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The Impact of Trade and Economic Growth on the Environment: Revisiting the Cross-Country Evidence

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The Impact of Trade and Economic Growth on the Environment: Revisiting the Cross-Country Evidence

Awudu Abdulai, Linda Ramcke

Abstract:
This paper explores the interrelations between economic growth, international trade and environmental degradation both theoretically and empirically. Panel data from developed and developing countries for the period of 1980 to 2003 is used and previous critique, especially on the econometric specification, is embedded. In particular, it is not assumed that there is a single link for all countries. Several environmental factors and one sustainability indicator are analyzed for the full sample, regions and income groups.
The results indicate that there is an Environmental Kuznets Curve (EKC) for most pollutants, but with several reservations. None of the various hypotheses that concern the link between trade and environmental degradation can be entirely confirmed. If anything, there is modest support for the Pollution Haven Hypothesis (PHH). In addition, there are signs that trade liberalization might be beneficial to sustainable development for rich countries, but harmful to poor ones. However, a sustainable development path is particularly important for developing countries, as the poor are most exposed and vulnerable to the health and productivity losses associated with a degraded environment. Given that developing countries do not usually have the institutional capacities to set up the appropriate environmental policies, it is on developed countries to take the lead in addressing environmental degradation issues and assisting developing countries.

Keywords: sustainable development, Pollution Haven Hypothesis, Environmental Kuznets curve, Adjusted Net Saving

JEL classifications: F18, Q56

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1 Introduction

The effects of international trade and economic development on the environment have been widely discussed in the economic literature. They have mostly been examined within the framework of Environmental Kuznets Curve (EKC henceforth), which postulates an inverted U-shaped relationship between environmental pollution and per capita income. Several indicators that capture changes in environmental conditions have also been developed in the last decades to actually incorporate environmental variables in the national accounts.

Earlier studies within the context of the EKC by Grossman and Krueger (1993 and 1995), Selden and Song (1994), Vincent (1997), and Gale and Mendez (1998) focused on the impact of economic growth on environmental degradation. These studies have, however, being criticized for a variety of reasons (Stern et al., 1996; Ekins, 1997; Stern and Common, 2001). First, most of the empirical studies concentrated on few pollutants. This concentration may lead to the incorrect interpretation that all other pollutants have the same relation to income.

Second, the relationship between the environment and income growth might vary with the source of income growth, since different types of economic activities have different pollution intensities. One implication of this concept phrased by Antweiler et al. (2001) is that the pollution consequences of economic growth are dependent on the underlying source of growth. Third, Cavlovic et al. (2000) demonstrate that methodological choices can significantly influence the results. In addition, several researchers have argued that the simplest form of the EKC does not account for trade patterns (Suri and Chapman, 1998; Antweiler et al., 2001; Cole, 2004). Specifically, they indicate that trade patterns may partially explain a reduction in pollution in high income countries, with the reverse occurring in low income countries. In particular, the pollution haven hypothesis (PHH) argues that differences in the strictness of environmental regulations between developing and developed countries will generally result in increased pollution intensive production in the developing countries (Cole, 2004). Wagner (2007) confirms this hypothesis for energy data. On the other hand, the Factor Endowment Hypothesis (FEH) postulates that factor abundance and technology determine trade and specialization patterns, and that such countries relatively abundant in factors used intensively in polluting industries will on average get dirtier as trade liberalizes and vice versa (Mani and Wheeler, 1998).

Numerous studies have examined the trade-environment relationship in the last few years. However, the empirical results reported from these studies appear to be mixed. For example, while the study by Antweiler et al. (2001) shows that trade liberalization reduces pollution, the findings by Dasgupta et al. (2002) appear to be skeptical about the positive environmental effects of trade liberalization. Furthermore, a number of studies find evidence in support of the PHH (Suri and Chapman, 1998; Mani and Wheeler, 1998), whereas others (Grossman and Krueger, 1993; Gale and Mendez, 1998) find empirical support in favor of the factor endowment hypothesis (FEH) and against a significant influence of environmental regulation on trade patterns.

Another issue that has received little attention in the debate on trade-environment nexus is the use of an environmentally adjusted income measure, or an indicator of sustainable development. The very few studies that have employed indicators of sustainable development also report findings that are mixed. For instance, UNEP (1999) and Castaneda (1998) conclude that trade liberalization has had a negative impact on the sustainable development of various developing countries, a finding that suggests there might be a trade-off between the economic gains from trade liberalization and its environmental consequences. However, a more recent study by UNEP (2001) finds an overall positive effect of trade on sustainable development for several developing countries.

Most of the studies mentioned above have focused on some economic regions, in particular OECD countries, or geographic regions, while some studies have investigated individual countries with time series data. Empirical analysis on different economic and geographic regions, using similar specifications are rare in the literature. Stern and Common (2001) examine an EKC for Sulphur for OECD and non-OECD countries, without considering the impact of trade. As argued by Stern and Common (2001), estimates from developed countries may not be informative about future development of emissions in developing countries, particularly when fixed effects estimators are employed. The present study therefore makes a contribution to the debate on the trade-environment relationship by using the EKC framework to examine regional and income groups separately. It also employs an environmentally adjusted income measure to explore whether trade liberalization would still be beneficial for (developing) countries, after controlling national income for potential harmful effects on the environment.

The remainder of the paper is organized as follows. The next section presents a brief discussion of the economic theories on the potential links between trade, economic growth and the environment. In section 3 an EKC framework is developed for the empirical investigation of these links with panel data for 90 countries. Section 4 discusses the data used in the study, while section 5 presents the empirical results. The final section presents concluding remarks.

2 The Environmental Kuznets Curve

Grossman and Krueger (1995) identify three different channels through which economic growth can affect the quality of the environment that shape the EKC: the scale effect, the increase in pollution when the economy grows, the composition, and the technique effect. The composition effect in this context refers to structural changes that occur in the economy, leading to different environmental pressures in the long-term. Furthermore it is assumed that the dominant role is played by public pressure towards more governmental regulation and the use of cleaner production techniques by firms (technique effect). This is based on the assumption that, as income grows income elasticity of the environmental quality increases. Therefore, after a threshold level of income, wealthier countries tend to be more willing and able to channel resources into environmental protection and higher environmental standards.

The reduced-form specification that is commonly employed in the empirical literature to examine the relationship between environmental degradation and per capita income in the context of the EKC is given as:

$$ED_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 X_{it}^3 + \beta_4 Z_{it} + \varepsilon_{it} \quad (1)$$

where ED_{it} represents environmental degradation, i.e. the specific pollutant that is used for the estimation, X_{it} is income per capita, and Z_{it} are other covariates, for example population density, population growth, or income inequality. The basic EKC models start from a simple reduced-form quadratic function, whereas most recent studies include the cubic level (X_{it}^{3})[1]. The inverted-U shaped curve derived from such a formula requires β_1 to be positive and β_2 to be negative. Trade has occasionally been included as an additional covariate in the EKC model. Although trade liberalization per se may not have a direct impact on the environment, this changes when environmental externalities are considered[2]. A widely cited framework for linking trade and the environment has been proposed by Grossman and Krueger (1993). Similar to the growth-environment link, the authors use the scale, composition and technique effects to explain how trade and foreign investment liberalization influence environmental quality.

Antweiler et al. (2001) develop this framework further in their study on the impact of free trade on the environment. Given the similarity between the empirical analysis undertaken here and the conceptual framework presented by Antweiler et al (2001), we present a summary of their model here. Assume a small open economy that produces two goods *X* and *Y*, with two inputs, labor (*L*) and capital (*K*). The production of *X* is assumed to be capital-intensive and generates pollution as a by-product, while the production of *Y* is labor-intensive and does not pollute at all. The economy faces trade frictions β, which influence the price of a product. The price *p* of product *X* depends on β and the world price of this product (p^w). Good *Y* is taken as the numeraire ($p_y = 1$ and $p_x = p = \beta p^w$). Pollution policy is determined by the government, which sets a pollution tax (τ). Given these assumption, total pollution can be expressed as:

$$Z = \varepsilon \psi S \tag{2}$$

[1] Some authors (e.g. Shafik, 1994; Grossman and Krueger, 1995) find evidence of an N-shaped curve ($\beta_3 > 0$). This implies that, at very high income levels, the scale of economic activity becomes so large that its negative impact on the environment cannot be counterbalanced by the positive impact of the composition and technique effects.

[2] In the standard Heckscher-Ohlin model, there is no change in the overall use of the environment. Freer trade leads to increased specialization in pollution-intensive goods in environment-abundant countries. But following the Stolper-Samuelson theorem, the price paid for using the environment is bid up assuming externalities are internalised, and firms shift to less pollution-intensive production techniques.

where ε represents the emissions per unit of output of *X* as a function of abatement intensity, ψ is the share of *X* in total output, and *S* is the scale of the economy. The percentage change in the demand for pollution is then given as:

$$\hat{z} = \hat{S} + \hat{\psi} + \hat{\varepsilon} \tag{3}$$

where $\hat{S}$ is the scale effect, $\hat{\psi}$ is the composition effect, and ,$\hat{\varepsilon}$ represents the technique effect. Assuming that trade liberalization fuels an expansion of economic activities in all participating countries, then *ceteris paribus* the total amount of pollution generated must increase. Moreover, a decline in emission intensity through technological innovations will *ceteris paribus* reduce the level of pollution. This is the technique effect, which can be divided into a technology and an income effect. For example, the OECD (1995) shows that 75 per cent of all international technology transfers stem from trade. Given that environmental quality is a normal good, if trade liberalization raises real income, the income effects will tend to reduce pollution via the demand of citizens for a cleaner environment (Copeland and Taylor, 2004). Overall, the technique effect is thought to be positive for environmental quality. Antweiler et al. (2001) decompose equation (3) to show how the individual factors mentioned above influence overall pollution:

$$\hat{z} = \pi_1\hat{S} + \pi_2\hat{\kappa} - \pi_3\hat{I} - \pi_4\hat{C} + \pi_5\hat{p}^w + \pi_6\hat{\beta} \tag{4}$$

where percentage change in demand for pollution now depends on the scale ($\hat{S}$), the K/L ratio (κ), the prices of goods, determined by p^w and β, the pollution tax (τ), real income per capita (I) and additional variables C that measure e.g. the number of people exposed to pollution or the type of government. All elasticities in (4) ($\pi_i, i = 1-6$) are expected to be positive (Antweiler et al., 2001).

While the scale and technique effects are generally considered negative and positive, respectively, the direction of the composition effect appears to be ambiguous, resulting in competing theories that attempt to explain which countries attract dirty industries, when trade is liberalized.

If comparative advantage lies in differences in environmental regulation or enforcement, then the composition effect of trade will be damaging to the environment in countries with relatively lax regulations, because each country would shift its production to activities that its government does not regulate strictly. The pollution haven hypothesis (PHH) claims that poor countries may have a comparative advantage in so called 'dirty' goods,[3] because of lax environmental policy or enforcement. The PHH result can be obtained as a special case of the simple three-effects-model: if all countries have the same relative factor endowments, but differ in per capita incomes, then richer countries will have stricter pollution policy and this will lead to a comparative advantage in clean goods.

As indicated earlier, under the Factor Endowment Hypothesis (FEH), the traditional sources of comparative advantage, namely factor abundance and technology determine trade and specialization patterns. Countries relatively abundant in factors used intensively in polluting industries will on average get dirtier as trade liberalizes and vice versa. According to the FEH, capital-abundant countries have a comparative advantage in dirty goods production, because capital-intensive industries are more polluting[4]. As high income countries are considered to be capital-abundant, the FEH yields the opposite predictions to the PHH. In reality, both factor endowments and policies differ between countries and influence trade patterns. Hence, the pattern of trade depends on the strength of the individual effects.

A related hypothesis is the race-to-the-bottom hypothesis, which argues that increased international competition for investment will cause countries to lower environmental regulations or to retain poor ones in a 'race to the bottom' in environmental standards, as countries compete to attract foreign capital and keep domestic investment at home, resulting in lower environmental standards.

These hypotheses have important implications for the EKC. International trade makes pollution demand more elastic and more responsive to changes in policy, because one key role for international trade is to offer an alternative abatement mechanism - import the good from abroad (Copeland and Taylor, 2004). Thus, it delinks consumption from production within a country. As indicated earlier, free trade normally contributes to growth in national income. However, if environmental costs are not

[3] Goods that are produced in a pollution-intensive production process are often called 'dirty' goods in environmental economic literature. By contrast, 'clean' goods cause comparatively little pollution in the production process.
[4] In most papers, this is seen as a fact. In addition, Mani and Wheeler (1998) find a strong correlation of dirty industries and capital-intensive industries for OECD countries.

internalized, free trade may not be welfare improving. Net welfare effects of a reduction in trade barriers in the presence of environmental externalities depend on comparative advantages and environmental policies. A first approach to analyzing these effects is to assume that environmental policy remains unchanged during trade liberalization (Pethig, 1976). When both trading partners have an environmental externality, there are multiple equilibria, whereby trade can be beneficial for either partners, to only one, or even reduce welfare vis-à-vis autarky for both countries. Rauscher (1991) shows that, when environmental policy is endogenous, increased economic integration reduces emissions from at least one of the two countries, but the effect on overall emissions is ambiguous and the welfare effects are also ambiguous.

Furthermore, trade allows a discrepancy between EKCs associated with consumption and production. In many cases, potentially harmful effects occur during the production process of environment-intensive goods, whereas consuming these goods releases no further significant quantities of pollution. One may therefore expect to find EKCs for the production of these goods, but perhaps none for consumption. In other words, a possible explanation for the downward sloping segment of the inverted-U shape of the EKC may be found in the hypothesized tendency of countries, as they get richer, to spin-off pollution-intensive products to lower income countries, which is in line with the PHH (Wagner, 2007).

The foregoing discussion indicates that trade may influence the EKC relationship both positively and negatively. The overall net effect of trade and income growth on the environment is therefore ambiguous and may not be uniform across countries, a reason why separate analyses are needed for high-income and low-income countries, as well as individual regions.

3 The Model

The empirical specification employed in the analysis is based on the standard EKC framework, with trade included as an additional explanatory variable. The specification which combines times series of environmental degradation and trade-per capita income across countries to obtain a panel data set is given as:

$$\begin{aligned} \mathrm{ED}_{\mathrm{it}} = \beta_1 \mathrm{TRADE}_{\mathrm{it}} + \beta_2 \mathrm{GDP}_{\mathrm{it}} + \beta_3 \mathrm{GDPSQ}_{\mathrm{it}} + \beta_4 \mathrm{LNPOPD}_{\mathrm{it}} \\ + \delta_t + \mu_i + \varepsilon_{it} \end{aligned} \tag{5}$$

where ED_{it} represents environmental degradation, δ_t are the time specific intercepts, μ_i represents country-specific effects that summarize the influence of unobserved variables such as infrastructure, period average climate, history and culture, and which are assumed to be distributed independently across countries, with variance σ_μ^2, and ε_{it} is the stochastic error term for each country *i* and year *t*. The time specific intercepts are included to account for time varying omitted variables and stochastic shocks that are common to all countries[5]. A variety of environmental indicators are used in the empirical analysis.

Given that OLS will yield biased results in the presence of unobserved heterogeneity, either random effects or fixed effects could be employed to obtain consistent results. While the fixed effects model treats the δ_t and μ_i as regression parameters, the random effects model treats them as components of the random disturbance. We employ a Hausman test to test for the inconsistency of the random effects estimate. Furthermore, since heteroscedasticity may be present in the sample because of large variations in the income and environmental variables, it needs to be tested for in the estimations. A likelihood-ratio test is used that compares a feasible general least squares regression (FGLS henceforth) that is corrected for heteroscedasticity with one that is not. Where the null hypothesis of homoscedasticity could be rejected, robust standard errors are used.

A final methodological issue concerns serial correlation in the error term. A Wooldridge test for autocorrelation in panel data and an Arellano-Bond test are used to test for autocorrelation.

Ignoring first order serial correlation still results in consistent, but inefficient estimates of the coefficients and biased standard errors (Baltagi, 2006). Therefore, where necessary, additional FE

[5] Time fixed effects account for time-varying omitted variables and stochastic shocks that are common to all countries, like new technological developments, the East Asian financial crisis 1997- 1999, the September 11, 2001 attacks, or the coming into effect of international treaties and conventions. A joint F-test for the significance of the time fixed effects as criterion for choosing between one and two-way FE models, keeping in mind degrees of freedom and collinearity.

models with (FGLS) correcting for AR(1) and FE regressions with Driscoll and Kraay (1998) standard errors are estimated and compared with the results of the other specifications.

4 The Data

The data used in the analysis consist of 90 developed and developing countries, and cover the period 1990-2003. A detailed list of the countries used in the analysis is presented in the appendix. Table 1 presents the variable names as used in the regressions, their definitions and their means and standard deviations (in brackets). Environmental quality has many dimensions, each of which may respond to economic variables differently. Hence, a study of the relationship between environment, trade and income should aim to be as comprehensive as possible.

The environmental variables considered include one sustainability indicator (adjusted net saving (ANS)), one environmental indicator that captures environmental impacts of several types indirectly (energy consumption), as well as one indicator for water quality (biochemical oxygen demand (BOD)) and one for air pollution (emissions of chlorofluorocarbons, henceforth CFCs). The emissions of chlorofluorocarbons (CFCs) in kilograms per capita account for anthropogenic sources of the decline of the ozone layer. The data was obtained from the United Nations Environment Programme Ozone Secretariat (UNEP, 2008). CFCs are greenhouse gases that were formerly used widely as refrigerants, aerosol propellants and cleaning solvent. When released into the atmosphere, they drift up into the stratosphere where they react with ozone (O_3) to form free chlorine atoms (*Cl*) and molecular oxygen (O_2), thereby destroying the ozone layer. CFCs are global pollutants that can remain in the atmosphere for more than a hundred years, whereas the next variable presented is a local water pollutant.

Biological oxygen demand—emissions of organic water pollutants—is measured in tons per day, with data from World Development Indicators (2007)[6]. BOD is a standard water treatment test for the

[6] There is no indication in the data on how BOD emissions have been measured exactly, i.e. if they are, for instance, average emissions per day or emissions on a specific day of the year. Therefore, although all the other variables are yearly data, they are not sampled up to yearly data. However, having BOD measured in tonnes either per day or per year is only a question of scale and does not change the nature of the effects.

presence of organic pollutants. It refers to the amount of oxygen that bacteria in water consume when breaking down waste. An overload of sewage in natural waters, for instance, exhausts the dissolved oxygen content of the water. Low levels of dissolved oxygen in water can impact the health of aquatic resources and ecosystems.

Energy consumption, measured here in tons of oil equivalent per capita (Source: WDI 2007), is an indirect source of pollution, especially air pollution. Around a third of all energy consumed in developing countries comes from wood, crop residues, straw and dung, which are often burned in poorly designed stoves within ill-ventilated huts. In addition, energy consumption is closely linked to the depletion of natural resources. CFC emissions and energy use are calculated in per capita terms to control for pollution caused by population growth. However, given that BOD emissions constitute a direct threat to humans and are mainly a result of industrial activity, it is not expressed in per capita terms.

Given that the basic idea behind this analysis is to explore whether trade liberalization is beneficial for countries after controlling for potential harmful effects on the environment and natural resource depletion, an ideal income measure would be one that accounts for environmental degradation and natural resource depletion. However, data for such sustainability indicators are often incomplete, particularly for developing countries, and are often subject to the critique of being subjective. Adjusted net saving (ANS), a widely accepted indicator for weak sustainability based on the concepts of green national accounts and on the Hartwick rule for weak sustainability[7] is employed in this study. The data is from the World Bank's World Development Indicators. It measures the rate of gross national savings in percentage of Gross National Income (GNI) after taking into account the depletion of fixed capital, education expenditures (in order to account for human capital formation), the depletion of certain natural resources (energy, minerals and net forest depletion) and pollution damages of carbon dioxide and particulate emissions (Hamilton, 2000). As in Costantini and Martin (2007), the

[7] If the 'Hartwick rule' is followed, so that investment in produced capital just equals current scarcity rents on the exhaustible resource at each point in time, then this is a sustainable economy (Hartwick, 1977). On the basis of the Hartwick rule, a simple criterion for weak sustainability is that the value of natural capital plus manufactured capital be not decreasing. Weak sustainability assumes that there are substitutes for all assets, whereas strong sustainability requires the preservation of critical natural capital in order for development to be sustainable.

specification with ANS as the dependent variable employs lagged income variable as the explanatory variable. This is due to the fact that ANS is measured as a percentage of GNI, as such using current income could result in biased estimates. Note that unlike in the other specifications, a positive coefficient will indicate a move towards more sustainability.

Data on income, trade and population density were also taken from the World Development Indicators. Gross domestic product (GDP) per capita in purchasing power parity (PPP) terms in constant 2000 international Dollars is used as income measure. Trade intensity as a percentage of GDP is calculated as the sum of exports (X) and imports (M) of goods and services measured as a share of GDP (X +M/GDP). Population density (POPD) (people per square kilometer) is used to control for pollution caused by an increasing population. Logarithms are applied to make the variable less sensitive to outliers.

Significant differences in the results between income groups and the full sample are possible. Turning points for EKCs might be different and EKCs might exist for some income ranges, but not for others. As indicated earlier, the estimated EKCs are conditional on the country and time effects in the selected sample of data. This means that an EKC estimated with FE using only developed country data might say little about the future behavior of developing countries and vice versa (Stern and Common, 2001). Even more interesting, the trade variable might be ambiguous in the regressions for all countries, but in income group regressions it should clearly reflect the PHH and FEH, if one of these hypotheses is true and dominant. According to the PHH, the trade coefficient must be positive for poor countries and negative for rich countries. If dirty industries are really capital-intensive and rich countries are generally considered capital-abundant, as argued in section 2, then the FEH implies that the signs are expected to be reversed.

To capture these differential effects, the sample is divided into two groups based on the countries' GNI per capita according to the World Bank classification (World Bank, 2008a). This results in a sample of 44 countries for the first group, called 'high income', and of 46 countries for the second group called 'low income'[8]. Mean values are lower for the low income group for all variables except

[8] In fact, the World Bank distinguishes four income groups (high income, upper middle income, lower middle income, and low income), but the two high and the two low income groups are merged.

BOD. As expected, this indicates that poorer countries use less environmental services on average. However, looking at ANS, a lower rate indicates that these countries are nevertheless less sustainable. This is due to a higher resource extraction, less investment, and thus less gross savings in many low income countries. By contrast, the ANS rates in the high income countries are higher due to large investments, lack of dependence on natural resource depletion and strong exports of high value-added goods and services (World Bank, 2008b). As for the high BOD figure for the low income group, a possible explanation is that less water is treated and water treatment plants do not exist or are less sophisticated than in high income countries.

In addition to the income group analysis, separate estimations are also conducted to identify possible differences between geographical regions. Five regions are identified for the analysis: 'Sub-Saharan Africa (SSA)', 'North Africa and the Middle East', 'Europe and Atlantic (EU & Atlantic)', 'Asia' and 'Latin America'[9]. The regional classification of countries in the sample is presented in the appendix. Possible differences between regions could arise due to different development paths (for example based on natural resource extraction, traditional industrial activity, or service industries), cultural differences, dissimilarities in climate and natural resource endowment, or different approaches towards environmental protection in the policy agenda.

The specification in the study does not include information on factors such as environmental policies and production technology that may affect environmental degradation but for which we have no data. These factors are therefore treated as country-specific effects. However, given that the estimation approach employed in the study uses fixed effects, the time invariant component of these effects gets eliminated and thus cross-sectional differences in infrastructure, production technology, environmental policy, etc. pose no problem.

5 Empirical Results

The fixed effects estimates from the EKC for the various specifications are presented in Tables 2 to 7. The test for heteroscedasticity revealed the presence of heteroscedasticity. We also tested for

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[9] Note that the true regional borders do not always exactly correspond to the names used. For example 'Asia' includes in fact Asia and the Pacific region.

autocorrelation, which was present of the first order. To account for the heteroscedasticity and autocorrelation, Driscoll-Kraay standard errors were computed and reported in the tables. The results for the other specifications, feasible general least squares and random effects, are not reported here but are available upon request. A Hausman test of the null hypothesis that the country-specific effects are uncorrelated with the explanatory variables was conducted in the fixed effects models. In the majority of cases, the null hypotheses could be rejected, suggesting that specifications that do not account for these correlations may produce biased and inconsistent results.

The results for the full sample, which are presented in Table 2, appear to be largely consistent with the EKC. In particular, GDP exerts a positive and highly significant impact on all environmental variables, the coefficients for GDP squared are all negative and significantly different from zero. Furthermore, the estimated coefficient for trade is not statistically significant in most cases, but this is in line with a priori reasoning that would suggest it to be ambiguous, as the three effects suggested by theory might work against each other. The first column presents the results for CFCPC. As CFCs are global pollutants, one could have expected either a monotonic increasing relationship with income or an EKC with very high turning points, but this is not the case. The explanation for the estimated results probably lies in their strength. CFCs are powerful greenhouse gases. For this reason, they have been phased out in many countries due to multilateral policy initiatives (e.g. the Montreal Protocol in 1987, the IPPC directive on greenhouse gases in 1994 and the Volatile Organic Compounds (VOC) directive of the European Union in 1997). Thus, CFC consumption is a good example for effective international pressure. The high turning point in the results for ANS in the last column indicates that income has a positive impact on sustainable development for current values of income.

Table 3 presents the results for high and low income countries. For the variables representing CFCPC and BOD, the estimates for both high and low income countries appear to be consistent with the EKC hypothesis, since GDP and GDP squared are significant with alternate signs. The first two columns present the results for CFCPC. The turning points are around US$ 5 000 and 16 000 for low-income and high-incomes groups, respectively. Contrarily to CFCs, BOD emissions are on average significantly higher in low income than in high income countries. The BOD income group regression results are presented in the third and fourth columns in the Table[10]. The income coefficients do not change much compared to the results for the whole sample, and are still supportive of an EKC for LNBOD. The turning points for BOD are around US$ 6 570 and US$ 27 924 for the low-income and high-income groups, respectively, which is high in the range of incomes in the respective groups[11].

For the analysis of the results for the ENERGYPC income group regression, it is significant to note that the average energy consumption in poor countries is only a small part of that in rich countries (0.7 versus 3.5 tons of oil equivalent per capita). For high income countries there is still a robust EKC, with a slightly lower turning point of about US$ 45 000. There is, however, no evidence of an EKC for low income countries, as both income and income squared variables turned out positive and significant, without any turning point. In addition, the estimated coefficients for the TRADE variable in the per capita energy consumption are statistically significant, with a negative sign for high income countries and a positive sign for low income countries. The negative coefficient for high-income countries indicates that trade helps to reduce the per capita energy use in these countries, whereas the positive coefficient for low income countries means that trade increases energy use in this group of countries. This lends support to the PHH. Together with the income coefficients, this is a good example of how in fact two EKCs for high income countries might exist, one for consumption and one for production, whereby rich countries are becoming cleaner in their production patterns, but the consumption EKC might not fall at higher income levels. The difference between the two curves is due to the specialization of low income countries in dirty good production, which are then exported to high income countries, a finding that is consistent with the suggestions put forward by Wagner (2007).

The estimates for the variable representing ANS also reveal different results for low-income and high-income groups. The coefficients for the income variables point towards an EKC for high income countries, but not for low income countries. As the turning point is very high for the low income group, this suggests that income growth is ultimately good for sustainable development for most

[10] A look at the BOD data reveals that outliers might be a problem. Based on this observation, a logarithmic transformation is appropriate. The new dependent variable is LNBOD and the estimates for the original variable are not presented.

[11] The turnoff point between high and low incomes is at US$ 3 595 and the highest income in the high income group is at US$ 35 407.

countries in this group. In addition, the estimates for the trade variable are striking. TRADE is highly significant and supportive of the PHH. This implies that, while income growth appears to be ultimately good for the sustainable development of low income countries, trade is detrimental to it.

The estimates for the regions are presented in Tables 4 to 7. Table 4 presents the results for the regional regressions with CFCPC as the dependent variable. For all regions, there are signs that the inverted-U relationship between CFCPC and GDP exists, although the estimated coefficients are not statistically significant for SSA. Furthermore, only in North Africa and the Middle East and in Latin America is increased trade more likely to result in more CFC consumption per capita. This could be due to the diversion of CFC intensive industries to these regions in connection with environmental protection in other regions, but as most countries in the two regions have ratified international conventions for the reduction of CFC emissions, there may also be other reasons.

The regional regressions for LNBOD presented in Table 5 imply slightly different conclusions compared to the full sample. In particular, for Sub-Saharan Africa no more EKC is found and for Asia the income variables have the right signs, but are not significant. As poor water quality in many SSA countries affects the health of its citizens severely, clear results and therefore policy implications would be important here. Furthermore, TRADE now has a clear positive impact on BOD emissions in Latin America. Poor water treatment in BOD-intensive exporting industries, like metal, textile and paper and pulp production, due to slack environmental regulation could be underlying this trend. In the other regions, the results are not that clear.

The results for the regional regressions for per capita energy consumption (ENERGYPC) are presented in Table 6. The estimates reveal an EKC for all regions, with the notable exception of Latin America. The trade coefficient is insignificant and ambiguous except for Asia, where it is positive and significant. The results generally reveal that the effects of trade on energy use differ between regions. Table 7 presents the estimates for Adjusted Net Savings (ANS). A striking finding here is the differential impact of income for the various regions. While the variable is positive and significant for EU and Atlantic as well as Asia, it is positive but not significant for SSA and Latin America, and then negative but insignificant for North Africa and Middle East. A possible reason is the respective underlying source of GDP growth. For instance, growth is mainly based on resource extraction in

Middle Eastern oil producing countries. The trade coefficient is statistically significant for EU and Atlantic and Asia. The negative coefficients for the regions, with the exception of Latin America suggest that trade could be harmful for sustainable development in most of the regions.

6 Concluding remarks

This paper analyzed the effect of trade liberalization on sustainable development within the framework of the Environmental Kuznets Curve (EKC), using a cross-section of countries over the period 1990-2003. Separate analyses were conducted for low-income and high-income groups, as well as regional groups. The empirical results appear to support the notion that no unique relationship exist between economic growth, trade and the environment across all countries and pollutants.

The income coefficients indicate that there is an EKC for most environmental indicators, but with several reservations. First, in all cases the turning points are higher than the mean income. As a result, there is a quasi monotonic increasing relationship for energy consumption and a long way to reach the turning point for most countries for the other variables. Second, for energy consumption there is a strictly increasing relationship for low income countries. This has two implications. The development path of environmental quality of the current poor countries may not replicate the path of the current rich countries, and pollution levels may not fall with higher incomes. Combining this result with the fact that there is evidence in favor of the PHH for energy consumption and ANS, there might in fact be a difference between a production and consumption EKC for rich countries as suggested by Wagner (2007).

In addition, none of the various theoretical hypotheses that consider the link between trade and the environment can be fully confirmed. If anything, there is support for the PHH in the income group regressions. The empirical results from the study and those of previous studies suggest that many poor regions of the world are failing to be on a sustainable path, although this is particularly important for developing countries, which are the most exposed and vulnerable to the health and productivity losses associated with a degraded environment. Specifically, the estimates from the Adjusted Net Savings measure indicate that trade liberalization might be beneficial for rich, but harmful for poor countries' sustainable development efforts.

The empirical results do have some policy implications. First, global pollution issues, such as global warming, require international cooperative action, because countries can get a ’free ride’ on the environmental efforts of others. One major challenge for policy interventions is that there can be significant delays between changes in human behavior, including policy choices, and their environmental impacts. However, the example of CFCs suggests that awareness of and pressure from various stakeholders can be crucial for the perceived benefits of environmental change and thus a strong driving force for policy makers.

Second, even in very low income economies, stricter pollution control can make sense, because solving environmental problems in developing countries does not necessarily hurt economic growth (Grossman and Krueger, 1995). Given that these countries do not usually have the institutional capacities to set up sound environmental policies, protecting some sectors for specified periods, while the institutional and regulatory capacities are put in place may be a realistic second-best policy option (World Bank, 2001). In addition to technical and financial assistance to help developing countries comply with rich countries’ environmental standards and set up sound environmental policy regimes, an improved environmental friendly development aid policy could include the support of higher-value added exports in the sense of promoting green products from developing countries in the markets of developed countries. Under such conditions, environmentally preferable products and production methods in developing countries would present new opportunities for trade and investment.

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5 Appendix

Countries According to Income and Region

Asia

Australia, Bangladesh, China, India, Indonesia, Japan, Malaysia, New Zealand, Nepal, Pakistan, Philippines Republic of Korea, Singapore, Sri Lanka, Thailand

Europe & Atlantic

Albania, Armenia, Austria, Azerbaijan, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Hungary, Iceland, Ireland, Kyrgyz Republic, Lithuania, Moldova, Norway, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine, United Kingdom, United States

Middle East & North Africa

Algeria, Iran, Islamic Rep., Israel, Jordan, Morocco, Oman, Saudi Arabia, Syrian Arab Republic, Tunisia

Latin America

Argentina, Bolivia, Brazil, Colombia, Chile, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela RB

Sub-Saharan Africa

Angola, Benin, Botswana, Cameroon, Ethiopia, Ghana, Kenya, Mali, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Zambia, Zimbabwe

Low income countries

Albania, Algeria, Angola, Armenia, Azerbaijan, Bangladesh, Benin, Bolivia, China, Cameroon, Colombia, Ecuador, El Salvador, Ethiopia, Guatemala, Honduras, Indonesia, Iran, Islamic Rep., Jamaica, Jordan, Morocco, Moldova, The former Yugoslav, Republic of Macedonia, Namibia, Peru, Philippines, Paraguay, Ghana, India, Kenya, Kyrgyz Republic, Mali, Mozambique, Nepal, Nigeria, Pakistan, Senegal, Sri Lanka, Sudan, Syrian Arab Republic, Thailand, Tunisia, Ukraine, United Republic of Tanzania, Zambia, Zimbabwe

High income countries

Argentina, Australia, Austria, Botswana, Brazil, Bulgaria, Canada, Chile, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Gabon, Hungary, Ireland, Iceland, Israel, Japan, Lithuania, Mexico, Malaysia, Norway, New Zealand, Oman, Panama, Poland, Republic of Korea, Romania, Russian Federation, Saudi Arabia, Singapore, Slovenia, Slovak Republic, South Africa, Switzerland, Trinidad and Tobago, Turkey, United Kingdom, United States, Uruguay, Venezuela RB

Table 1: Variable Definitions and Summary Statistics

Variable Name	Definition and Units	Mean and Standard Deviation
CFCPC	consumption of chlorofluorocarbons (CFCs) in kilograms per capita	0.08 (0.19)
BOD	emissions of organic water pollutants in tons per day	301.32 (906.22)
ENERGYPC	energy use in tons of oil equivalent per capita	2.07 (2.11)
ANS	Adjusted Net Saving in percentage of Gross National Income	6.90 (14.07)
TRADE	trade as a percentage of GDP	72.89 (38.95)
GDP	GDP per capita in PPP terms in constant 2000 international Dollars	8781.10 (8504.98)
GDPSQ	square of GDP per capita in PPP terms in constant 2000 international Dollars	1.49e+08 (2.52e+08)
POPD	population density (people per square kilometer)	153.98 (581.16)

Table 2: Fixed Effects Regression Results for all Countries

Dependent Variable / **Independent Variables**	CFCPC	LNBOD	ENERGYPC	ANS
GDP	0.0000389***	0.0001063***	0.000263***	0.0009468**
	(0.0000141)	(0.0000196)	(7.80e-06)	(0.0005069)
GDPSQ	-1.71e-09***	-1.47e-09***	-2.78e-09***	-1.11e-08
	(3.86e-10)	(5.18e-10)	(1.48e-10)	(7.08e-09)
LNPOPD	0.8711874***	2.36028***	1.198016***	14.79392*
	(0.2718907)	(0.2878819)	(0.0684384)	(6.223477)
TRADE	-0.0001154	-0.0003069	-0.0003389	-0.0161648
	(0.0002291)	(0.0006498)	(0.0004284)	(0.0190704)
Observations	1044	880	1220	1107
Hausman Test	63.22 (0.00)	11.35 (0.01)	3.92 (0.27)	8.42 (0.038)
$\hat{\rho}$	0.5987	0.6990	0.7022	0.4583
turning point	11397.38	27030.48	47242.87	42679.06
adjusted R^2	0.476	0.972	0.986	0.839
F Test	388079.26***	683.58***	227507.20***	3517269.28***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. For ANS, LAGGDP and its square (LGDPSQ) are used instead of GDP and GDPSQ. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.

Table 3: Fixed Effects Regression Results for Income Group Regressions

Dependent Variable	CFCPC		LNBOD		ENERGYPC		ANS	
Independent Variables	High Income	Low Income	High Income	Low Income	High Income	Low Income	High Income	Low Income
GDP	0.0000614***	0.0000221*	0.0000785***	0.0003337***	0.0002068***	0.0001615***	-0.0008883**	0.0087031***
	(0.0000187)	(6.95e-06)	(0.0000231)	(0.0001177)	(0.0000118)	(0.0000469)	(0.0004452)	(0.0022224)
GDPSQ	-1.91e-09***	-2.15e-09**	-1.41e-09*	-2.54e-08*	-2.30e-09***	1.06e-08*	2.60e-08***	-4.51e-07**
	(4.47e-10)	(1.14e-09)	(6.02e-10)	(1.16e-08)	(2.82e-10)	(4.73e-09)	(7.56e-09)	(2.28e-07)
LNPOPD	1.27318***	0.1446448***	3.832962***	2.807735***	1.376608***	1.052642***	12.50275	14.3723
	(0.3909674)	(0.0267223)	(0.5188415)	(0.1432308)	(0.144545)	(0.118552)	(7.529385)	(10.93753)
TRADE	-0.0007914	-0.0000391	-0.0001218	0.0016038	-0.0020834*	0.0006007***	0.0494445***	-0.0676325***
	(0.0005999)	(0.0001571)	(0.0007299)	(0.0010319)	(0.0009724)	(0.0002099)	(0.0153289)	(0.0231223)
Observations	481	563	480	400	593	627	535	572
Hausman Test	36.90 (0.00)	120.94 (0.00)	16.31 (0.001)	1.84 (0.61)	39.71 (0.00)	5.03 (0.17)	4.69 (0.096)	4.65 (0.20)
$\hat{\rho}$	0.5837	0.5678	0.6473	0.6282	0.6396	0.6814	0.4846	0.3837
turning point	16088.38	5145.426	27923.77	6570.487	44931.05	–	17103.89	9648.408
adjusted R^2	0.477	0.670	0.974	0.884	0.976	0.971	0.871	0.822
F Test	126569***	274168***	28199***	9928***	126.38***	18489***	164912***	1.22e+09***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. For ANS, LAGGDP and its square (LGDPSQ) are used instead of GDP and GDPSQ. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.

Table 4: Fixed Effects Regression Results for CFCPC Regional Regressions

Regions / **Independent Variables**	SSA	North Africa & Middle East	Latin America	EU & Atlantic	Asia
GDP	0.0000282 (0.0000222)	0.0001311*** (0.0000198)	0.0000365*** (0.0000123)	1.39e-06 (9.40e-06)	0.000017** (8.03e-06)
GDPSQ	-1.82e-09 (1.66e-09)	-8.87e-09*** (1.27e-09)	-1.76e-09* (7.82e-10)	-1.05e-09*** (2.80e-10)	-1.86e-09*** (5.15e-10)
LNPOPD	-0.0493564*** (0.0058085)	-0.2773961*** (0.0431515)	0.1923302* (0.0913717)	1.205371* (0.5457715)	-0.0495221 (0.0397315)
TRADE	-0.0001267 (0.0000775)	0.0007739** (0.0003726)	0.0001354 (0.000153)	-0.0010344 (0.0007522)	-0.0008746*** (0.0001538)
Observations	208	106	235	301	194
Hausman Test	4.83 (0.19)	40.08 (0.009)	122.51 (0.00)	3.17 (0.3663)	51.66 (0.00)
$\hat{\rho}$	0.6439	0.4841	0.3971	0.5260	0.5961
turning point	7748.349	7391.529	10355.26	659.3712	4573.48
adjusted R^2	0.347	0.821	0.696	0.446	0.591
F Test	62.58***	48.91***	11795.73***	319511.13***	18.87***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.

Table 5: Fixed Effects Regression Results for BOD Regional Regressions

Regions / **Independent Variables**	SSA	North Africa & Middle East	Latin America	EU & Atlantic	Asia
GDP	-0.0000298	0.0004083**	0.0007644***	0.000082***	0.0000124
	(0.0001487)	(0.0002022)	(0.0002007)	(0.000014)	(0.0000496)
GDPSQ	6.67e-09	-1.01e-08**	-5.75e-08***	-9.93e-10*	-2.19e-09
	(9.80e-09)	(4.71e-09)	(1.25e-08)	(4.77e-10)	(1.62e-09)
LNPOPD	-0.2171832***	1.994766***	0.7820432***	1.756729***	1.204728**
	(0.062093)	(0.3584576)	(0.2639926)	(0.4284524)	(0.5998215)
TRADE	-0.0017676**	0.0001045	0.0047417***	0.0006601	0.001526
	(0.0008407)	(0.0024021)	(0.0008358)	(0.0005165)	(0.0029031)
Observations	133	92	159	348	148
Hausman Test	17.88 (0.00)	5.71 (0.13)	28.13 (0.00)	126.25 (0.00)	16.53 (0.00)
$\hat{\rho}$	0.6335	0.6521	0.6033	0.7187	0.4698
turning point	2231.082	20196.49	6643.118	41287.53	2818.949
adjusted R^2	0.889	0.909	0.877	0.874	0.887
F Test	18.38***	19.79***	21.09***	3586013***	32.43***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.

Table 6: Fixed Effects Regression Results for Energy Use Regional Regressions

Regions / **Independent Variables**	SSA	North Africa & Middle East	Latin America	EU & Atlantic	Asia
GDP	0.0001302*** (0.0000422)	0.0002173* (0.0000717)	-0.0003798* (0.0001385)	0.0002025*** (0.0000184)	0.0002501*** (0.0000146)
GDPSQ	-5.35e-09** (2.87e-09)	-2.11e-09 (1.34e-09)	4.63e-08*** (9.72e-09)	-1.67e-09*** (3.02e-10)	-2.51e-09*** (4.96e-10)
LNPOPD	-0.0853605*** (0.0146042)	0.6929093*** (0.0796977)	-3.416712*** (0.6223582)	2.984873*** (0.2142053)	-0.1707554* (0.0744525)
TRADE	-0.0002025 (0.0001641)	0.0007719 (0.0014323)	0.0013958 (0.0009369)	-0.0006379 (0.0007242)	0.0015242** (0.0008318)
Observations	230	125	252	400	213
Hausman Test	1.40 (0.70)	6.30 (0.098)	5.14 (0.16)	26.36 (0.00)	1.51 (0.47)
$\hat{\rho}$	0.5614	0.8222	0.7215	0.5562	0.7863
turning point	12175.85	51583.0	4102.443	60697.79	49738.32
adjusted R^2	0.956	0.968	0.974	0.924	0.935
F Test	26.24***	34.65***	189.03***	655.71***	1062.71***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.

Table 7: Fixed Effects Regression Results for ANS Regional Regressions

Regions / **Independent Variables**	SSA	North Africa & Middle East	Latin America	EU & Atlantic	Asia
LAGGDP	0.0059123	-0.0031986	0.0019869	0.0018352*	0.0009057**
	(0.0060036)	(0.0046356)	(0.0052774)	(0.000737)	(0.0004681)
LGDPSQ	-3.38e-07	-3.07e-08	-2.00e-07	-2.70e-08	-3.68e-08***
	(4.43e-07)	(1.15e-07)	(3.35e-07)	(1.22e-08)	(1.12e-08)
LNPOPD	27.27917**	50.62133*	12.30683**	-5.86881	18.06991***
	(15.09526)	(19.68875)	(6.519929)	(6.403558)	(5.80904)
TRADE	-0.002605	-0.1341149	0.0182942	-0.0403456***	-0.0550912*
	(0.0288216)	(0.1231506)	(0.0177105)	(0.0105747)	(0.0213386)
Observations	212	114	233	353	195
Hausman Test	4.28 (0.23)	3.18 (0.36)	12.47 (0.002)	1.53 (0.47)	7.15 (0.07)
$\hat{\rho}$	0.2546	0.4523	0.4283	0.5670	0.5264
turning point	8738.536	–	4970.826	34016.59	12320.89
adjusted R^2	0.847	0.769	0.779	0.849	0.712
F Test	8486.19***	10.90***	1022.91***	36.48***	34.52***

Notes: Standard errors are in parenthesis. Driscoll-Kraay (DK) standard errors are used. * significant at 5%; ** significant at 10%, and *** significant at 1% level. LAGGDP and its square (LGDPSQ) are used instead of GDP and GDPSQ. p-values for the Hausman test are in parenthesis. $\hat{\rho}$ is the estimated residual autocorrelation coefficient. Turning point displays the estimated turning points.