macroeconomics and environmental their OLG framework was extended in John et al. (1995). Taking intergenerational externalities into account is beyond the scope of short-living decisions makers. This can only be achieved in the model by an infinitely living social planner.

In line with these models, which put their main emphasis on income elasticity for environmental quality als the main driving factor for an EKC, also Stockey (1998) was focussing on preferences. Instead of income elasticity with resprect to pollution, she looked at consumption. Using three versionis of a static model for einvironmental regulation, one with endogenous, two with exogenous growth, she reproduced the empirical findings of Grossmand and Kruger (1995) only for income elasticities greater than one. Seing their work as an direct extenstion to Stockey's approach Jones and Manuelli (1995 and 2001) focus on the implementation part of environmental policy. They use an OLG growth model where voters can either decide on effluent charges or the direct regulation of production-technology. In the long-run both decision-problems lead to the same result, but the different institutions result in different income-pollution paths. Relevant for our analysis on CO_2 is the fact that there is no environmental regulation if externalities are allowed in the model.

Doubting the sufficency of income elasticity for environmental quality as the main cause of the emergence of an EKC for local pollutants, a series of models deviated from that path discussing alternative causes. Beside focussing on the income elasticity, Bulte and van Soest (2001) looked at imperfect markets to replicate the EKC for resource depletion in developing economies using a convential household model. Their results were also dependent on the indicator used for environmental pressure, a finding found also in the empirical literature by the meta-study on the EKC by Cavlovic et al. (2000). Working in a static framework, McConnell (1997) shows on the contrary that rising abatement costs and especially the effect of pollution on output can override those preferences, making demand for environmental quality not a necessary condition to produce an EKC. Using a median voter framework Magnani (2001) discussed with the difference between the median and the average income as driving force for envirionmental quality.

López and Mitra (2000) found in a game theoretical setting that corruption will not preclude the exisitence of an EKZ, but will increase pollution and shift the turning point to the right compared with the social optimum. Due to the persistence of corruption within the institution in many developing nations, especially fast growing India and China, one should be careful to extend the existing emporical results on the EKC for developed nations to these countries. Their work give also strong support to use corruption and the quality of institutions as controls in future empirical applications. Looking at the cost structure or renewable and non-renewable resources within a satatic growth model with endogenous technological change, Tahvonen and Salo (2001) analyse energy use over time. Even in the absence of environmental policy their model produces an inverted U-shape for the use of non-renewables, and their corresponding CO_2 emissions independently of technological change. Focusing on the investment into abatement activities in order to create sustainable growth, Dinda (2005) remained in an endogenous growth model. The model shows that an EKC is not automatic, but occurs only if enough investment into abatement is undertaken. While this explains why for some pollutants such as CO_2 no EKC can be observed, he says nothing about the underlying causes of investment decisions. A similar result is gained by Smulders et al. (2011) who looked at incentives to investin cleaner production technology within a Schumpeterian growth model. The downward-sloping part of the EKC occurs only if there are enough incentives to invest in new clean technologies.

A striking result of the empirics on the EKC is the fact that the phenomenon could be found primarily for local pollutants with strong negative health effects on the polluting population, while pollutants that can easily be externalized or isolated from the polluters, such as CO_2 and municipal waste show a monotonic increase with income. (Shafik and Bandyopadhyay 1992) So abating CO_2 at a local level is costly and bears almost no local benefit, resulting in a monotonic increase of CO_2 emissions with income or extremely high turning points in empirical applications (Cavlovic et al. 2000 and McConnell 1997). Using a classical growth model allowing for transboundary pollution, Ansuategi and Perrings (2000) approach this phenomenon theoretically. The higher the share of the pollutant that can be externalized, the less likely the emergences of an EKC becomes until ther is a monotonic increase with income of a fully externalized pollutant. According to the authors the driving force behind this phenomenon is institutional. Only rich countries can afford the effective and expensive institutions required for dealing with transboundary pollutants. Panayotou et al. (2000), however, found empirical evidence that structural changes as economies transfrom from agricultural over industrialized to service dominated economies are more important in explaining an EKC behavior than behavioral changes. This would explain also an EKC behavior for global pollutants and the empirical findings for an EKC for CO_2 as in (citations).

A number of theoretical explanations for the emergence of an EKC has now presented. Andreoni and Levinson (2001) assume most of them can just be seen as special cases of increasing returns scale for abatement. Using a neoclassical static model they show that this is sufficient to create an EKC for pollutants. As people become richer they demand more consumption and a cleaner environment, increasing returns to scale in abatement allows to achieve both of these goals. Working on the same line of argumentation, Egli and Steger (2007) extended the work of Andreoni and Levinson by a dynamic model for the EKC. Focussing on the determination of the turning point and the effictiveness of public policy measures, they showed that IRS of abatement and the peferences for a clean environment determine the turning point of pollutants. Since CO_2 emissions are primarily created by energy production, which is very closely connected to economic growth, abating CO_2 emissions has strong and direct impacts on growth (Kaika and Zervas 2013). This may make abatement of CO_2 more costly an lead to no increasing scales of abatement.

Going beyong the traditional used prodcution-functions which dominated the presented literature on the EKC so far, Kijima et al. (2011) framed the pollution transition with respect to policy choices over time instead of income per capita. Moving from a microeconomic-based perspective they showed hat a classical EKC as well as a N-shaped pollution path is compatible with their model, using CO_2 data for the United Kingdom and China. Gawande et al. (2001) also deviated from the predominant production-based framework to a consumption-based perspective. They showed that for hazardous waste sites the emergence of an EKC may rather be the result a spatial equilibrium by consumption-decisions by perfectly mobile agents. The latter assumption may be problematic in cross-country analysis their model allows for the explanation of an EKC for long-living pollutants which are difficult to abate, which was a considerable step forward compared to traditional production-based models which relied on abatement for the emergence of an EKC.

A theoretical critique not discussed so far is the role of international trade in the EKC literature. Depending whether trade induces scale, or compositon or technology effects dominate, trade might be beneficial for the environment or not, as noted in Frankel and Rose (2005). Research in this field is focused on the question if the hypothesis of a pollution heaven is true or if there is just a pollution heaven effect, as stated in Copeland and Taylor (2004). On the other hand is trade supposed push income upwards which should reduce pollution, if an EKC exists which is also galles a gains from trade hypothesis as mentioned in Frankel and Rose (2005). As Jaunky (2011) notes, international trade allows rich nations to relocate their consumption of dirty goods to the developing world. So those countries can reduce their production of pollution while increasing pollution somewhere else by increasing consumption of imported dirty goods. This can be the result of stricter environmental regualations in the rich countries, which is called the pollution heaven hypothesis in the literature, as in Copeland and Taylor (2004). There are many other factors in deciding where to locate production, except environmental regulation. If these factors dominate, then Copeland and Taylor (2004) speak of an pollution heaven effect. Either way, such a reallocation has considerable effects on the results on the EKC so far. If pollution in the rich countries decreases due to the reallocation of the production of dirty goods, then today's developing countries will not be able to follow a similar income-pollution path due to the lack of countries to shift their dirty production to.

While trade-variables were implemented in the traditional EKC empirical framework, a clear connection between emissions and trade could not be established (citations). In the empirical part of their work Antweiler et al. (2001) estimated the effect of trade on SO_2 emissions to assess the validity of the pollution heaven hypothesis. They also decomposed the effect into its scale, composition and techique effect. Applying GEMS data in a panel framework they reject the pollution heaven hypothesis on the ground that factor endowments dominate trade patterns and not abatement costs. Overall they find a small negative composition effect of trade on SO_2 for an average economy. Together with trade induced growth of income they conclude an positive effect of trade on SO_2 pollution. Using a general equilibrium model which can capture comparative advantage in factor endowments or based on technology, as established in the trade literature, Copeland and Taylor (2004) show that the composition effect determines whether trade is benefical for the environment or not. It is the comparative advantage a country has that determines the composition effect of trade. While there is no emporical evidence for the existence of the pollution heaven hypothesis, they find ample theoretical and empirical support of an pollution heaven effect. Also work on embodied CO_2 emissions in trade, as in Fernández-Amador et al. (2013) and others, gives strong support for the pollution heaven effect as well, since industrialized countries are strong net-importers of CO_2 emissions. Using consumption- as well as production-based inventories for CO_2 emissions, we can provide strong insights into this issue.

3 Empirical framework and previous evidence on the EKC

The standard reduced form model for estimating an EKC in the early literature is well described in Stern (2004), de Bruyn et al. (1998) and Galeotti and Lanza (2005), among others. Most of the early work on the EKC applied an equation for and index of pollution per capita depending on income and quadratic income. The single equation is supposed to capture the effect of income on the before mentioned scale, technology and composition effects as well as factors such as environmental policy. Applying such a direct estimation of income on pollution of course does not allow to analyze the underlying causes of this relationship. To avoid negative pollution, which makes sense in some cases like deforestation only, usually but not exclusively a logarithmic variables were preferred, Grossman and Krueger (1991) being a noteworthy exception:

$$\ln e_{it} = \alpha_i + \gamma_i + \beta_1 \ln y_{it} + \beta_2 (\ln y)^2_{it} + \epsilon_{it} \tag{1}$$

Per capita pollution and income are denoted by e and y respectively, while ϵ is the error-term. Parameters α and γ are country and time effects. It is common to estimate the model as fixed effects as well as random effects model although the first one is more established and sometimes a time trend is included (Galeotti and Lanza 2005). An important, although limited, step to improve this basic model was to estimate a cubic functional form as well in order to assess a potential N-shape of the EKC as well (Galeotti and Lanza 2005). If there is a significant quadratic term, an EKC is assumed and the resulting turning point is given by

$$\tau = \exp\left(-\beta_1 / \left(2\beta_2\right)\right) \tag{2}$$

where there is a maximum in pollution (Stern 2004). (citations) Stern (2004) identified two major issues one can run with such a framework. Correlation between α and γ the explanatary variables. In this case only the fixed effects model can be estimated consitently so lots of studies followed this path after conducting a Hausman (1978) test. This makes the model very dependent on the used sample of countries, however, severely limiting the potential to draw general conclusions from the model results. **cite Stern 04 and use for comparisons of our results and Aichele/Felbermayr** The second type of problems that may arise is connected to use panel data with longer time dimensions and studies that estimated the EKC using time series, since log income per capita and its squared term may be cointegrated, meaning they follow a common stochastic trend, as pointed out also in Müller-Fürstenberger and Wagner (2007). They also find that those studies that tested for cointegration relied mainly on cointegration tests relying on cross-sectional independence of the error term, a wiedely unrealistic assumption for the panel models used by most of these studies. Wagner (2008) shows that applying a second generation cointegration test allowing for cross-sectional correlation can make the difference whether an EKC is found or not and demonstrates this with a study on CO_2 and SO_2.

Concerning the fixed effects model de Bruyn et al. (1998) point out, that the time trend for most pollutants is negative. So estimating equation (1) in a panel framework the resulting EKC may most likely not be able to capture the turning point of an individual country.

In order to connect inequality with the EKC framework, Borghesi (2000) and Scruggs (1998) estimates the effect of inequality on income and CO_2 emissions. The findings are rather inconclusive and depend heavily on the specification of the model. Neither theoretical nor empirical there seems to be a clear relationship betweeen inequality and environmental quality.

As it could be seen estimating the EKC using a polynomial functional form leads to mixed results, especially when applied on a global pollutant such as CO_2. Stern (2004) notes that the econometric framework applied in the EKC literature is plagued by methodological weaknesses. Multicollinearity, especially between GDP p.c. and its squared and cubic transformations, and the use of potentially non-stational variables such as GDP and pollution indicators are the most important ones. The latter problem may cause spurious regressions. These models also implicitly assumed an unidirectional causality from per capita income to environmental pollution.

3.1 The EKC and endogeneities

A potentially important econometric issue that has to be considered when applying the standard reduced-form EKC equation is to account for reversed causality and endogeneity. While assuming implicitly a uni-directional causality from income to emissions, causalities in the other direction or bi-directional causalities are also plausible (Jaunky, 2011), assuming, for example, that richer countries have stricter environmental regulations. Porter and van der Linde (1995) plausible argue that environmental regulation may cause increasing efficiency and, thus, higher income. Higher regulation may also increase production costs and slow economic growth and trade may have a similar effect on income, as it is argued in Frankel and Rose (2005).

The results in the literature on on causality is rather inconclusive. Coondoo and Dinda (2002) were one of the first in the field to focus on the causational relationship between income and emissions by applying Granger causality tests on a paneal of 88 countries for 1960 to 1990. The authors found unidirectional causations in both directions as well as bi-direcitonal relationships, depending on the group of countries analyzed. Soytas et al. (2007) found no Granger causality between income and emissions or income and energy consumption in any direction. But they found clear evidence for engergy consumption Granger causing emissions for the United States, a result also found for seven on 16 countries in a previous work of Soytas and Sari (2003).

Applying a Hausman specification test Cole (2004) concludes that there is no bias from exogeneity due to causality from emissions to income, since the null of exogeneity is accepted. Acaravci and Ozturk (2010) found mixed results on the direction of causality for 19 European countries as well, using error-correction based Granger causality tests. For most countries there is a long-run unidirectional causality running from income to CO_2 emissions. Using a VECM-based causality test Jaunky (2011) finds uni-directional causality from income to emissions in the short- and the long-run.

To account for potential endogeneity of trade and income, Frankel and Rose (2005) instrumented income by lagged income, population size and rates of investment and human capital formation. The resulting IV estimations confirmed their previous OLS results for the relationship between income and several local air pollutants. Their main focus, however, lies on the potential endogeneity of income and trade in the EKC framework.

Emissions by countries and may also be driven by commitments to international climate regimes such as the late Kyoto Protocol by influencing environmental regulations of member states. Following the lines of Aichele and Felbermay (2012) we include Annex I membership of the protocol as control variable in our models. As with most applications on intergouvenmental institutions also Kyoto-commitment may be subject to self-selection and endogeneity which has to be accounted for. Most important for us, income per capita might drive willingness to commit into multilateral institutions. But also trade-related considerations, like endowments and competitiveness considerations, might drive the decision for being a Kyoto Annex I member, making it possible that non-binded developing members would have slowly be driven to Annex I membership as income rises, as memntioned in Copeland and Tailor (2005).

Since the commited countries in the Kyoto-protocial (Annex I) are primarily rich OECD countries, while the non-committed members of the protocol mainly consist of the developing south, per capita production and consumption in both groups might have developed in the same way even if the Kyoto protocol would have never been implemented, simply due to issues of comparative advantage, for example. As Aichele and Felbermayr (2013) pointed out, this may be a potential source of identification failure bias causing spurious results. Implementing a fictious Kyoto ratification in 1997 or 1998 and comparing only developed non-Annex I countries they found no support for identification failures. The authors claim that trade shocks between rich and developing countries would produce biases with opposite direction between both trade partners, limiting the potential for and general upward bias. Using time and country effects should do the rest to avoid identification failure. Closer trade may potentially cause policy coordination and, thus, spurious results. We will follow the approach of Aichele and Felbermayr (2012 and 2013) and address the causality issue with their suggested IV approach.

When it comes to trade and its effect on the environment several authors (citations) noted that the intensity of trade may be determined simultanously by income on pollution. Frankel and Rose (2005) were the first adressing this issue of endogeneity explictly in their work on trade and the environment. Relying on results of the gravity-model they used geographical varibles as instruments for trade and also instrumented income by varibles such as lagged income and population size. They found and EKC for three important air pollutants, changing from OLS to IV, however, did not reverse the results but had considerable effects on the significance of some of the varibles. As previous studies before they found no significant relationship between income or trade and CO_2 emissions, highlighting its role as a global pollutant. In general no negative effect of trade on the environment was found for trade and pollution in their cross-section up to 147 countries using 1990 data. By promoting economic growth trade in any case has a considerably indirect effect on the environment.

3.2 Previous results on the EKC:

Studies of the EKC for various air pollutants are numerous. Special attention shall be given on EKC studies looking at CO_2 emissions, since this is the main topic of this work. Kaika and Zervas (2013) offer a recent and comprehensive summary or studies on the EKC for CO_2 emissions. The field is characterized by mixed, not seldom conflicting, results. Most studies use either panel data or time-series and conclude a monotonic increase of CO_2 emissions with income. Those studies who found an EKC either find it only for a single country, only a part or their sample or used a small sample of rich countries (usually OECD) to begin with. Examples for this first group were Carson et al. (1997), applying cross section on the 50 U.S. states for seven air pollutants, Lindmark (2002) and Jalil and Mahmud (2009) using time series for Sweden and China respectively, the latter finding a positive but insigificant effect of trade on emissions. The results of Carson et al. (1997) could not be replicated by Aldy (2005) using panel data.

Among the earliest studies that found an CO_2-EKCs for (sub-)samples of rich countries were Roberts and Grimes (1997), using cross sections for the years 1962-1991, who found significant turning ponts beginning with 1982, driven by rich countries which became less carbon-intensive jsut before the first oil crisis. Moomaw and Unruh (1997) got similar results applying panel data on 16 OECD countries finding an N-shaped income-pollution path with a very low turning point. Applying a structural transition model they conclude that the external oil-shocks of the 1970s were responsible for the observed emission reductions. Emissiosn remained low but the rich countries managed to regain economic growth after the crises. So the observed N-shape is just the result of polynomial curve-fitting.

Panyotou et al. (2000) and Dijkgraaf and Vollebergh (2001) confirmed the EKC rich countries using panel data, the former authors relying on a panel with a relatively long time frame of 124 years, making it possible complement their study with time series as well. Dijkgraaf and Vollebergh (2001) reject the assumption of homogeneity implied by panel estimations using fixed effects and the spline model first implemented by Schmalensee et al. (1998) in an EKC framework. While claiming their panel results to be inconsitent they still find support for an EKC for 11 of their 24 OECD countries in the sample using time series analysis. Cole (2004) found strong support for an EKC for OECD countries again, putting also special emphasis on the pollution heaven hypothesis in his work, for which he found limited support.

Later studies focussing on OECD countries found only limited support for and EKC within this group as well. Examples are Pauli (2003), who finds only an EKC for CO_2 emissions for 12 of the 29 OECD countries in his sample. Acaravci and Ozturk (2010) find an EKC only for 2 of the analyzed 19 European countries when taking cointegration into account in their time series analysis. Also Jaunky (2011) finds an EKC only for 5 of the 36 high-income countries in his panel dataset by comparing short- and long-rund income elasticities for CO_2 emissions instead of testing for a conventional polynomial equation. By applying a series of tets for cointegration on his panel he detects that CO_2 emissions and income are cointegrated and both integrated by order one. This would explain the more pessimistic results comparing to previous panel studies on rich countries.

The eariest notable exception of studies that found EKCs for broader samples is Schmalensee et al. (1998), who found an EKC for a panel of 140 countries applying a reduced-form model with fixed time and country effects and piecewise linear splines. Also Galeotti and Lanza (1999) found and EKC behavior using panel data for 119 countries relying on alternative non-linear functional forms. Both studies rely on panel data. In light of the results of Müller-Fürstenberg and Wagner (2007) and Wagner (2008) concerning cointegration of income and its squared term and the limitations of the cointegration test available for panel data at that time, those resuls should not be taken too robust. To summarize, essentially the existing literature found only weak support for an EKC for CO_2 emissions which was reduced as the literature and applied methods developed.

4 CO_2 emission data and production- and consumption-based CO_2 inventories

We have adopted a multi-regional input output table (MRIOT) model based on the Global Trade Analysis Project (GTAP) database to compute production- and consumption-based carbon emission inventories applied to the EKC estimations in this paper. The GTAP database is an established source for environmental economic analysis as noted Peters (2008) and Davis et al. (2010) among others. It comprises input-output tables linked by international trade data and investment flows. The sectoral detail of the GTAP database is suitable for MRIOT analysis, and its regional coverage presents some advantages respect to other available MRIOT databases (see Peters et al. (2011), Davis et al. (2010) and Su et al. (2010)).

It is a balanced database, because it is primarily constructed for applied computable general equilibrium analysis. This has some advantages for the construction of a MRIOT model out of the database. However, the magnitude of GTAP data manipulation is unknown and causes uncertainty about the origin of divergences when comparing the dataset with other sources. Moreover, the underlying structural relationships of the database may be older than the suggested benchmark year. The energy volume database, which includes the usage of five energy commodities per sector and the global multi-region input-output table will be the basis for calculating production- and consumption-based emission inventories.

We calculated carbon emissions directly from the energy volume databases of GTAP releases 5, 6 and 8. The GTAP energy volume database is based on International Energy Agency (IEA) data and provides energy usage per country and sector of six energy commodities. McDougall and Lee (2006) offer a more comprehensive description of this database. We followed the revised 1996 guidelines for national greenhouse gas emission of the International Panel of Climate Change, IPCC (1996) to get actual carbon emissions out of the energy consumption per sector. This approach was applied on the GTAP database before by Lee (2002 and 2008). Further sectoral treatment of emissions was given by Ludena (2007).

In order to compute consumption-based emission inventories, the GTAP input-output data was transformed into a MRIOT model following Peters et al (2011). Here only the basic principles of the MRIOT framework will be discussed as it is done, for example, in Peters (2008), Davis and Caldeira (2010) and Davis et al. (2011).

In a multi-regional setting the vector of output of each sector in region r (x_r) can be expressed as

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1m} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2m} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & A_{m3} & \cdots & A_{mm} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} + \sum_r \begin{pmatrix} y_{1r} \\ y_{2r} \\ y_{3r} \\ \vdots \\ y_{mr} \end{pmatrix} , \tag{3}$$

where sub-matrices A_{rs} such that $r = s$ denote normalized domestic requirements matrices and A_{rs} normalized trade in intermediates between region r and s, being $r, s \in [1, m]$ and m the number of regions. y_{rs} denotes vectors of trade to final consumers from region r to s, being y_{rr} the vector of domestically produced and consumed final demand. Since the GTAP database provides us only with bilateral trade data, these data had to be split into trade in intermediaries and trade in final demand. The method to do so is described in Peters et al. (2011).

Rewritting the expression above as $x = Ax + y$ and recognizing that output can also be expressed as $x = (I - A)^{-1}y$ yields the so called Leontief-inverse $(I - A)^{-1}$, where I is the identity matrix. Each element $(I - A)^{-1}_{rs}$ of the Leontief-inverse denotes the direct and indirect inputs needed to produce one unit of output in sector s, as it is also described in Francois et al. (2013). From this setting CO_2 emissions embodied in final consumption f^c_r can be calculated as

$$f^c_r = F \left(I - A\right)^{-1} c_r \ , \tag{4}$$

where F is a row-vector containing regional carbon emissions per unit of output in each sector, and c_r the vector of final consumption

$$c_r = \begin{pmatrix} y_{1r} \\ y_{2r} \\ y_{3r} \\ \vdots \\ y_{mr} \end{pmatrix} , \tag{5}$$

where y_{rr} is again domestic final consumption and y_{sr} are imports in final consumption. Therefore, MRIOT methodology allows us to follow the flows of carbon through sectors and borders to the country where the final product is consumed.

At this place some words should be spend on the system boundary of the used CO_2 inventories in this work. The environmental Inpout-Output analysis used here corresponds to the National Matrix with Environmental Accounts (NAMEA) (see Peters (2008)). While such an approach is quite close to widely reported territorial-based CO_2 inventories, such as reported, for example, by the UNFCCC, the system boundary of both approaches differs in relevant ways. While NAMEA assigns emissions to institutional units, territorial approaches are strictly limited to geographic borders. That leaves emissions from international bunker fuels out of the territorial approach as noted in Peters and Hertwich (2007) and Peters (2008). Also emissions from tourism is not allocated to the country of residence in territorial-based inventories. Depending on the country under consideration, international trade and transport hubs, for example, differences between both approaches might be considerable (see Kanemoto et al. 2012).

We compared our production-based CO_2 emissions inventories with other databases to assess the divergences between our data and computations from other sources and methodologies. In particular, we compared our production-based emissions computations with Lee's (2002 and 2008) calculations, the GTAP 8 emissions database, the Carbon Dioxide Analysis Center (CDIAC) and the US Energy Information Agency (EIA) databases on carbon dioxide emissions based on fossil fuel consumption. We also compared our calculations with those from Davis et al. (2011). Our dataset remains relatively close to them in global terms. Deviations on country levels are larger, though only remarkable in the case of composite regions. Neither global nor individual deviations are different to those existing between those other datasets.

A broad and sophisticated analysis of the difference of production- and consumption-based emission constructed by IO analysis can be found in Peters et al. (2012). While global emissions in all analyzed studies in are relatively close together, considerable variations on country and sectoral level are not uncommon. Instead of being caused by uncertainties in the estimation techniques, differences in the emission inventories presented in the analyzed studies are primarily the result of different input data for the calculation of production-based emissions, different definitions of consumption and different treatment of bunker fuels. Corrected for that, the results of the analyzed studies converged. Our results are within the range of differences observed in Peters et al. (2012), so we consider our database as very robust.

Data for income and population was taken directly from the GTAP database. We calculated deflated GDP per capita since the GTAP database provided GDP in nominal terms only.

5 Econometric specification and results

We estimate three functional forms reflecting three alternative hypothesis about the relationship between CO_2 and income. We did this for both of our emission inventories. The first one is the standard EKC regression model

$$\log(E)_{it} = \alpha_i + \beta_1 \log(y)_{it} + \beta_2(\log(y))^2_{it} + \beta_3(\log(y)^3_{it}) + \gamma' Z\delta d_t + u_{it}, \tag{6}$$

where E is annual CO_2 emissions per capita of country i in period t, y is annual real GDP per capita of country i in period t, Z is a vector of controls, d_t stands for a year dummy vector, and u are the disturbances. We add the cubic term in (6) to allow for a N-shaped form, since it is also standard in the literature. A second alternative is a monotonic (linear) CO_2-income relationship

$$\log(E)_{it} = \alpha_i + \beta_1 \log(y)_{it} + \gamma' Z\delta d_t + u_{it} \tag{7}$$

A third functional form considered is a threshold linear specification

$$\log(E)_{it} = \alpha_i + \beta_{L1} \log(y)_{it} I(q_{it} \leq \tau) + \beta_{U1} \log(y)_{it} I(q_{it} > \tau) + \gamma' Z\delta d_t + u_{it}, \tag{8}$$

where $I(\cdot)$ is an indicator function determining two regimes depending on whether the threshold variable q_{it} is smaller or larger than the threshold τ. q_{it} stands for the Human Development Indicator in period. The threshold is estimated endogenously following the procedure described in Hansen (1999).

In order to assess the robustness of our approach we implemented equation (6) as fixed effects, random effects, between, maximum likelihood and pooled OLS estimators. We included no controls, but used individual- and/or time effects in the models if appropriate. For all the models we were not able to find a significant cubic model indicating an N-shape of and emission-growh path. So we dropped the cubic tern and focused on the squared model. Table (xx) shows the results of the pooled OLS and the fixed effects model without time effects.

We got significant turning points for both inventories in the pooled OLS model, while the fixed effects model did not show a significant squared term. We present the fixed effects model due to a conducted Hausman tests which did not allow us to reject the null of not systematic different residuals. Also the implied turning point of the OLS model lies at the end of sample for production and way out of sampe for consumption, indicating essentially a monotonic increase of CO_2 per capita emissoins with income.

Table 1: Pooled OLS and fixed effects without time effects

	(1) OLS		**(2) FE**	
	prod.	cons.	prod.	cons.
ln Income	3.5984***	2.7702***	0.3979	0.9700**
	(0.2712)	(0.2144)	(0.4823)	(0.3812)
ln Income^2	**-0.1695*** **	**-0.1200*** **	**0.0022**	**-0.0247**
	(0.0164)	(0.0130)	(0.0304)	(0.0240)
Constant	-16.6708***	-13.2218***	-1.3246	-4.4631***
	(1.0922)	(0.8633)	(1.8798)	(1.4858)
Turning Point	40.700	103.000	–	–
N	312	312	312	312
adj.R^2	0.811	0.865	0.983	0.988
R^2	0.8122	0.8657	0.9870	0.9907
F	668.2523	996.2675	222.8683	312.8845
p	0.0000	0.0000	0.0000	0.0000
Ll	-284.6703	-211.2738	131.8374	205.2301
-67.3714	-49.4797			
Aic	575.3406	428.5476	-103.6748	-250.4601
140.7428	104.9595			
Bic	586.5696	439.7766	195.7654	48.9801
151.9718	116.1885			

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The other basic models we estimated confirmed that results (shown in the appendix). The random-effects models produced significant turning points as well, but in this case always out of sample and always higher for consumption. The MLE estimator did not return a significant EKC behavior. The next step is to add a set of theory-guided controls to our preferred two models.

5.1 Used controls, sources and theoretic guidance

Focussing on the pooled OLS and the fixed effects model, we next iclude a set of controls guided by the literature on the EKC into our equations. All other things equal, countries with a different involvement in international trade should show different emission-structures. Grossman and Kruger (2001) were the first who analyzed the impact of trade on the environment. Quite analogue to the overal EKC, trade affects emissions via a scale, a technology and a composition effect. Countries that trade gain income and pollution worsens due to the scale effect.

On the other hand it is likely that the technology effect works against inceasing pollution by stimulating technological progress and the proliferation of cleaner technologies from high regulation countries to developoing countries, as it is mentioned in Frankel and Rose (2005). Antweiler et al. (2001) and Copeland and Taylor (2001) found that overall a beneficial technology effect offsets the scale effect and results in an overal beneficial effect of trade on pollution in the case of SO_2 emissions.

The pollution heaven hypothesis“(PHH) claims that trade is used by rich countries to re-allocate their dirty industries in developing countries, increasing pollution there. Cole (2004) looks especially at this effect of trade which is based on conventional comparative advantage theories and the main driver of the compositon effect. He finds only weak support for this assumption and we do not look at the PHH explicitly.

Frankel and Rose (2005) argue that trade may have a negative effect on global environment by affecting regulations due to the race to the bottom hypothesis“. This means the crowding out of environmental regulation due to competition among trading partners. So overall it is difficult to suggest the sign of trade opennes in an EKC a priori on theoretical grounds. This is also reflected by the studies which included trade opennes in their equations. Cole (2004) finds a negative non-singificant effect of trade on pollution, which is almost close to zero. Also Frankel and Rose (2005) did not find a significant effect of trade opennes on CO_2, althouth their effect was positive.

Following the literature we define trade openness as the sum of the value of exports and imports of a country divided by its GDP. We took the data for the value of national export- and import-values and GDP from the GTAP database.

This leaves us essentially with a linear relationship between carbon dioxide emisssions and income. Since applying Hausman tests did not allow us to stay with the random effects model we relied on fixed effects and the pooled OLS model for further analyisis. For the OLS models we find that controlling for development, polity, population growth, wheter a country is a net exporter of CO_2, trade openness and wether a country is a Annex I member as defined in the Kyoto protocol has the greatest effect on emissions. The whole set of controls that work for consumption as well as production of CO_2 can be found in table x. Two striking facts are worth metioning here. The first is about the trade controls opennes and the dummy for a net exporter of CO_2.

Trade has been an important issue in the literature on the EKC, but including traditional trade controls based on US-Dollars provided only disappointing results (citations). We defined those measures in terms of embodied CO_2 emissions according to our database created by MRIO methodology and they work remarkably well in the case of production as well for consumption. Interestingly, a higher opennes to trade measured by CO_2 emissions is reducing emissions on average, supporting the arguments of (check literature). Being a net exporter of CO_2 increases the emissions of a country of course. Supporting our argumentation, however, is that both controls have far lesser effects when we look at consumption of CO_2. So being an open economy has a stronger effect on the CO_2 a country produces but a less strong effect on its consumption.

However, while we found a set of strong controls, an xx-test (check) does not allow us to prefer the pooled OLS over the fixed effects model. This is unfortunate limiting our ability of economic interpretation of our results. So, although have found a set of significant controls which allow us some important insights, in the end we have to stay with the fixed effects model. In the fixed effects model only a limited set of controls was significant, so we stayed with a reduced set of controls that were significant in the production case. We also stayed with the Annex I dummy due to its importance.

As it can be seen in table (x) the fixed effects model, including time effects as well, estimate a lower constant but a higher increase for the consumption-based CO_2 emissions than for the production based ones. This is a strong argument that supports our hypothesis that there is a systematic difference in the production- and consumption-pattern of CO_2 among developing and rich countries. While rich countries reduce their production of CO_2 emissions after they reach a certain income, their consumption of emissions is almost not affected by this. As Stern (2004) argued, rich countries simply have slower rates of growth than emerging markets (see Stern 2004) and thus the technology and substitution effect can outweigh the scale effect of increasing pollution, this results in reduced emissions of rich countries even if there is no Kuznets-Curve. Our Analysis renders such an argumentation obsolete, since there is strong support that consumption of CO_2 is hardly affected, if it is affected at all, in high income countries. So after reaching a certain income level countries seem just to export their pollution to the emerging markets.

Our results seem to be fairly robust, but depend on the the time effect used in the fixed effects models. To further asses the robustness of our findings wie will implement a threshold model in our framework which confirmed/not confirmed our linear results.

5.2 Scenarios of $\mathrm{CO_2}$ and economic growth

We now carry out a prediction exercise based on the estimated EKC for production-based and consumption-based $\mathrm{CO_2}$ emissions and GDP growth. We assume several scenarios of economic growth for the horizon 2020 based on our model. The selection of 2020 as our horizon allows us to further assume constant technology and policy frameworks, since changes in both require some time to impact in the economy. We will confront the scenarios implied by our estimations of the EKC with two projections based on our CGE model. The first one assuming constant sector shares per country based on 2007 data. The second one pressumes changes in sectoral weights by using the rate of change underlined by the trend over the 1997-2007 period. Thus, those rates of change are extrapolated to the horizon 2020, ensuring that those weights add 100% on the national basis.

6 Conclusion

Finally, it should be noted that the pollution-income relationship is a complex one affected by the multiple factors that form the economic-environmental system. Reduced forms are unable to discriminate among the main factors governing the shape of such a relationship, and to offer insights for specific policy design. The dataset here presented leaves several doors open for future research on a sectoral dimension, as well as for structural analysis based on general equilibrium simulations.

Table 2: Final pooled OLS and FE models with controls

	OLS Prod.	OLS Cons.	OLS Prod.	OLS Cons.	FE Prod.	FE Cons.	FE Prod.	FE Cons.
ln Income	1.7185***	1.1044***	3.3833***	2.7512***	0.4017***	0.5166***	0.3131**	0.5446***
	(0.4523)	(0.3942)	(0.2735)	(0.2178)	(0.1326)	(0.1492)	(0.1281)	(0.1552)
ln Income^2	-0.0803***	-0.0425*	-0.1614***	-0.1239***	—	—	—	—
	(0.0258)	(0.0225)	(0.0165)	(0.0132)	—	—	—	—
Pop. density	-0.0001*	-0.0000	-0.0001**	0.0000	-0.0009***	-0.0008***	-0.0006*	-0.0008***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0003)	(0.0002)	(0.0003)	(0.0001)
Trade openness	0.2750***	0.2624***	0.3327***	0.2784***	0.0435	0.0549	0.0648	0.0445
	(0.0588)	(0.0542)	(0.0713)	(0.0584)	(0.0556)	(0.0487)	(0.0486)	(0.0512)
Annex I	0.3021***	0.3495***	0.3315***	0.3761***	0.0006	0.0505	-0.0405	0.0265
	(0.0700)	(0.0631)	(0.0816)	(0.0651)	(0.0529)	(0.0469)	(0.0467)	(0.0348)
Fossil fuels %	0.0048***	0.0035***	0.0086***	0.0052***	0.0092***	0.0075***	0.0107***	0.0078***
	(0.0009)	(0.0008)	(0.0010)	(0.0008)	(0.0022)	(0.0021)	(0.0020)	(0.0019)
Dirty Sectors %	0.0121**	0.0180***			0.0091*	0.0055		
	(0.0054)	(0.0043)			(0.0048)	(0.0041)		
VA Industry %	0.0287***	0.0318***			-0.0029	0.0013		
	(0.0094)	(0.0081)			(0.0095)	(0.0071)		
VA Services %	0.0291***	0.0315***			-0.0029	-0.0004		
	(0.0097)	(0.0085)			(0.0077)	(0.0058)		
NX CO_2	0.6300***	0.2900***			0.1810***	-0.0129		
	(0.0573)	(0.0468)			(0.0567)	(0.0395)		
Middle Dev.	0.5608***	0.4904***			0.0919	0.1099		
	(0.1487)	(0.1260)			(0.1104)	(0.1114)		
High Dev.	0.8274***	0.7682***			0.1283	0.1808		
	(0.1845)	(0.1630)			(0.1448)	(0.1315)		
Very high Dev.	1.1156***	0.9363***			0.2530	0.1916		
	(0.2126)	(0.1867)			(0.1620)	(0.1452)		
2001	-0.1038	-0.1134*	-0.1154	-0.0957	-0.0617**	-0.0714**	-0.0756**	-0.0725**
	(0.0686)	(0.0598)	(0.0908)	(0.0731)	(0.0301)	(0.0286)	(0.0319)	(0.0291)
2004	-0.3007***	-0.2895***	-0.2438**	-0.2401***	-0.0203	-0.0470	0.0078	-0.0378
	(0.0792)	(0.0693)	(0.0995)	(0.0795)	(0.0427)	(0.0401)	(0.0439)	(0.0444)
2007	-0.3844***	-0.3600***	-0.3311***	-0.2953***	-0.0244	-0.0537	0.0070	-0.0375
	(0.0801)	(0.0699)	(0.1015)	(0.0811)	(0.0541)	(0.0505)	(0.0555)	(0.0601)
Constant	-11.5993***	-9.2108***	-16.0087***	-13.1487***	-2.6371**	-3.5251***	-1.8691*	-3.4755***
	(1.3708)	(1.2006)	(1.0965)	(0.8612)	(1.2068)	(1.1719)	(1.0547)	(1.2647)
Turning Point	44,377.96	439,301.47	35,635.69	66,336.93				
Observations	312	312	312	312	312	312	312	312
Adj. R^2	0.915	0.925	0.856	0.895	0.342	0.436	0.247	0.425
R^2	0.9194	0.9285	0.8606	0.8982	0.3738	0.4630	0.2662	0.4398
rho					0.9815	0.9835	0.9778	0.9830
F	216.0974	309.6581	201.0494	326.6941	10.7697	22.1750	18.3750	30.7541
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LL	-152.6731	-112.9777	-238.1851	-168.1525	184.2974	248.1342	159.5519	241.5354
Aic	339.3461	259.9555	496.3703	356.3051	-338.5947	-466.2684	-303.1039	-467.0709
Bic	402.9772	323.5865	533.8003	393.7351	-282.4497	-410.1234	-273.1598	-437.1268

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Final IV models for pooled OLS and FE

	OLS Prod. IV	OLS Cons. IV	FE Prod. IV	FE Cons. IV
ln Income	1.7855***	1.1805***	0.2951**	0.5619***
	(0.4662)	(0.4145)	(0.1314)	(0.1011)
ln Income^2	-0.0839***	-0.0465*	—	—
	(0.0277)	(0.0246)	—	—
Pop. density	-0.0000	-0.0000	-0.0006**	-0.0007***
	(0.0000)	(0.0000)	(0.0002)	(0.0002)
Trade openness	0.2403***	0.2189***	0.0144	0.0074
	(0.0779)	(0.0692)	(0.0781)	(0.0600)
Annex I	0.4897***	0.5836***	0.0554	0.0989**
	(0.1279)	(0.1137)	(0.0631)	(0.0485)
Fossil Fuels %	0.0050***	0.0037***	0.0107***	0.0077***
	(0.0009)	(0.0008)	(0.0023)	(0.0018)
Dirty Sectors %	0.0137***	0.0200***		
	(0.0048)	(0.0043)		
VA Industry %	0.0279***	0.0309***		
	(0.0079)	(0.0071)		
VA Services %	0.0267***	0.0286***		
	(0.0083)	(0.0074)		
NX of CO_2	0.6221***	0.2801***		
	(0.0571)	(0.0508)		
Middle Dev.	0.5505***	0.4786***		
	(0.1255)	(0.1116)		
High Dev.	0.7878***	0.7199***		
	(0.1642)	(0.1460)		
Very high Dev.	1.0739***	0.8841***		
	(0.2049)	(0.1821)		
2001	-0.1032	-0.1129*	-0.0785***	-0.0772***
	(0.0670)	(0.0595)	(0.0298)	(0.0229)
2004	-0.3620***	-0.3661***	-0.0223	-0.0654**
	(0.0796)	(0.0707)	(0.0398)	(0.0306)
2007	-0.4446***	-0.4352***	-0.0193	-0.0660*
	(0.0806)	(0.0716)	(0.0505)	(0.0388)
Constant	-11.7573***	-9.3859***	-1.7090	-3.6008***
	(1.4493)	(1.2885)	(1.0611)	(0.8159)
Turning Point	41,799.67	325,640.21		
Observations	312	312	312	312
rho			0.9773	0.9815
F				
p			0.0000	0.0000
LL	379.2856	415.9825		
Aic	-700.5712	-773.9650	.	.
Bic	-592.0241	-665.4179	.	.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Models 1-3

	OLS Prod.	OLS Cons.	FE Prod.	FE Cons.	RE Prod.	RE Cons.
linc	0.0608	0.0005	0.1285	0.4750	0.1606	-0.0060
	(0.2856)	(0.2480)	(0.3376)	(0.3297)	(0.5904)	(0.4921)
lincp2	0.0456***	0.0477***	0.0180	0.0042	0.0380	0.0469*
	(0.0158)	(0.0137)	(0.0196)	(0.0191)	(0.0326)	(0.0272)
Polity	-0.0145***	-0.0154***	0.0079*	0.0102**	-0.0200**	-0.0221***
	(0.0042)	(0.0037)	(0.0044)	(0.0043)	(0.0083)	(0.0069)
Opennes CO2	-0.4691***	-0.1292**	-0.5973***	-0.0813	-0.4552***	-0.1912*
	(0.0602)	(0.0523)	(0.0682)	(0.0666)	(0.1262)	(0.1052)
Fossil Fuel %	0.0038***	0.0031***	0.0085***	0.0071***	0.0031***	0.0024**
	(0.0006)	(0.0005)	(0.0019)	(0.0019)	(0.0011)	(0.0009)
NX of CO2	0.5348***	0.2560***	0.1624***	-0.0044	0.6569***	0.3282***
	(0.0409)	(0.0355)	(0.0344)	(0.0336)	(0.0885)	(0.0737)
Annex I	0.1276**	0.1378***	-0.0189	0.0028	0.2937	0.3167*
	(0.0586)	(0.0509)	(0.0364)	(0.0355)	(0.2024)	(0.1687)
Development	0.0569	0.0157	0.0114	0.0153	0.1011	0.0747
	(0.1005)	(0.0873)	(0.0702)	(0.0685)	(0.2429)	(0.2025)
Pop. Growth	-0.1651***	-0.1551***	-0.0352	-0.0231	-0.1556***	-0.1494***
	(0.0211)	(0.0183)	(0.0255)	(0.0249)	(0.0471)	(0.0392)
Dirty Sectors %	0.0109***	0.0122***	0.0031	0.0015	0.0128*	0.0165***
	(0.0031)	(0.0027)	(0.0030)	(0.0030)	(0.0065)	(0.0054)
Agriculture	-0.0249***	-0.0211***	-0.0002	-0.0029	-0.0271***	-0.0230***
	(0.0048)	(0.0042)	(0.0049)	(0.0048)	(0.0097)	(0.0081)
Skilled Labor %	0.5368	0.7608*	0.3455	0.2177	0.9924	1.1818
	(0.4625)	(0.4015)	(0.3868)	(0.3778)	(1.0062)	(0.8388)
1997bn.yr	.	.	.	.	.	.
	.	.	.	.	.	.
2001.yr	-0.1865***	-0.2050***	-0.0805***	-0.1379***	.	.
	(0.0484)	(0.0421)	(0.0289)	(0.0282)	.	.
2004.yr	-0.2820***	-0.3004***	-0.0365	-0.1265***	.	.
	(0.0499)	(0.0433)	(0.0395)	(0.0386)	.	.
2007.yr	-0.4479***	-0.4607***	-0.0679	-0.1892***	.	.
	(0.0535)	(0.0464)	(0.0575)	(0.0562)	.	.
Constant	-3.0267**	-2.8044**	-1.7228	-3.7218**	-3.7231	-3.0943
	(1.3826)	(1.2004)	(1.5465)	(1.5106)	(2.8800)	(2.4008)
Observations	312	312	312	312	312	312
Adjusted R^2	0.954	0.960	0.9903	0.9894	0.965	0.973
r2	0.9562	0.9622	0.9932	0.9925	0.9709	0.9769
rho			0.9715	0.9531		
F	430.6046	502.2628	17.0740	11.1119	180.4734	228.7155
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll	-57.6548	-13.5655	232.0908	239.4185	2.0808	16.2761
aic	147.3095	59.1311	-432.1816	-446.8370	21.8385	-6.5522
bic	207.1976	119.0191	-372.2936	-386.9489	70.4975	42.1069

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Models 4-7

	Walhus P.	Walhus C.	Amemiya P.	Amemiya C.	Swar P.	Swar C.	MLE Prod.	MLE Cons.
main								
linc	0.7335**	0.0992	0.7322**	0.0985	0.7793*	0.9708***	0.0826	0.3364
	(0.318)	(0.2158)	(0.3178)	(0.2157)	(0.3986)	(0.3242)	(0.2938)	(0.2705)
lincp2	0.0052	0.043***	0.0053	0.043***	-0.0088	-0.015	0.0466***	0.0307**
	(0.0172)	(0.0116)	(0.0171)	(0.0116)	(0.0216)	(0.0175)	(0.0163)	(0.0150)
Polity	-0.0179***	-0.0161***	-0.0179***	-0.0161***	0.0081	0.0097*	0.0048	0.0046
	(0.0061)	(0.0041)	(0.0061)	(0.0041)	(0.0065)	(0.0054)	(0.0044)	(0.0041)
Opennes CO2	0.1085	0.0525	0.1087	0.0526	0.0076	0.0084	-0.5266***	-0.0523
	(0.0775)	(0.0526)	(0.0774)	(0.0525)	(0.0501)	(0.0432)	(0.0605)	(0.0556)
Fossil Fuel %	0.0077***	0.0046***	0.0077***	0.0046***	0.0084***	0.0052***	0.0057***	0.0049***
	(8e-04)	(6e-04)	(8e-04)	(6e-04)	(0.0016)	(0.0012)	(0.0011)	(0.0009)
NX of CO2	0.1184**	0.074**	0.1183**	0.0739**	0.0404	0.0376	0.2618***	0.0783**
	(0.0549)	(0.0372)	(0.0548)	(0.0372)	(0.0331)	(0.0286)	(0.0358)	(0.0332)
Annex I	0.1089	0.0177	0.1088	0.0176	0.043	-0.003	0.0032	0.0298
	(0.0698)	(0.0474)	(0.0698)	(0.0474)	(0.0604)	(0.0512)	(0.0365)	(0.0344)
Development	0.0894	0.0608	0.0887	0.0605	0.0647	0.0499	-0.0059	-0.0143
	(0.1048)	(0.0711)	(0.1047)	(0.0711)	(0.0763)	(0.0654)	(0.0713)	(0.0673)
Pop. Growth	-0.2328***	-0.1851***	-0.2328***	-0.1851***	-0.1559***	-0.1023***	-0.1120***	-0.0958***
	(0.0289)	(0.0196)	(0.0289)	(0.0196)	(0.033)	(0.0273)	(0.0230)	(0.0215)
Dirty Sectors %	0.0045	0.0098***	0.0045	0.0098***	0.0112***	0.0082**	0.0067**	0.0054**
	(0.0041)	(0.0028)	(0.0041)	(0.0028)	(0.0043)	(0.0036)	(0.0029)	(0.0027)
Agriculture	-0.0249***	-0.0211***	-0.0002	-0.0029	-0.0271***	-0.0230***	-0.0085*	-0.0100**
	(0.0065)	(0.0044)	(0.0065)	(0.0044)	(0.0068)	(0.0057)	(0.0047)	(0.0044)
Skilled Labor %	-0.326	-0.19	-0.3277	-0.1909	0.4355	0.4629*	0.5545	0.4423
	(0.3953)	(0.2683)	(0.3951)	(0.2682)	(0.275)	(0.2363)	(0.3779)	(0.3539)
1997bn.yr	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.
2001.yr						.		
					.	.	(0.0250)	(0.0236)
2004.yr					.	.	-0.2272***	-0.2678***
					.	.	(0.0277)	(0.0257)
2007.yr					.	.	-0.3765***	-0.4171***
					.	.	(0.0333)	(0.0303)
Constant	-5.9099***	-3.2475***	-5.9045***	-3.2446***	-5.9494***	-6.8365***	-3.4895**	-4.5099***
	(1.5312)	(1.0403)	(1.5305)	(1.0399)	(1.8805)	(1.5315)	(1.3718)	(1.2678)
sigma_u								
Constant							0.3136***	0.2625***
							(0.0306)	(0.0262)
sigma_e								
Constant							0.1455***	0.1386***
							(0.0071)	(0.0068)
Observations	312	312	312	312	312	312	312	312
Adjusted R^2	0.87095	0.91225	0.87106	0.91232	0.57262	0.71837		
r2	0.90882	0.95192	0.90893	0.95199	0.59752	0.7496		
rho							0.8229	0.7820
F	248.339	493.295	248.69	494.034	36.9911	74.5913		
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll							42.7066	67.3591
aic							-49.4131	-98.7181
bic							17.9609	-31.3441

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Models 1-3

	OLS Prod.	OLS Cons.	FE Prod.	FE Cons.	RE Prod.	RE Cons.
linc	0.8776***	0.8550***	0.4272***	0.5447***	0.8415***	0.8349***
	(0.0419)	(0.0366)	(0.0897)	(0.0875)	(0.0849)	(0.0717)
Polity	-0.0152***	-0.0161***	0.0078*	0.0102**	-0.0210**	-0.0233***
	(0.0043)	(0.0037)	(0.0044)	(0.0043)	(0.0082)	(0.0070)
Opennes CO2	-0.4413***	-0.1001*	-0.6099***	-0.0843	-0.4327***	-0.1634
	(0.0602)	(0.0526)	(0.0668)	(0.0651)	(0.1250)	(0.1055)
Fossil Fuel %	0.0040***	0.0033***	0.0084***	0.0071***	0.0033***	0.0027***
	(0.0006)	(0.0006)	(0.0019)	(0.0019)	(0.0011)	(0.0010)
NX of CO2	0.5458***	0.2675***	0.1632***	-0.0042	0.6711***	0.3457***
	(0.0413)	(0.0360)	(0.0344)	(0.0335)	(0.0878)	(0.0741)
Annex I	0.1552***	0.1667***	-0.0064	0.0057	0.3214	0.3509**
	(0.0586)	(0.0512)	(0.0338)	(0.0329)	(0.2015)	(0.1700)
Development	0.1969**	0.1623**	0.0273	0.0190	0.2489	0.2573
	(0.0892)	(0.0779)	(0.0680)	(0.0663)	(0.2077)	(0.1753)
Pop. Growth	-0.1595***	-0.1493***	-0.0319	-0.0223	-0.1538***	-0.1472***
	(0.0212)	(0.0186)	(0.0252)	(0.0246)	(0.0472)	(0.0398)
Dirty Sectors %	0.0109***	0.0122***	0.0029	0.0015	0.0126*	0.0162***
	(0.0031)	(0.0027)	(0.0030)	(0.0030)	(0.0066)	(0.0055)
Agriculture	-0.0200***	-0.0161***	0.0012	-0.0026	-0.0227**	-0.0175**
	(0.0046)	(0.0040)	(0.0046)	(0.0045)	(0.0089)	(0.0075)
Skilled Labor %	1.0301**	1.2769***	0.3336	0.2149	1.5163*	1.8288**
	(0.4351)	(0.3801)	(0.3864)	(0.3768)	(0.9027)	(0.7616)
1997bn.yr	.	.	.	.	.	.
	.	.	.	.	.	.
2001.yr	-0.1836***	-0.2020***	-0.0727***	-0.1361***	.	.
	(0.0490)	(0.0428)	(0.0276)	(0.0269)	.	.
2004.yr	-0.2860***	-0.3046***	-0.0247	-0.1238***	.	.
	(0.0505)	(0.0441)	(0.0373)	(0.0364)	.	.
2007.yr	-0.4455***	-0.4581***	-0.0492	-0.1848***	.	.
	(0.0541)	(0.0473)	(0.0537)	(0.0524)	.	.
Constant	-6.8711***	-6.8264***	-2.9318***	-4.0036***	-6.9691***	-7.1030***
	(0.3820)	(0.3337)	(0.8103)	(0.7901)	(0.7340)	(0.6193)
Observations	312	312	312	312	312	312
Adjusted R^2	0.953	0.959	0.9903	0.9894	0.965	0.972
r2	0.9549	0.9606	0.9931	0.9925	0.9703	0.9758
rho			0.9734	0.9542		
F	449.6327	517.8667	18.2464	11.9540	195.6946	241.9752
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll	-61.9963	-19.8305	231.4917	239.3843	1.2743	14.5275
aic	153.9927	69.6610	-432.9834	-448.7686	21.4514	-5.0550
bic	210.1377	125.8060	-376.8383	-392.6236	66.3675	39.8610

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Models 4-7

	Walhus P.	Walhus C.	Amemiya P.	Amemiya C.	Swar P.	Swar C.	MLE Prod.	MLE Cons.
main								
linc	0.8296***	0.8858***	0.8299***	0.886***	0.6211***	0.6926***	0.9131***	0.8831***
	(0.0493)	(0.0343)	(0.0493)	(0.0342)	(0.0572)	(0.0465)	(0.0469)	(0.0420)
Polity	-0.0179***	-0.0158***	-0.0179***	-0.0158***	0.0081	0.01*	0.0049	0.0048
	(0.0061)	(0.0042)	(0.0061)	(0.0042)	(0.0064)	(0.0054)	(0.0044)	(0.0042)
Opennes CO2	0.1108	0.071	0.111	0.0711	0.0087	0.0097	-0.5321***	-0.0534
	(0.077)	(0.0535)	(0.0769)	(0.0534)	(0.0501)	(0.043)	(0.0616)	(0.0560)
Fossil Fuel %	0.0077***	0.0045***	0.0077***	0.0045***	0.0085***	0.0053***	0.0056***	0.0048***
	(8e-04)	(6e-04)	(8e-04)	(6e-04)	(0.0016)	(0.0012)	(0.0011)	(0.0009)
NX of CO2	0.1197**	0.0846**	0.1196**	0.0846**	0.0403	0.0362	0.2672***	0.0803**
	(0.0546)	(0.0379)	(0.0546)	(0.0379)	(0.0331)	(0.0284)	(0.0361)	(0.0332)
Annex I	0.109	0.0185	0.1089	0.0184	0.0433	-0.0026	0.0330	0.0481
	(0.0697)	(0.0484)	(0.0697)	(0.0484)	(0.0604)	(0.051)	(0.0353)	(0.0332)
Development	0.0879	0.0495	0.0873	0.0492	0.066	0.0504	0.0610	0.0323
	(0.1045)	(0.0726)	(0.1044)	(0.0725)	(0.0763)	(0.0651)	(0.0683)	(0.0635)
Pop. Growth	-0.2305***	-0.1663***	-0.2305***	-0.1663***	-0.1584***	-0.1046***	-0.1049***	-0.0900***
	(0.0279)	(0.0194)	(0.0279)	(0.0194)	(0.0327)	(0.0269)	(0.0231)	(0.0214)
Dirty Sectors %	0.0045	0.0103***	0.0045	0.0103***	0.0113***	0.0084**	0.0067**	0.0053*
	(0.0041)	(0.0028)	(0.004)	(0.0028)	(0.0043)	(0.0036)	(0.0029)	(0.0027)
Agriculture	-0.0273***	-0.0192***	-0.0273***	-0.0192***	-0.0069	-0.0103*	-0.0047	-0.0073*
	(0.0062)	(0.0043)	(0.0062)	(0.0043)	(0.0064)	(0.0054)	(0.0046)	(0.0042)
Skilled Labor %	-0.3431	-0.3273	-0.3447	-0.3283	0.4372	0.4703**	0.6859*	0.5412
	(0.3908)	(0.2714)	(0.3906)	(0.2713)	(0.2751)	(0.2351)	(0.3794)	(0.3526)
1997bn.yr							.	.
							.	.
2001.yr							-0.1735***	-0.2054***
							(0.0253)	(0.0236)
2004.yr							-0.2198***	-0.2631***
							(0.0281)	(0.0258)
2007.yr							-0.3634***	-0.4086***
							(0.0337)	(0.0304)
Constant	-6.348***	-6.8324***	-6.35***	-6.8336***	-5.2443***	-5.5649***	-7.2109***	-6.9722***
	(0.5411)	(0.3786)	(0.5413)	(0.379)	(0.6136)	(0.5015)	(0.4443)	(0.3988)
sigma_u								
Constant							0.3181***	0.2681***
							(0.0312)	(0.0264)
sigma_e								
Constant							0.1473***	0.1389***
							(0.0072)	(0.0068)
Observations	312	312	312	312	312	312	312	312
Adjusted R^2	0.87384	0.91313	0.87394	0.91319	0.5769	0.71513		
r2	0.9088	0.94966	0.90889	0.94972	0.59998	0.74374		
rho							0.8234	0.7884
F	271.762	514.475	272.08	515.104	40.9058	79.1527		
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll							38.6624	65.2845
aic							-43.3248	-96.5691
bic							20.3063	-32.9380

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Models 1-4 without controls

	OLS Prod.	OLS Cons.	FE Prod.	FE Cons.	RE Prod.	RE Cons.	BE Prod.	BE Cons.
linc	2.1902***	1.3133***	0.1953	0.7089***	1.2855***	1.4948***	2.2183***	1.1823**
	(0.3588)	(0.2617)	(0.3423)	(0.2637)	(0.3697)	(0.2968)	(0.7052)	(0.4976)
lincp2	-0.0656***	-0.0167	0.0137	-0.0046	-0.0369*	-0.0447***	-0.0656	-0.0077
	(0.0206)	(0.0150)	(0.0204)	(0.0157)	(0.0208)	(0.0168)	(0.0405)	(0.0286)
Constant	-13.1886***	-9.2294***	-0.4540	-3.8677***	-7.3715***	-8.5215***	-13.4415***	-8.7911***
	(1.5400)	(1.1232)	(1.5837)	(1.2200)	(1.6320)	(1.3061)	(3.0208)	(2.1315)
Observations	312	312	312	312	312	312	312	312
Adjusted R^2	0.831	0.897	0.983	0.989			0.856	0.918
r2	0.8323	0.8979	0.9878	0.9917			0.8595	0.9201
rho					0.8885	0.8627		
F	766.8722	1358.8836	226.2207	334.3944			229.4875	431.8543
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll	-267.0097	-168.5425	141.8831	223.2868			-59.2590	-32.0600
aic	540.0195	343.0849	-117.7661	-280.5736	.	.	124.5179	70.1201
bic	551.2485	354.3139	192.9032	30.0957	.	.	135.7470	81.3491

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Models 5-8 without controls

	Walhus P.	Walhus C.	Amemiya P.	Amemiya C.	Swar P.	Swar C.	MLE Prod.	MLE Cons.
main								
linc	1.6992***	1.6059***	0.6161*	1.042***	1.4948***	1.4948***	0.7924**	1.1579***
	(0.3826)	(0.3001)	(0.3317)	(0.2629)	(0.2968)	(0.2968)	(0.3570)	(0.2791)
lincp2	-0.0514**	-0.0429**	-0.0125	-0.0328**	-0.0447***	-0.0447***	-0.0190	-0.0363**
	(0.0217)	(0.0171)	(0.0185)	(0.0147)	(0.0168)	(0.0168)	(0.0195)	(0.0153)
Constant	-9.9124***	-9.6805***	-3.3422**	-5.4091***	-8.5215***	-8.5215***	-4.3978***	-6.1639***
	(1.6709)	(1.3058)	(1.4891)	(1.1803)	(1.3061)	(1.3061)	(1.6477)	(1.2865)
sigma_u								
Constant							0.8915***	0.7123***
							(0.0910)	(0.0744)
sigma_e								
Constant							0.1903***	0.1510***
							(0.0096)	(0.0077)
Observations	312	312	312	312	312	312	312	312
Adjusted R^2	0.5863	0.7406	0.2234	0.387	0.6109	0.6109		
r2	0.592	0.7478	0.2255	0.3908	0.6168	0.6168		
rho							0.9564	0.9570
F	224.211	458.091	44.9892	99.0951	121.118	248.729		
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ll							-99.9584	-28.3114
aic							209.9167	66.6227
bic							228.6317	85.3377

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Final models for IV estimations

	OLS Prod. IV	OLS Cons. IV	FE Prod. IV	FE Cons. IV
main				
linc_g	2.1260***	1.5890**	0.7141***	0.8611***
	(0.6481)	(0.6479)	(0.1214)	(0.1237)
linc_gp2	-0.1009***	-0.0683*		
	(0.0384)	(0.0384)		
hdi_vld			-0.1129	-0.1485**
			(0.0689)	(0.0702)
opn_usd	0.4652***	0.2490***	0.2105***	0.1085
	(0.0950)	(0.0949)	(0.0680)	(0.0692)
opn_co2	-0.5830***	-0.1566	-0.7333***	-0.1754**
	(0.0971)	(0.0971)	(0.0712)	(0.0725)
ann_i	0.8599***	0.9850***	0.0926	0.1425**
	(0.2631)	(0.2630)	(0.0703)	(0.0716)
nx_co2	0.4506***	0.2086***	0.1806***	0.0151
	(0.0614)	(0.0614)	(0.0371)	(0.0378)
pop_gr	-0.1400***	-0.1162***		
	(0.0419)	(0.0419)		
out_dirty	0.0218***	0.0233***		
	(0.0055)	(0.0055)		
va_ind	0.0229**	0.0241**		
	(0.0096)	(0.0096)		
va_ser	0.0192**	0.0209**		
	(0.0096)	(0.0096)		
foss_shr	0.0045***	0.0042***		
	(0.0009)	(0.0009)		
nx_foss	0.0715	0.0548		
	(0.0646)	(0.0646)		
1bn.hdi_l	.	.		
	.	.		
2.hdi_l	-0.2825**	-0.2005		
	(0.1436)	(0.1436)		
3.hdi_l	-0.4039**	-0.3191*		
	(0.1801)	(0.1800)		
4.hdi_l	-0.5408**	-0.5423**		
	(0.2199)	(0.2198)		
2001.yr	-0.0708	-0.1130*	-0.0322	-0.0890***
	(0.0677)	(0.0677)	(0.0261)	(0.0266)
2004.yr	-0.3069***	-0.3440***	-0.0223	-0.1050***
	(0.0834)	(0.0834)	(0.0336)	(0.0342)
2007.yr	-0.5066***	-0.5519***	-0.0648	-0.1719***
	(0.1137)	(0.1137)	(0.0474)	(0.0482)
Constant	-11.5409***	-9.6498***	-4.3695***	-5.7596***
	(2.0587)	(2.0579)	(1.0066)	(1.0255)
Observations	312	312	312	312
Adjusted R^2				
r2				
rho			0.9351	0.9204
F				
p			0.0000	0.0000
ll	-254.7296	-254.6172		
aic	573.4591	573.2343	.	.
bic	693.2352	693.0104	.	.

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Final models for IV estimations

	OLS Prod. IV	OLS Cons. IV	FE Prod. IV	FE Cons. IV
main				
linc_g	0.7725***	0.7633***	0.7141***	0.8611***
	(0.0683)	(0.0648)	(0.1214)	(0.1237)
opn_usd	0.5058***	0.2913***	0.2105***	0.1085
	(0.0874)	(0.0829)	(0.0680)	(0.0692)
opn_co2	-0.6178***	-0.1780**	-0.7333***	-0.1754**
	(0.0880)	(0.0835)	(0.0712)	(0.0725)
ann_i	0.0973	0.3168	0.0926	0.1425**
	(0.2426)	(0.2300)	(0.0703)	(0.0716)
hdi_vld			-0.1129	-0.1485**
			(0.0689)	(0.0702)
nx_co2	0.4564***	0.2125***	0.1806***	0.0151
	(0.0564)	(0.0535)	(0.0371)	(0.0378)
pop_gr	-0.2510***	-0.2108***		
	(0.0373)	(0.0354)		
out_dirty	0.0121**	0.0145***		
	(0.0051)	(0.0049)		
va_ind	0.0172***	0.0137**		
	(0.0065)	(0.0062)		
va_ser	0.0102	0.0079		
	(0.0072)	(0.0068)		
foss_shr	0.0044***	0.0042***		
	(0.0008)	(0.0008)		
nx_foss	0.0457	0.0353		
	(0.0591)	(0.0560)		
1bn.hdi_l	.	.		
	.	.		
2.hdi_l	0.3539***	0.3264***		
	(0.1009)	(0.0957)		
3.hdi_l	0.4385***	0.4024***		
	(0.1518)	(0.1440)		
4.hdi_l	0.3765*	0.2908		
	(0.2197)	(0.2083)		
2001.yr	-0.0498	-0.0883	-0.0322	-0.0890***
	(0.0621)	(0.0589)	(0.0261)	(0.0266)
2004.yr	-0.0779	-0.1394*	-0.0223	-0.1050***
	(0.0785)	(0.0745)	(0.0336)	(0.0342)
2007.yr	-0.1357	-0.2210**	-0.0648	-0.1719***
	(0.1078)	(0.1022)	(0.0474)	(0.0482)
Constant	-6.9534***	-6.7212***	-4.3695***	-5.7596***
	(0.4544)	(0.4309)	(1.0066)	(1.0255)
Observations	312	312	312	312
Adjusted R^2				
r2				
rho			0.9351	0.9204
F				
p			0.0000	0.0000
ll	-229.1482	-212.5352		
aic	520.2964	487.0703	.	.
bic	636.3295	603.1034	.	.

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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7 Appendix: