THE EFFECTS OF TRADE LIBERALIZATION ON THE ENVIRONMENT: AN EMPIRICAL STUDY

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Abstract

We seek to contribute to the emerging economic theory on trade, the environment and development. Using panel data across countries, econometric models are estimated to predict the effects of openness on organic water pollutant (BOD) and carbon dioxide (CO2) emissions. Results indicate that freer trade significantly increases emissions of both pollutants, thus reducing environmental quality. Moreover, the panel nature of the data allows heterogeneity across countries to be controlled, so that comparisons can be made of how different national characteristics influence the environmental impact of freer trade. By testing the effects of democratic versus autocratic governance, it is found that while greater democracy can induce significant reductions in BOD emissions as openness increases, it may also lead to increased CO2 levels. Meanwhile, by testing for and failing to reject the pollution haven hypothesis, it is suggested that environmental gains from openness in relatively rich countries may be coming at the expense of environmental degradation in poorer countries.

1.0. Introduction

Few economists would argue with the assertion that trade liberalization increases incomes across countries. Freer trade leads to more goods available at lower prices than would otherwise be the case. However, many questions still revolve around other potential effects of openness to trade. This paper will focus on one of these questions: What is the effect of freer trade on the environment? Issues that are examined include how trade liberalization affects the environment in individual nations and whether or not these effects can be assumed to carry across both developed and developing countries. Attention is also focused on how different trade policies may distort the relationship between openness and the environment, and what potential policy responses may be implemented to balance these effects. The approach taken is based on emerging economic theory on trade, environment and development.

Extensive debate currently exists over these issues. Many environmentalists are concerned that trade liberalization will create international political pressure to reduce the stringency of environmental regulations, creating a "race to the bottom". Advocates of freer trade counter that openness between countries generates an economic surplus which can be applied to environmental protection (Damania *et al*, 2003; Karp *et al*, 2003). A central issue in this discussion is the potential for trade liberalization to increase incomes, encouraging economic growth. Two studies by Grossman and Krueger (1993; 1995), find evidence in support of an inverse U-shaped relationship between per capita income growth and pollution levels. Referred to as the Environmental Kuznet's Curve (EKC), this relationship hypothesizes that economic growth in a country will bring an initial period of environmental deterioration, followed by a subsequent phase of improvement. The policy impacts of the EKC hypothesis could be significant, since it finds no evidence that economic growth related to free trade does unavoidable harm to the environment. (Grossman and Krueger, 1995)

According to Antweiler *et al* (2001), however, the relevant economic theory gives little reason to believe that free trade will influence all countries in the same way. Instead, when considering the relationship between openness and the environment, it is important to consider the interactions between scale, composition, and technique effects created by different national characteristics and trading opportunities (Antweiler *et al*, 2001; Copeland and Taylor, 2004). The scale effect of openness to trade increases environmental degradation through more intensive production. The technique effect reflects cleaner production processes, which arise from increasing demands for environmental quality as income levels rise. The composition effect will shift production between environmentally beneficial or damaging goods, depending on the competitive advantages between trading partners. The relative strength and direction of these effects will cause the impact of trade liberalization on the environment to differ across countries.

Furthermore, theoretical analysis highlights the potential for government policy and environmental regulations to determine these effects. The pollution haven effect hypothesizes that the stringency of environmental regulation distorts how competitive advantages are utilized by influencing plant location decisions and trade flows (Copeland and Taylor, 2004). Meanwhile, Deacon and Mueller (2004) argue that corrupt governance may impede the technique effect by rendering governments unresponsive to public demands for greater environmental quality. Damania *et al* (2003) and Welsch (2004) also find that corruption can directly cause environmental degradation by reducing the effectiveness of environmental regulations such as emissions limits. Both the pollution haven effect and corrupt governance could thus affect the transferability of the EKC between countries.

To investigate these relationships further, an empirical study of the effects of trade liberalization on a country's environment is reported in this paper. Panel data across countries is utilized, including measures of pollution such as carbon dioxide emissions and organic water pollutant emissions, to evaluate the environmental effects of freer trade. Models test the effects of trade liberalization to see whether an EKC is observable in all or only particular countries. Moreover, the panel nature of the data allows heterogeneity between nations to be controlled, so that comparisons can be made of how national characteristics influence the impact of freer trade. Consequently, the hypothesis that the environmental effects of trade liberalization are transferable between developed and developing countries can be tested. Finally, a variable to control for governance is included in the model to specifically estimate the influence of democracy in determining the environmental impacts of openness to trade. This study is unique in its application of panel data to evaluate the impacts of trade liberalization on the environment while controlling for national characteristics that can distort the competing scale, technique and composition effects among countries.

2.0. Literature Review

This paper adds to a larger literature which has sought to identify the relationships between trade, economic growth and environmental quality. In addition to the works described above, Antweiler *et al* (2001) apply panel data on sulphur dioxide (SO2) concentrations to a theoretical model which divides trade's impact into scale, technique and composition effects. Their findings indicate that while the scale effect of openness increases concentrations of SO2 by 0.25 to 0.5 percent, it is outweighed by a larger reduction in concentrations (1.25 to 1.5 percent) from the trade induced technique effect.[1] The overall effect of trade on pollution concentrations is thus beneficial, leading Antweiler *et al* (2001: 878) to conclude that "free trade is good for the environment."[2]

Frankel and Rose (2005) use cross-country data to address the question: "what is the effect of trade on a country's environment, for a given level of GDP?" Results of this study for three measures of air pollution show that openness tends to reduce sulphur dioxide (SO2), nitrogen oxide (NO2), and particulate matter emissions.[3] Furthermore, the authors also test the pollution haven hypothesis by adding an interaction between

[1] The composition effect is found to only lead to slight changes in pollution concentrations, and does not affect overall results (Antweiler *et al*, 2001).

[2] Of interest for the present study, Antweiler *et al* (2001: 878) make special note of the panel structure of their data set, which they were able to exploit in order to distinguish empirically between the negative scale effects of trade on the environment, and the positive technique effects of trade on the environment.

[3] It is interesting to note that only the reduction in SO2 emissions indicated strong statistical significance. The effect of openness in reducing NO2 was "moderately" significant, while the effect on particulates lacked statistical significance (Frankel and Rose, 2005).

openness and per capita income to their model, but find little evidence in favour of the hypothesized effect. From their findings, Frankel and Rose (2005) conclude that while some results indicate that openness may help to reduce air pollution, there is little evidence that trade causes significant environmental degradation, *ceteris paribus*. One important exception in their results is carbon dioxide (CO2) emissions, which trade tended to increase with moderate significance. Frankel and Rose (2005: 88) account for this difference by observing that "CO2 is a purely global externality, and unlikely to be addressed by regulation at the national level."

Further investigating this issue of global externalities and transboundary pollutants, Ansuategi (2003) tests the hypothesis that EKC's only exist for pollutants with semi-local and medium term impacts.[4] Focusing on the relationship between income growth and sulphur emissions, Ansuategi (2003) finds that local pollutants are more likely to be effectively dealt with by governments than pollution that can be easily externalized to other countries. These results mirror the findings of Cole *et al* (1997), who study 1986 CFC and halon emissions across countries. Cole *et al* (1997) conclude that transboundary pollutants will increase monotonically with income or have EKC turning points at higher levels of per capita income if they are not subjected to a substantial government policy initiative. Interestingly, Copeland and Taylor (2005) study the effects of policies that unilaterally reduce emissions in open economies and find that with free trade in goods, there are an infinite number of ways to reduce pollution efficiently, while in autarky there is only one.[5] Open economies may therefore be able to adopt emission reduction policies with greater efficiency than closed economies, creating a greater incentive to do so.

Several authors have also addressed the more specific impacts of governance on environmental quality. As described in the introduction, corrupt governance can directly reduce the effectiveness of environmental policies that limit pollution, causing an upward

[4] This hypothesis draws on the findings of Ansuategi and Perrings (2000) who show that self-interested planners deal with environmental problems sequentially, addressing those with the most immediate costs first, and those with costs more displaced in space later.
[5] The key to this finding, according to Copeland and Taylor (2005), is that international markets create asymmetries across countries that do not exist in autarky. Openness thus generates the possibility of gains from trade effects, which can create an infinite number of efficient emission reduction paths for an economy.

shift in an EKC and an increase the per capita income level at which environmental improvements are realized (Damania *et al*, 2003; Welsch, 2004).[6] However, Welsch (2004) also identifies an indirect effect through which corruption reduces prosperity, thus decreasing per capita income levels. This indirect effect will increase emissions for rich countries that operate on the downward sloping portion of their EKC, but reduce emissions for poor countries on the upward sloping portion. It is interesting to note, then, that in the case of strictly declining environmental quality with economic growth, corruption may actually improve environmental conditions. The net impact on emission levels of the direct and indirect effects of governance may therefore be counteracting, and must be empirically observed.

3.0. Methodology

3.1. Data

Panel data across countries is used to estimate the environmental effects of openness to trade. All data, except for the governance index, has been obtained from the *World Development Indicators* Online Database, which is assembled by the World Bank.[7] The dependent variables under consideration are carbon dioxide (CO2) emissions and organic water pollutant (BOD) emissions. CO2 emissions (measured in kilotons) are those stemming from the burning of fossil fuels and the manufacture of cement. They include emissions produced during consumption of solid, liquid and gas fuels and gas flaring. The dataset for CO2 is composed of measurements for 143 countries spanning the years 1970 to 2000. Emissions of organic water pollutants (in kilograms per day) are measured by biochemical oxygen demand (BOD), which refers to the amount of oxygen that bacteria in water will consume when breaking down waste. BOD is a standard water-treatment test for the presence of organic pollutants. The dataset for BOD includes observations for 119 countries spanning the years 1980 to 1995.

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[6] Lopez and Mitra (2000) also investigate the effects of political corruption on the occurrence of an EKC for several pollution variables in developing countries. Their results indicate an upward shift in the turning point of an EKC for developing countries with more corrupt governance.

[7] *World Development Indicators* is the World Bank's database on development measures, and includes social, economic, financial, natural resources and environmental indicators for over 200 countries. Data is freely available online at http://devdata.worldbank.org/dataonline.

As discussed above, income may play a strong role in determining the environmental outcomes of trade across countries. Per capita Gross Domestic Product (GDP), measured in constant 1995 US$, is therefore obtained to act as a proxy for the per capita income of a country. To estimate the effects of openness on emissions, cross-country data on trade levels, measured by the sum of exports and imports of goods and services as a percentage of GDP, is also obtained. Additional data is gathered on total population levels per country, domestic land area (in square kilometers), and urban population levels (as a percentage of total population) in order to control for the possible influences of these national characteristics in explaining emissions of CO_2 and BOD.

Data on governance is retrieved from the University of Maryland's *Polity IV* project.[8] This dataset is assembled as an index, measuring the degree to which a nation is either autocratic or democratic on a scale from -10 to +10.[9] The *Polity IV* project considers fully democratic countries to display three essential elements: fully competitive political participation, institutionalized constraints on executive power, and guarantees of civil liberties to all citizens in their daily lives and political participation. Of note, for some countries and years *Polity IV* uses special codes instead of the -10 to +10 scale to indicate interruptions in government such as foreign occupations, collapses of central authority, or transitional political periods. For estimation purposes, these special codes were re-fitted into the -10 to +10 scale as the average of the other autocratic/democratic observations for the country in question. So as not to create bias, a dummy variable (*Disrupt*) was then created and set equal to one for the particular years in which a country had been coded as having a disruption in government.[10]

Descriptive information on the datasets is provided in **Appendix A**. For the BOD dataset, **Table A:1** summarizes the mean data values and number of years observed for each of the 119 countries in the panel. Similar information for the CO_2 dataset is

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[8] The *Polity IV* project looks at political regime characteristics and transitions across countries, and is available from the World Resources Institutes' Earth Trends website, http://earthtrends.wri.org.
[9] The scale is established with (-10=strongly autocratic, +10=strongly democratic).
[10] An alternative approach to the specially coded governance data would have been to simply drop these observations. However, given the economic theory relating governance to the environment, it was hypothesized that political disruption could have significant environmental implications, meaning that these observations needed to be retained in the dataset. Re-fitting these codes to the index, while adding a dummy variable as described above, was considered the best method to capture these effects.

summarized by **Table A:2**. From this information, it should be addressed that complete panels of data could not be obtained for all countries in the dataset. This is a common problem with panel data and can be corrected by using unbalanced panel estimation methods (Greene, 2003; Verbeek, 2004). Unbalanced panel estimation avoids losses in efficiency by using all available observations, including those for countries that are not observed in all years of the dataset.

3.2. Econometrics[11]

The use of panel data allows for the modeling of differences in behaviour across subjects. Heterogeneity across countries is therefore the central focus of the empirical analysis in this paper. To estimate models based on panel data, we can start with a simple linear model such as:

$$y_{it} = x'_{it}\beta_{it} + \varepsilon_{it} \tag{1}$$

where β_{it} measures the partial effects of x_{it} in year t for country i. Panel data estimation then places additional structure on the coefficients, with the standard assumption being that β_{it} is constant for all i and t. To capture the effects on y_{it} that are peculiar to each country $i = 1, \ldots, N$, a separate set of N parameters, α_i, are added to the model. If the α_i are assumed to be N fixed unknown parameters, capturing the effects of the independent variables that are specific to country i and constant over time, then we have the fixed effects model for panel data. Alternatively, if the country specific parameters α_i are treated as random drawings from a distribution with mean μ and variance σ_α^2, then we have the random effects model for panel data.

Evaluating the use of fixed effects versus random effects models, we find an important difference in the interpretation of results between the two. According to Verbeek (2004), fixed effects models concentrate on the differences "within" individuals, therefore explaining to what extent the observed y_t for country i differs from that country's mean y. A fixed effects model would therefore be appropriate if we wanted to

[11] The econometric theory depicted in this section draws largely from the works of Greene (2003) and Verbeek (2004).

make predictions about the changes in emissions over time for a particular country, since the fixed effects estimators consider the distribution of y_{it} given α_i. In random effects models, meanwhile, the estimated y_{it} are not conditional on the individual country's α_i, as the model instead "integrates out" these random parameters. A random effects model is thus more appropriate if we are not interested in the particular value of an individual country's α_i, but instead want to focus on the differences in emission levels across countries with certain characteristics. Since the objective of this paper is to make inferences regarding the effect of openness on environmental quality, conditioned on the potential for national characteristics to influence results, the random effects model will be applied to our dataset.

Applying the assumptions of the random effects model to the simple linear model developed earlier, equation (1) can now be expressed as:

$$y_{it} = \mu + x'_{it}\beta + \alpha_i + \varepsilon_{it}\,; \qquad \alpha_i \sim IID(0, \sigma_\alpha^2), \quad \varepsilon_{it} \sim IID(0, \sigma_\varepsilon^2) \tag{2}$$

where μ is the intercept term and the random parameters α_i are assumed independently and identically distributed (IID) over countries. Now, $\alpha_i + \varepsilon_{it}$ can be treated as a single error term consisting of two components: an individual specific component α_i which does not vary over time and a remainder component ε_{it} assumed to be uncorrelated over time. The random effects estimators will be unbiased and consistent if α_i and ε_{it} can be assumed mutually independent, as well as independent of the observed x variables.[12]

Applying this econometric theory, the model depicted in equation (2) will be estimated twice, once with BOD emissions as the dependent variable, and again with CO_2 emissions as the dependent variable. All variables included in the models are described in **Table 1**.

[12] Verbeek (2004) notes that the structure of the error component $\alpha_i + \varepsilon_{it}$ will inherently induce a particular form of autocorrelation in random effects models. Standard OLS estimators will therefore be inefficient, and this effect is corrected by deriving Feasible GLS estimators instead. If all other assumptions hold, FGLS estimators in a random effects model will be efficient and asymptotically normal, so that the usual test statistics can be applied.

Table 1: Descriptions of all Variables included in the Random Effects Models Estimating the Effects of Openness on BOD and CO2 Emission Levels while Controlling for National Characteristics.

VARIABLE	***DESCRIPTION***
BOD	Organic Water Pollutant Emissions (kg per day).
CO2	Carbon Dioxide Emissions (kt per year).
GDP	Gross Domestic Product per Capita (Constant 1995 US$).
GDP2	Square of *GDP*. Included to capture non-linear effects of per capita income growth on emissions.
Trade	Trade (% of GDP). Included as a proxy for openness.
Polity	The degree to which a country is either democratic or autocratic, as indicated by the *Polity IV* index (-10 = strongly autocratic; +10 = strongly democratic).
Pop	Total population.
Land	Land area (Square km).
Urban	Urban population (as a % of total population).
Disrupt	Variable created to capture the years in which a country was coded by the *Polity IV* project as having had a disruption in governance (1 = coded for disruption; 0 = no disruption, regular polity index applies).
Respond	Interaction term capturing the specific effects of GDP per capita for countries coded as democratic (index ≥ 1) by the *Polity IV* project.
Respond2	Interaction term capturing the specific non-linear effects of GDP per capita (i.e. *GDP2*) for countries coded as democratic (index ≥ 1) by the *Polity IV* project.
ATrade	Interaction term capturing the specific effects of openness to trade (*Trade*) for countries coded as strongly autocratic (index ≤ -5) by the *Polity IV* project.
Haven	Interaction term capturing the combined effects of GDP per capita (*GDP*) and openness to trade (*Trade*).

1 Dependent Variables = *BOD / CO2*.
2 Model for *BOD* includes observations on 119 countries over 16 years (1980-1995).
3 Model for *CO2* includes observations on 143 countries over 31 years (1970-2000).

The effect of openness on environmental quality will be given by the coefficient on the variable *Trade*. The quadratic term *GDP2* is included in order to capture any non-linearity in the effects of income per capita on environmental quality. An EKC would thus be indicated by a positive coefficient on *GDP* coupled with a negative coefficient on *GDP2*. The coefficient on the variable *Polity* will describe the direct effect of a country's governance on its environmental quality, but of greater interest for the purposes of this paper will be the estimators on the terms interacting governance with openness, *ATrade*, and with income: *Respond* and *Respond2*. Drawing from the economic literature discussed above, the interaction *ATrade* is included in order to test the hypothesis that openness will affect the environment differently in more autocratic countries than in more democratic ones. *Respond* and *Respond2* are included in order to test the hypothesis that democratic countries will be more responsive to increased demands for environmental quality as per capita incomes grow, indicating a stronger technique effect from trade. Finally, again based on the economic theory developed earlier, a third interaction term *Haven* is also included in the model. *Haven* is estimated in order to test the hypothesis of a pollution haven effect between relatively rich and poor countries.[13] The random effects models to be estimated therefore take the following form:

$$BOD_{it} = \mu + \beta_1 GDP_{it} + \beta_2 GDP2_{it} + \beta_3 Trade_{it} + \beta_4 Polity_{it} + \beta_5 Pop_{it} + \beta_6 Land_{it} + \beta_7 Urban_{it} + \beta_8 Disrupt_{it} + \beta_9 Respond_{it} + \beta_{10} Respond2_{it} + \beta_{11} ATrade_{it} + \beta_{12} Haven_{it} + \alpha_i + \varepsilon_{it} \quad (3)$$

$$CO2_{it} = \mu + \beta_1 GDP_{it} + \beta_2 GDP2_{it} + \beta_3 Trade_{it} + \beta_4 Polity_{it} + \beta_5 Pop_{it} + \beta_6 Land_{it} + \beta_7 Urban_{it} + \beta_8 Disrupt_{it} + \beta_9 Respond_{it} + \beta_{10} Respond2_{it} + \beta_{11} ATrade_{it} + \beta_{12} Haven_{it} + \alpha_i + \varepsilon_{it} \quad (4)$$

where *i* again represents the country and *t* the year.

Initial estimates of models (3) and (4) were run and the results are summarized by **Table B:1** in **Appendix B**. Since Verbeek (2004) identifies that the use of goodness of fit measures is rather uncommon in panel data applications, we instead test our random effects model specification using the Hausman test.[14] The Hausman test evaluates the consistency of the random effects feasible GLS estimators by testing the null hypothesis that x_{it} and α_i are **not** correlated.[15] The random effects model with *BOD* as the dependent variable generates a Hausman test statistic of 254.83, which with 12 degrees of freedom rejects the null hypothesis at the 1% level of significance. Similarly, the model with *CO2* as the regressand generates a Hausman test statistic of 97.85 which again with 12 degrees of freedom leads to the rejection of the null hypothesis at the 1% significance level. Rejecting the null hypothesis in each case suggests that the x_{it} and α_i **are** correlated in both random effects models. This is problematic since it also suggests that the coefficients estimated with the random effects method will be inconsistent.

The potential correlation between the x_{it} and α_i in our random effects models can be corrected by deriving instrumental variable estimators. Hausman and Taylor (1981)

[13] This approach to testing the pollution haven hypothesis is the same as that applied by Frankel and Rose (2005).

[14] The main reason that goodness of fit measures are generally not applied to panel data models is that the usual R^2 and adjusted R^2 indicators are only appropriate if the model is estimated with OLS (Verbeek, 2004).

[15] Correlation between x_{it} and α_i violates the random effects model's assumption that $\alpha_i \sim IID(0, \sigma_\alpha^2)$, which is required for the FGLS estimator to be both consistent and efficient.

show that this can be accomplished by instrumenting the correlated variables by their value in deviation from the individual (or in our case country) specific means. Thus, while the exogenous variables $x_{1,it}$ serve as their own instruments, the variables correlated with α_i (referred to as $x_{2,it}$) are instrumented as $x_{2,it} - x_{2\,i}$. These new instrumental variable estimators, referred to as the Hausman-Taylor estimators, are by construction uncorrelated with α_i.

This Hausman-Taylor approach is advantageous since it does not require the adoption of external instruments (Verbeek, 2004). However, deriving instruments within the model will require the researcher to impose their own assumptions about which variables are correlated with α_i. By inspecting the data sets, it is found that the maximum observations for both the GDP per capita and population data significantly diverge from the much lower mean and median values of the sample.[16] Moreover, these outlying values are observed for relatively few countries. Therefore, hypothesizing that the these large outlying observations for GDP per capita and total population are driving the correlation between the x_{it} and α_i in our models, the variables *Pop*, *GDP*, and *GDP2*, as well as those interacted with GDP per capita: *Respond*, *Respond2*, and *Haven*, are instrumented using the Hausman-Taylor technique.

4.0. Results

By regressing the dependent variables *BOD* and *CO2* on our newly derived instrumental variables, we obtain consistent Hausman and Taylor estimators to which test statistics can be applied and inferences drawn concerning the hypothesized relationships between openness and environmental quality. Results for the Hausman and Taylor instrumental variable estimators are summarized in **Table 2**.

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[16] To demonstrate this observation, scatter plots of both the GDP per capita and population data are provided in **Appendix B**.

Table 2: Hausman and Taylor Instrumental Variable Estimators for Panel Data Models Estimating the Effects of Openness on BOD and CO2 Emission Levels while Controlling for National Characteristics.

VARIABLE	***REGRESSAND = BOD*** ***(MODEL 3)***	***REGRESSAND = CO2*** ***(MODEL 4)***
GDP	42.8956* (16.1562)	20.3391* (2.7251)
GDP2	-0.00155 (0.000979)	-0.000323* (0.0000797)
Trade	849.4993* (391.0458)	282.5713* (70.7702)
Polity	2544.4887 (2437.3317)	-736.8967** (422.6989)
Pop	0.00741* (0.00026)	0.00363* (0.000049)
Land	-0.05629* (0.0233)	0.0339* (0.0103)
Urban	4529.1797* (1385.09)	144.4103 (201.7152)
Disrupt	-1006.3682 (6521.4633)	2615.0143* (1256.1187)
Respond	-25.8889* (12.1007)	1.1796 (1.8762)
Respond2	0.00125 (0.000938)	0.0002* (0.00007)
ATrade	782.1948* (337.1787)	50.4677 (60.0931)
Haven	-0.10007** (0.05928)	-0.1002* (0.0084)
Constant	-403635.9* (85796.9)	-117481.6* (25159.6)
# Countries	N = 119	N = 143
Years	1980 - 1995	1970 – 2000

1 Standard errors provided in parentheses.
2 * indicates significance at the 5% level or better
3 ** indicates significance at the 10% level or better
4 The panel data in this study required the application of unbalanced panel estimation techniques.

A few notes on specification deserve mention. The interactive term *ATrade* was initially specified to interact the effects of openness with countries that were ranked lower than zero by the polity index, thus capturing the specific impacts of freer trade for autocratic versus democratic countries. However, t-tests on the initial estimates for both models found this variable to be insignificant in explaining variation in either BOD or CO2 emission levels. An alternate hypothesis was thus formulated to test if strongly autocratic countries reacted differently to trade liberalization than weakly autocratic or democratic countries. *ATrade* was therefore re-specified to interact the effects of openness with countries ranked -5 or lower by the polity index, and it is these results that are summarized by **Table 2**.[17] A similar test was conducted for the two *Response* variables, however the results of increasing incomes for strongly democratic countries (ranked higher that +5 on the polity index) were not found to be significantly different from those for all democratic countries. Consequently, the more general result is taken to provide greater insight, and both *Response* and *Response2* in **Table 2** capture the interaction between per capita GDP and those countries ranked above zero on the polity scale.

4.1. Estimated Effects for Organic Water Pollutant (BOD) Emissions

Several inferences can be drawn from the estimated effects of the instrumental variables on the dependent variable *BOD* (Model 3). First of all, considering the direct effect of freer trade on emission levels, we can see that the variable *Trade* is significant at the 5% level, leading us to reject the null hypothesis that increased openness does not affect environmental quality across countries. Moreover, the positive coefficient on *Trade* indicates that water quality, as reflected by BOD emissions, will be worse in more open economies, *ceteris paribus*.

However, when the estimator on the interaction variable *ATrade* is considered in addition to the results for *Trade*, an interesting picture emerges. The positive coefficient and small standard error on *ATrade* suggest that the environmental effects of openness to trade will be significantly different in strongly autocratic countries versus democratic or even weakly autocratic countries.[18] Moreover, the magnitude of the *ATrade* estimator, in comparison to the marginal effects on *Trade*, suggests that the increase in emissions for strongly autocratic countries will be empirically significant as well. Therefore, to the extent that an EKC for BOD emissions is observable, strongly autocratic governance will cause an upward shift in emissions for any given level of per capita income, meaning a

[17] Upon re-specifying the variable *ATrade* to capture the effects of strongly autocratic countries only, an additional interaction term was added to each model to test the additional hypothesis that openness affects the environment differently in strongly democratic countries, compared to either weakly autocratic or weakly democratic countries. This additional interactive variable was found to be insignificant in both models, leading us to fail to reject the null that strongly democratic countries react similarly to freer trade as weakly autocratic or weakly democratic countries. This variable was therefore dropped from the specification in order to highlight the effects of openness on strongly autocratic versus all other kinds of governance, as captured by *ATrade*.

[18] As discussed above, *ATrade* specifies "strongly" autocratic countries as those ranked -5 or lower on the *Polity IV* governance index.

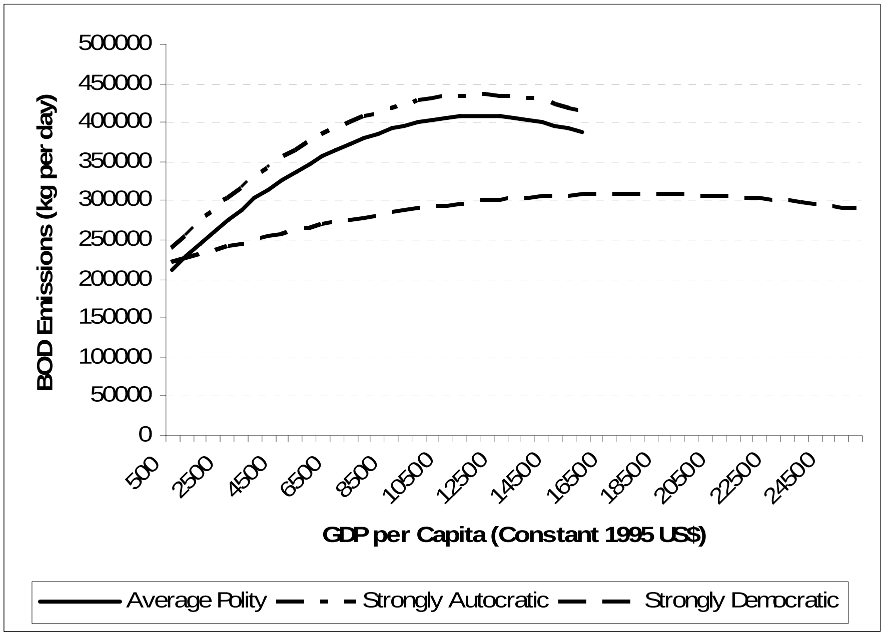
higher peak in the EKC and greater degradation before environmental improvements occur.

To investigate the EKC hypothesis further, we must look at the estimators for the income per capita variables. The positive coefficient on *GDP* coupled with the negative coefficient for *GDP2* indicate that a representative country in our sample will follow an EKC path of BOD emissions as per capita income levels grow. However, while the estimated effect for *GDP* is highly significant, the large standard error and relatively small marginal effect for *GDP2* suggest that the downward sloping portion of the EKC might not be empirically significant.

Extending this analysis to test the hypothesis that increased incomes will lead to similar environmental quality responses in both democratic and autocratic countries, we next consider the estimators for *Respond* and *Respond2* in combination with the GDP per capita coefficients. The negative, strongly significant coefficient on *Respond* indicates democratic governance reduces the increases in BOD emissions that will result from per capita income growth. Moreover, the magnitude of this estimator for *Respond*, in comparison to that for *GDP*, suggests that the marginal effect of an increase in per capita income will be significantly reduced for democratic countries not only statistically, but also empirically. We thus reject the null hypothesis that democratic and autocratic countries will be equally responsive to demands for environmental quality when per capita incomes grow. However, we also observe that the quadratic term *Respond2*, like *GDP2*, appears both statistically and empirically insignificant. This again suggests that non-linear effects of income growth on BOD emissions may not be observable, and thus casts doubt on the EKC hypothesis.

These results for the regression of *BOD* on our instrumental variables are depicted in **Figure 1** below. The more gradual slope for the strongly democratic country reflects the significant impact of the *Respond* variable, which reduces the marginal effect of increasing per capita incomes on BOD emissions. The upward shift in the emissions path for strongly autocratic countries, resulting from the significantly different effects of openness on these countries as suggested by the estimator on *ATrade*, is also readily apparent.

Figure 1:Predicted BOD Emission Levels for Countries with Different Types of Governance as per Capita Incomes Increase. [19]



1 Average polity provided as a base case: *Polity* = 0.
2 Strongly Autocratic: *Polity* = - *5*.
3 Strongly Democratic: *Polity* = + *5*.

To depict the relationships in **Figure 1**, all control variables are entered at their mean values; except for the dummy variable *Disrupt* which is included at its mode. Of interest, both higher total population levels, as indicated by *Pop*, and a higher percentage of urban as opposed to rural population, indicated by *Urban*, are found to significantly increase BOD emissions across countries. Meanwhile, a higher total land area, captured through *Land*, is found to reduce BOD emissions, suggesting that a country's population density may be significant in explaining organic water pollutants.

4.2. Estimated Effects for Carbon Dioxide (CO2) Emissions

Interpreting the estimated effects of the instrumental variables on the dependent variable *CO2* (Model 4) yields some interesting comparisons. The variable *Trade* has a positive coefficient, indicating that CO2 emissions increase with openness to trade, and the small standard error on this estimator again lead us to reject the null hypothesis that increased openness does not affect environmental quality across countries. Furthermore,

[19] Depictions for countries of average or strongly autocratic governance types are cut off at a per capita GDP of $15,000.00 because the BOD dataset does not support observations beyond this point.

the variable *Polity* is weakly significant in this model, and its negative estimator indicates that an increase in the democracy level of a country (or lessening of autocracy) will marginally decrease emissions of CO2.[20] However, the inclusion of *ATrade*, which interacts the effects of these two variables, is now found to be insignificant in explaining variations in air quality across countries. Therefore, while finding that both freer trade and governance significantly explain differences in CO2 emissions, *ceteris paribus*, we also fail to reject the null hypothesis that openness affects the environment similarly in autocratic and democratic countries.

Investigating the model further, we find a positive coefficient on the *GDP* variable and a negative coefficient on the *GDP2* variable, again indicating a possible EKC path for the relationship between emissions and income per capita. Moreover, unlike the estimators for BOD, both the linear and non-linear terms are now statistically significant, lending credibility to the hypothesis of reduced CO2 emissions at higher levels of income per capita. However, a curious result is obtained when the *Respond* and *Repsond2* variables are considered in conjunction with these results. The insignificance and relatively small magnitude of the estimator on *Respond* suggests that there is little difference between democratic and autocratic countries regarding the linear effects of income per capita on emissions. The non-linear terms describe a different story, though. Here, the positive coefficient and statistically significant effect of the *Respond2* term directly counteracts the marginal effect of the *GDP2* estimator. Moreover, the similar magnitude of these two estimators indicates that for democratic versus autocratic countries, the non-linear component of the EKC will be almost entirely reversed.

These results for the regression of *CO2* on our instrumental variables are depicted in **Figure 2** below. Since *ATrade* does not significantly explain any variation in this model, we no longer observe an upward shift in the CO2 Emissions – Income per Capita curve for strongly autocratic countries as opposed to all other governance levels. Consequently, only two emissions paths are needed to explain the observed relationships: one for democratic countries, one for autocratic countries. The curve for autocratic countries clearly displays the effects of both the *GDP* and *GDP2* estimators, as we see it

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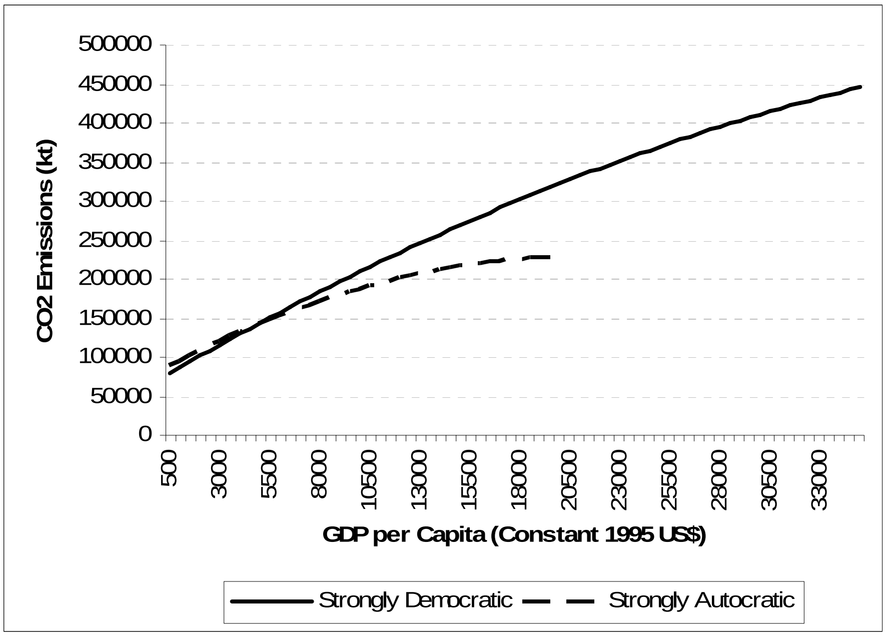
[20] The magnitude of the estimators on both *Trade* and *Polity* indicate good economic significance for their respective marginal effects as well.

begin to bend back down at higher per capita income levels. The more linear emissions path for democratic countries reflects the interaction of the *GDP2* and *Respond2* marginal effects.

Figure 2: Predicted CO2 Emission Levels for Countries with Different Types of Governance as per Capita Incomes Increase.[21]



1 Strongly Democratic: *Polity* = + 5.
2 Strongly Autocratic: *Polity* = - 5.

To depict the relationships in **Figure 2**, all control variables are again entered at their mean values, except for the dummy variable *Disrupt* which is included at its mode. Total population levels (*Pop*) are again found to significantly increase CO2 emissions across countries. The estimator on *Land* remains significant but becomes positive in this model, suggesting that the larger a country's land area, the higher its emissions of CO2. This may reflect a need to regularly travel greater distances in large countries, thus producing more pollution. The percentage of urban population (*Urban*) is insignificant in explaining CO2 emissions, but the dummy variable *Disrupt* is now significant at the 5% level, indicating that the occurrence of a disruption in governance will increase emissions of CO2 in the destabilized country.

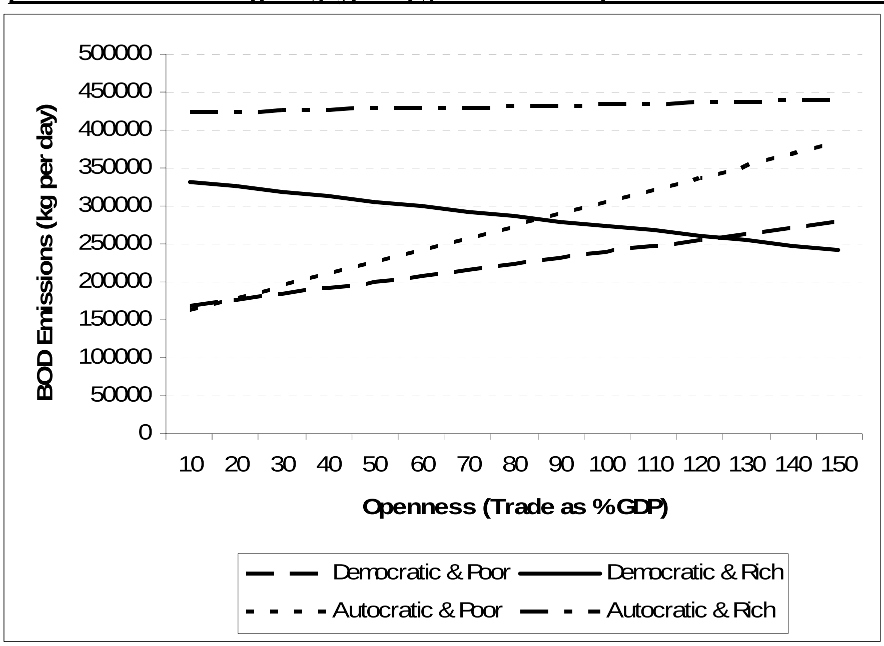
[21] The depiction for strongly autocratic countries is cut off at a GDP per capita of $20,000.00 because the CO2 dataset does not support observations beyond this point.

4.3. The Pollution Haven Effect

The hypothesis of a pollution haven effect between relatively rich and poor countries is tested by including the variable *Haven* in each model. As discussed earlier, the pollution haven effect hypothesizes that relatively rich countries, which experience greater demand for environmental quality, may enact more stringent environmental regulation while taking advantage of trade and allowing poorer open countries produce and sell products with high emissions. A negative coefficient on the *Haven* variable, which interacts *GDP* (income) with *Trade* (openness), would thus indicate that rich countries are utilizing trade to transfer pollution intensive activities outside their borders.[22]

The estimators on the *Haven* variables in each model are, indeed, negative. Moreover, this effect is strongly significant in the CO2 model and weakly so in the BOD model. We therefore fail to reject the hypothesis of a pollution haven effect between relatively rich and poor open economies. Depictions of these effects are provided in **Figures 3** and **4** below.

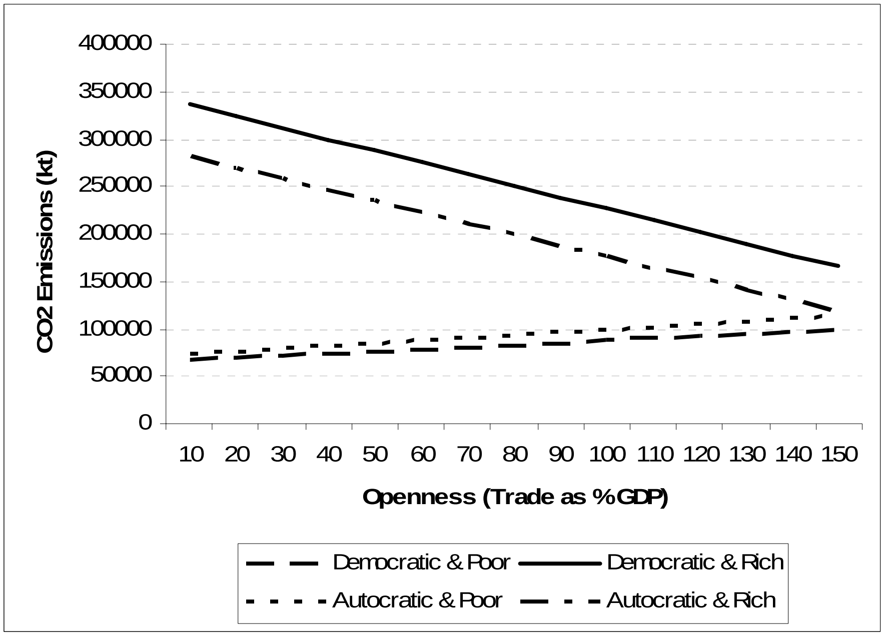
Figure 3: Pollution haven effects for BOD emissions considering relatively rich vs. poor countries with differing types of governance as openness to trade increases.



1 Rich countries are depicted with GDP per capita = $15,000.00
2 Poor countries are depicted with GDP per capita = $500.00
3 Democratic countries displayed at an index value of *Polity* = + 5.
4 Autocratic countries displayed at an index value of *Polity* = - 5.

[22] The development of these ideas and test method closely follow the work of Frankel and Rose (2005).

Figure 4: Pollution haven effects for CO2 emissions considering relatively rich vs. poor countries with differing types of governance as openness to trade increases.



1 Rich countries are depicted with GDP per capita = $15,000.00
2 Poor countries are depicted with GDP per capita = $500.00
3 Democratic countries displayed at an index value of *Polity* = + 5.
4 Autocratic countries displayed at an index value of *Polity* = - 5.

Interpreting the results in **Figures 3** and **4** provides some interesting insights.[23] To begin, as reflected by the negative coefficients on the *Haven* variables, we see that in both models emissions increase as poor countries become more open to trade, but tend to decrease with greater openness in rich countries. In general, these observations support the potential for a pollution haven effect. The one exception to this trend is for relatively rich, autocratic countries in **Figure 3** (the BOD model), where emissions appear to stay relatively constant as openness increases.

This anomaly can be accounted for by drawing on the observations in **Figure 1**. Recall that when estimating BOD emissions, autocratic countries were observed to experience higher emissions over all per capita income levels due to the positive, significant effect of the variable *ATrade*. Since *ATrade* captures the specific effect of increasing openness for strongly autocratic countries, its marginal effect increases as we

[23] Of note, **Figures 3** and **4** are shown with relatively rich countries assumed to have a per capita GDP of $15,000.00, while relatively poor countries are assumed to be at $500.00. These assumptions provide the largest divergence between rich and poor possible while remaining within observational limits of the dataset. Meanwhile, *Polity* values of (+ 5, - 5) are chosen as they reflect the mid-point values on both the democratic and autocratic sides of the *Polity IV* governance index.

move along the x-axis in **Figure 3**. Consequently, BOD emissions increase for autocratic countries as free trade increases, which likely negates any decline in emissions that results from a pollution haven effect. Moreover, this effect could also explain the steeper slope for poor, autocratic nations compared to the poor democratic ones in **Figure 3**. The increased BOD emissions from the pollution haven effect are augmented for poor, strongly autocratic countries by further increases in emissions due to the more open economy as we move along the x-axis. These explanations for the different slopes observed in **Figure 3** are supported by the results in **Figure 4**, where the lack of a significant coefficient on *ATrade* for CO2 emissions generates parallel effects of increased openness for democratic and autocratic countries at the same income level.

5.0. Discussion

In the models estimated above, we find a *ceteris paribus* effect in which freer trade significantly increases emissions of both BOD and CO2. However, the panel data used in this study allows heterogeneity between nations to be controlled, so that comparisons of how national characteristics influence the impact of freer trade on the environment can be made. According to Frankel and Rose (2005: 85), analysis of how country specific effects influence this relationship may be the most fundamental issue for policy, since; "if it is established that trade has an adverse effect on the environment solely because openness raises countries' incomes, …, not many would choose deliberate self-impoverishment as a means to a clean environment."

The model predicting BOD emissions suggests that encouraging more democratic governance may help to mediate the increasing emissions that arise with openness to trade. Interacting governance with income levels, it is observed that democratic governments can induce significant reductions in pollution as income levels rise. This may reflect the technique effect proposed by Copeland and Taylor (2004). Moreover, the interaction of governance and openness finds that strongly autocratic governments lead to an upward shift in an emissions path, so that pollution is higher at any given income level for open countries. This result is supported by the argument of Damania *et al* (2003) and Welsch (2004) that corrupt governance can reduce environmental quality by failing to enforce regulations such as emission limits. These observations could be interpreted to suggest that the promotion of democracy will improve the relationship between trade liberalization and environmental quality.

The results from the model predicting CO2 emission levels are more troubling, however. In line with the arguments of Cole *et al* (1997), we find that for democratic countries CO2 emissions, as a purely global externality, appear to increase almost monotonically with income, and thus with trade. These effects appear to be moderated for autocratic countries, though, where the data suggests the possibility of an EKC as per capita incomes increase. It is thus unclear how to interpret these results, as it makes little sense to suggest promoting autocracy as a means for reducing CO2 emissions. Alternatively, Welsch (2004) suggests that we may be observing an indirect effect of governance on environmental quality, through which corruption reduces prosperity, thereby reducing per capita income levels. The result of this effect is to reduce emissions for poor countries on the upward sloping portion of an Emissions-Income curve. Still, further research into the relationship between trade and purely global externalities, such as CO2, is clearly needed. One potential avenue is proposed by Copeland and Taylor (2005), who find that international agreements reducing pollutants, such as the Kyoto Accord, may be more efficient under conditions of free trade in goods.

Finally, the results from testing for the pollution haven effect also provide some cause for concern. Analyzing these effects indicates that relatively rich countries may be experiencing improved environmental quality through reduced emissions associated with openness to trade. These improvements are reflected by the downward sloping emissions paths as rich countries become more open to trade in **Figures 3** and **4**.[24] However, by failing to reject the pollution haven hypothesis, it is suggested that these environmental gains may be coming at the expense of environmental degradation in poorer countries. Emissions would thus not be reduced, but instead shifted outside of rich countries to poorer "pollution havens". The transferability of the environmental improvements that rich, developed countries appear to experience through trade liberalization is thus called into question, since currently developing countries may not be able to shift emissions outside their borders in the same way.

[24] As previously discussed, the only relatively rich group of countries that did not reduce emissions as openness increased were the strongly autocratic countries in **Figure 3**.

6.0. Conclusion

The purpose of this paper was to report an empirical study into the effects of trade liberalization on the environment. Econometric models are estimated to predict the effects of openness on organic water pollutant (BOD) and carbon dioxide (CO_2) emissions, and both models find that freer trade significantly increases emissions, thus reducing environmental quality. However, the panel data used in this study allowed inferences to be drawn beyond these *ceteris paribus* effects of trade liberalization. By controlling for the unobserved heterogeneity between countries, several additional observations are made regarding how national characteristics influence the impact of freer trade on the environment.

To acquire these results, initial estimates of models regressing both BOD and CO_2 emissions were conducted with the random effects approach to panel data. The random effects model was chosen for estimation due to the desire to identify differences in emission levels across countries with certain national characteristics. Applying the Hausman test, however, it was found that the observed values of the explanatory variables were correlated with the country specific, randomly distributed error terms, thus violating one of the key assumptions for consistency of the random effects estimator. Accordingly, instrumental variables were introduced by transforming the dataset following Hausman and Taylor (1981). The resulting Hausman and Taylor estimators, consistent and uncorrelated with the country-specific errors by definition, were thus used to derive and analyze our results. Finally, given the size and nature of our dataset (spanning 31 years and 143 countries for CO_2; 16 years and 119 countries for BOD) unobserved values were unavoidable. The flexibility of the random effects model and Hausman and Taylor estimators to adjust to unbalanced datasets was thus essential to the successful completion of this study.

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Appendix A: Descriptive Information

Table A:1: Descriptive Information for the BOD Dataset:
Mean Variable Values and Number of Years Observed for Each Country.

PANELS		*VARIALBE MEANS WITHIN PANELS*							
Country Number	*Years Observed*	*BOD*	*GDP*	*Land*	*Polity*	*Pop*	*Trade*	*Urban*	*Disrupt*
1	6	20422.9	789.702	27400	-0.33333	3.23E+06	47.8882	37.1167	0.000
2	13	100055	1644.85	2.38E+06	-6.46154	2.42E+07	48.2119	50.3385	0.000
3	3	3253.45	554.889	1.25E+06	-5	9.99E+06	101.965	27.5333	-5.000
4	14	210984	6895.87	2.74E+06	4.14286	3.10E+07	15.7978	85.645	0.000
5	5	19755.3	490.771	28200	6.2	3.43E+06	101.692	66.366	0.000
6	16	173406	17969.4	7.68E+06	10	1.64E+07	34.4326	85.8388	0.000
7	16	94743.1	25691.5	82730	10	7.68E+06	74.429	65.6413	0.000
8	3	47415.7	596.603	86600	-1.66667	7.49E+06	142.647	52.78	0.000
9	14	116700	269.352	130170	-3.07143	1.01E+08	19.9286	18.1057	0.000
10	14	120549	23554.8	30278	10	9.92E+06	134.641	96.0507	0.000
11	2	1800.02	374.87	110620	-7	3.51E+06	56.514	27.685	0.000
12	16	8262.63	872.611	1.08E+06	6.8125	6.29E+06	47.736	52.815	0.000
13	16	3074.92	2501.9	566730	7.5625	1.18E+06	108.985	34.5631	0.000
14	11	773708	4055.16	8.46E+06	2.72727	1.40E+08	18.7828	72.0782	0.000
15	16	138059	1568.18	110550	-1.375	8.78E+06	82.1063	65.0981	0.000
16	4	2423.04	220.815	273600	-7	7.23E+06	39.5507	9.35	0.000
17	8	1298.73	199.442	25680	-7	5.00E+06	35.0901	5.6225	0.000
18	12	15677	755.354	465400	-6.58333	1.11E+07	48.8608	38.3458	0.000
19	16	311417	18191.2	9.22E+06	10	2.69E+07	55.3413	76.5444	0.000
20	13	904.224	377.781	622980	-5.92308	2.75E+06	47.7275	36.7177	0.000
21	16	56476.2	3143.87	748800	0.25	1.26E+07	55.3881	82.8938	0.000
22	16	5.43E+06	326.444	9.33E+06	-7	1.09E+09	27.9723	25.3088	0.000
23	16	96642.1	2046.93	1.04E+06	8.1875	3.34E+07	30.8075	67.0781	0.000
24	8	2056.99	922.577	341500	-8	2.09E+06	105.319	45.1712	0.000
25	12	27181.4	2993.71	51060	10	3.00E+06	71.7998	53.335	0.000
26	6	13250.1	1004.71	318000	-8	1.03E+07	74.6848	37.5483	0.000
27	5	60254.6	3996.77	55920	-3.4	4.75E+06	112.672	55.082	0.000
28	16	6872.93	9005.73	9240	10	667625	105.961	61.1269	0.000
29	2	283941	4975.19	77280	8	1.03E+07	93.1488	75.15	0.000
30	16	74195.4	30642.9	42395.6	10	5.14E+06	67.192	84.4969	0.000
31	6	54053.1	1334.97	48380	6	6.07E+06	47.758	52.575	0.000
32	16	25336.2	1741.28	276840	8.75	9.68E+06	55.0845	52.8575	0.000
33	16	193023	901.262	995450	-4.3125	4.95E+07	57.0366	43.5275	0.000
34	10	8215.78	1463.18	20720	4	5.00E+06	55.2376	48.227	0.000
35	2	45.145	333.521	28050	-7	344000	106.909	33.005	0.000
36	15	19511.6	106.5	1.00E+06	-6	4.78E+07	25.4647	12.276	-0.933
37	14	4226.09	2265.4	18270	5.28571	704786	101.802	40.0179	0.000
38	16	80139.1	23886.7	304590	10	4.94E+06	55.8226	60.6125	0.000
39	16	659215	24205.8	550100	8.625	5.59E+07	43.3206	73.9406	0.000
40	7	2145.91	4616.72	257670	-5.42857	949143	90.7721	66.44	0.000

41	4	695.832	369.835	10000	7.5	756750	113.501	21.5425	0.000
42	5	845025	29527	348950	10	8.10E+07	48.5394	86.02	0.000
43	11	13590.1	338.334	227540	-4.18182	1.37E+07	31.5725	34.4018	0.000
44	16	62512.9	10669.5	128900	9.25	1.01E+07	46.6204	58.5831	0.000
45	14	18394.9	1413.18	108430	-0.53571	8.24E+06	37.4609	40.0736	-0.107
46	3	14130.5	788.814	196850	-7	761667	153.008	30.8	0.000
47	9	5151.51	562.818	27560	-8.55556	5.77E+06	44.8843	25.8511	-1.778
48	16	19034.3	695.466	111890	5.3125	4.55E+06	65.5834	38.8462	0.313
49	16	177631	4531.81	92341.3	0.375	1.05E+07	73.4631	60.4569	0.250
50	16	1.42E+06	294.213	2.97E+06	8.0625	8.08E+08	16.0323	24.8906	0.000
51	16	421660	714.968	1.81E+06	-7	1.71E+08	49.1479	28.5219	0.000
52	14	94186.3	1370.63	1.64E+06	-6.28571	4.89E+07	26.9383	54.175	-1.143
53	16	37106.2	13528.7	68890	10	3.52E+06	112.326	56.6044	0.000
54	16	46634	13567.9	20620	9	4.56E+06	88.1305	89.9112	0.000
55	16	394474	16838.6	294110	10	5.67E+07	42.3368	66.7787	0.000
56	13	15929.7	1962.17	10830	9.76923	2.36E+06	103.809	50.3915	0.000
57	16	1.50E+06	35542	365031	10	1.22E+08	21.0945	61.9188	0.000
58	16	8229.15	1724.63	88930	-6.5625	3.04E+06	122.892	69.2787	0.000
59	16	38302.3	335.693	569140	-6.25	2.16E+07	58.1211	22.6275	0.000
60	16	334166	7189.3	98730	0.65625	4.17E+07	62.7207	68.6825	0.031
61	14	8486.01	11931.7	17820	-8.42857	1.68E+06	98.6987	93.9029	0.000
62	4	26308	530.083	191800	-3	4.53E+06	75.919	36.865	0.000
63	5	33253.5	2206.22	62050	8	2.59E+06	106.094	69.29	0.000
64	8	1788.13	420.573	30350	-3.25	1.50E+06	136.123	16.405	0.000
65	3	50522.4	2204.28	64800	10	3.68E+06	110.985	67.4067	0.000
66	5	27149.4	2455.96	25430	6	1.94E+06	84.0628	58.954	0.000
67	9	11990.9	288.369	581540	-6	9.89E+06	34.167	20.54	0.000
68	16	9539.94	147.823	94080	-6.9375	7.80E+06	58.2758	11.0369	0.000
69	16	97974.9	2994.35	328550	3.9375	1.70E+07	131.682	48.2269	0.000
70	16	14875.3	2494.89	2030	9.875	1.04E+06	115.942	41.3162	0.000
71	16	175869	3232.63	1.91E+06	-1	7.94E+07	33.3987	70.5869	0.000
72	5	42631	641.635	32910	6.2	4.35E+06	118.86	46.45	0.000
73	15	10594.5	434.757	1.57E+06	-1.53333	2.02E+06	110.091	55.666	0.000
74	16	49235.2	1222.17	446300	-7.75	2.29E+07	54.6652	46.6125	0.000
75	3	22183.3	129.256	784090	-6.66667	1.42E+07	47.6051	20.92	0.000
76	9	23980.5	185.205	143000	1.11111	1.78E+07	36.3055	8.83667	0.000
77	16	139235	23362.4	33880	10	1.48E+07	105.778	59.6362	0.000
78	16	54567.3	15250.9	267990	10	3.37E+06	57.8522	84.2725	0.000
79	6	10862.2	650.678	121400	-3.91667	3.16E+06	50.9226	50.97	-1.083
80	3	305.083	321.049	1.27E+06	-7	5.77E+06	60.0473	12.93	0.000
81	11	64314.8	255.439	910770	-1.45455	8.98E+07	58.311	32.8545	0.000
82	16	57487.9	27915.8	306830	10	4.21E+06	73.3388	71.7475	0.000
83	10	1436.31	5539.92	309500	-9.5	1.74E+06	85.3919	60.946	0.000
84	12	91628.7	392.755	770880	-1.25	9.63E+07	34.9678	29.4525	0.000
85	15	9484.64	2778.8	74430	-0.46667	2.26E+06	75.1999	52.7	0.000
86	10	5303.96	832.719	452860	10	3.48E+06	94.3954	13.105	0.000
87	15	52159.4	2288.48	1.28E+06	5.66667	2.04E+07	32.6675	67.6707	0.000

88	16	167214	1080.2	298170	1.9375	5.78E+07	57.6098	45.8506	0.063
89	6	403516	2984.64	304408	7.66667	3.84E+07	47.2776	61.0117	0.000
90	16	116483	8834.33	91500	9.875	9.92E+06	65.7081	41.1662	0.000
91	5	370717	1483.76	230340	5	2.29E+07	49.7807	53.89	0.000
92	3	1.80E+06	2876.45	1.69E+07	4	1.48E+08	58.2786	73.36	0.000
93	3	2093.98	312.714	24670	-7	6.05E+06	31.9015	5.01	0.000
94	3	20364.4	9959.89	2.15E+06	-10	1.40E+07	80.1456	74.7967	0.000
95	16	9346.04	558.23	192530	-1.0625	6.88E+06	65.9927	39.1237	0.000
96	3	2633.29	316.635	71620	-7	3.65E+06	49.2498	27.2667	0.000
97	4	69544	3421.1	48800	7	5.32E+06	117.971	56.645	3.500
98	3	42508.3	9063.44	20120	10	1.98E+06	114.667	50.77	0.000
99	16	249742	4206.28	1.22E+06	5.125	3.33E+07	47.9298	49.2537	0.875
100	16	325995	12647.9	499444	9.875	3.85E+07	38.1167	74.6094	0.000
101	16	54119.4	585.836	64630	5.125	1.59E+07	70.3366	21.3669	0.000
102	16	3328.51	1304.86	17200	-9.8125	719938	159.885	21.6406	0.000
103	16	112605	26060.6	411620	10	8.49E+06	61.3749	83.11	0.000
104	10	137488	43907.6	39550	10	6.76E+06	69.5099	67.065	0.000
105	16	23780.2	707.486	183780	-9	1.13E+07	51.9068	48.36	0.000
106	4	31766.4	182.254	883590	-5.25	2.75E+07	54.389	24.3	0.000
107	9	264245	1840.42	510890	3.55556	5.42E+07	66.8452	28.9567	0.000
108	5	1041.69	413.531	54390	-7	2.69E+06	102.447	24.35	0.000
109	5	34846	1858.99	155360	-5.2	7.87E+06	90.3153	57.104	0.000
110	16	167500	2372.04	769630	5.4375	5.31E+07	31.8292	54.7475	0.000
111	6	6831.3	232.581	197100	-4.5	1.53E+07	26.9168	10.2917	-0.333
112	5	623500	1343.53	579350	6	5.20E+07	63.8548	66.872	0.000
113	16	753899	16673.6	240880	10	5.72E+07	52.0328	88.5419	0.000
114	16	2.56E+06	24371.2	9.16E+06	10	2.44E+08	19.7559	75.1219	0.000
115	16	31975.4	5193.61	175020	4.4375	3.06E+06	40.7585	88.0387	0.000
116	16	90352	3563.58	882050	8.75	1.84E+07	48.6054	82.7763	0.000
117	6	7584.31	261.712	527970	-2	1.39E+07	77.7712	22.4383	-1.000
118	5	13791.4	529.871	743390	-6	6.85E+06	73.2059	39.29	0.000
119	16	35893.6	625.946	386850	-2.1875	9.38E+06	50.6096	27.1162	0.000

1 Dataset includes observations for 119 countries over maximum range of 16 years (1980-1995).
2 Countries not observed in all years of the dataset still provide efficiency in model estimation through unbalanced panel estimation techniques.

Table A:2: Descriptive Information for the CO2 Dataset:
Mean Variable Values and Number of Years Observed for Each Country.

PANELS		*VARIABLE MEANS WITHIN PANELS*							
Country Number	*Years Observed*	*CO2*	*GDP*	*Land*	*Polity*	*Pop*	*Trade*	*Urban*	*Disrupt*
1	21	4846.91	845.228	27400	-2.28571	3.07E+06	46.4639	36.9529	0.000
2	31	64470.7	1573.78	2.38E+06	-6.96774	2.20E+07	54.8342	47.6645	0.000
3	15	5573.16	590.592	1.25E+06	-5.26667	1.02E+07	105.55	27.8733	-1.667
4	31	108733	7204.96	2.74E+06	2.06452	3.01E+07	15.9992	84.7181	0.000
5	9	3155.11	507.763	28200	3	3.29E+06	86.8547	65.7989	0.000
6	31	232814	17650.3	7.68E+06	10	1.59E+07	33.8904	86.3816	0.000
7	31	56479.4	24474.5	82725.2	10	7.68E+06	72.9133	65.5642	0.000
8	9	35238.3	497.235	86600	-4.88889	7.75E+06	100.802	51.82	0.000
9	21	12652.8	9384.13	698.571	-9.61905	501619	180.786	88.1733	0.000
10	29	12982.8	274.719	130170	-0.55172	9.99E+07	21.691	17.0414	0.000
11	9	67708.7	1645.7	207480	-1.55556	1.01E+07	126.101	68.32	0.000
12	31	111691	22928.2	30278	10	9.93E+06	127.756	95.7297	0.000
13	31	687.425	365.232	110620	-2.27419	4.20E+06	47.1975	30.3661	-0.016
14	21	171.824	376.622	47000	-8	620571	70.2449	5.61905	0.000
15	31	5907.71	925.432	1.08E+06	2.96774	6.07E+06	49.6871	50.5281	0.000
16	29	1783.48	2276.52	566730	7.62069	1.15E+06	110.412	31.2814	0.000
17	31	193336	3927.2	8.46E+06	1.54839	1.34E+08	17.6235	69.7945	0.000
18	21	68664.1	1536.49	110550	0.857143	8.65E+06	87.4585	65.8852	0.000
19	31	574.184	227.65	273600	-4.5	8.06E+06	35.4712	11.0358	0.016
20	31	146.087	177.682	25680	-6.16129	4.89E+06	31.8681	5.3829	-0.774
21	8	549.143	326.611	176520	0.375	1.13E+07	78.344	15.0737	0.000
22	31	3577.41	715.211	465400	-6.74194	1.04E+07	48.3447	35.5813	0.000
23	31	407305	17545.9	9.22E+06	10	2.62E+07	56.5732	76.5997	0.000
24	31	186.273	393.116	622980	-3.83871	2.69E+06	51.0954	36.1955	0.000
25	31	148.332	225.026	1.26E+06	-6.08065	5.32E+06	43.4527	19.1829	-1.758
26	31	32895.5	3197.74	748800	0.451613	1.22E+07	50.1066	81.7094	0.000
27	31	2.00E+06	326.699	9.33E+06	-7.19355	1.05E+09	23.9913	24.3058	0.000
28	31	47851.9	1954.24	1.04E+06	7.80645	3.19E+07	31.4815	65.7097	0.000
29	21	57.4025	499.003	2230	-1.42857	437190	58.6773	28.0229	0.190
30	31	3283.19	244.99	2.27E+06	-8.64516	3.34E+07	39.262	28.9016	-2.323
31	29	1429.2	735.296	341500	-4.94828	2.20E+06	108.414	43.4731	-0.052
32	31	3067.2	3015.61	51060	10	2.69E+06	74.4244	49.8226	0.000
33	31	6200.73	1002.18	318000	-7.58065	1.02E+07	70.0318	36.8513	-0.032
34	9	18548.4	4355.95	55920	-2.33333	4.58E+06	96.2028	56.1933	0.111
35	25	3997.56	8789.44	9240	10	668720	104.634	59.6496	0.000
36	9	123888	5035.28	77280	9.77778	1.03E+07	116.504	74.5511	0.000
37	31	57242	29952.8	42393.2	10	5.14E+06	65.1195	83.6939	0.000
38	6	373.117	781.091	23180	-3.5	624167	103.534	80.7233	0.000
39	31	10027.4	1385.53	48380	3.93548	6.39E+06	57.2783	51.8868	0.000
40	31	15533.9	1677.8	276840	5	9.14E+06	53.9824	50.5071	0.000
41	31	65154.5	825.981	995450	-5.03226	4.71E+07	52.411	43.2242	0.000

42	31	2995.3	1583.63	20745.2	3.06452	4.87E+06	57.7082	47.4329	0.000
43	14	171.424	443.923	28050	-6.14286	369786	133.258	36.2064	0.000
44	8	364.109	166.596	101000	-6	3.73E+06	103.667	17.6112	0.000
45	9	18966.5	3130.13	42270	6	1.43E+06	156.262	69.8711	0.000
46	20	3042.59	107.76	1.00E+06	-4.25	5.12E+07	29.416	12.835	-0.700
47	31	686.208	2288.52	18270	6.46774	679484	103.573	40.4255	0.177
48	31	50630.7	22659.8	304590	10	4.90E+06	56.9438	59.28	0.000
49	31	404092	23157.1	550100	8.48387	5.52E+07	42.0387	73.689	0.000
50	31	4799.07	4838.55	257670	-7.30645	840871	96.2009	58.1065	-0.210
51	31	160.862	358.393	10000	4.6129	812516	104.43	21.7484	0.000
52	9	6413.63	657.504	69490	4.66667	5.34E+06	81.2796	53.6256	0.000
53	10	837300	30421.9	348950	10	8.15E+07	52.8955	86.575	0.000
54	31	3590.94	378.293	227540	-2.98387	1.34E+07	42.7303	34.5965	-0.145
55	31	59397.5	10487.5	128900	6.79032	9.82E+06	43.4313	57.6013	0.016
56	31	4822.14	1418.38	108430	0.66129	7.94E+06	41.0315	39.661	-0.048
57	15	1118.01	550.857	245720	-4.06667	6.26E+06	50.7752	27.5347	0.000
58	27	412.839	217.273	28120	-4.03704	967815	50.755	22.3252	0.370
59	31	1476.95	774.781	196827	-0.70968	743258	162.019	32.1723	0.000
60	31	829.837	495.82	27560	-5.08065	6.00E+06	39.7727	26.9158	-0.435
61	31	2523.79	685.755	111890	3.48387	4.30E+06	72.0616	37.2968	0.161
62	31	70848	4258.5	92328.7	-0.45161	1.04E+07	83.289	58.3394	0.129
63	31	559291	291.438	2.97E+06	8.29032	7.72E+08	15.9161	24.0761	0.000
64	31	129574	660.17	1.81E+06	-6.03226	1.63E+08	49.8085	27.2729	0.000
65	27	193398	1548.23	1.64E+06	-5.62963	4.89E+07	37.8162	54.5781	-0.889
66	31	27941.3	13767.3	68890	10	3.43E+06	112.434	55.9013	0.000
67	31	32534	13141	20620	9.06452	4.41E+06	89.4591	88.9565	0.000
68	31	368189	15870.7	294110	10	5.64E+07	42.8598	66.3955	0.000
69	31	7672.78	2053.52	10830	9.74194	2.26E+06	94.2973	48.3252	0.000
70	31	976810	33170	365432	10	1.19E+08	21.2915	60.5926	0.000
71	25	9476.13	1646.11	88930	-6.2	3.18E+06	120.572	69.4876	0.000
72	9	161317	1440.91	2.70E+06	-3.66667	1.56E+07	88.6059	56.3156	0.000
73	31	5570.5	323.724	569140	-5.87097	2.02E+07	60.3902	21.2052	0.000
74	31	202401	6764.74	98730	-0.40323	4.02E+07	61.273	63.5564	0.016
75	29	29576.7	16429.7	17820	-8.34483	1.51E+06	98.0552	90.6124	0.000
76	9	6311.04	431.728	191800	-3	4.69E+06	84.2726	35.7033	0.000
77	15	269.181	336.14	230800	-7	4.25E+06	43.5325	15.86	0.000
78	9	9118.48	2148.57	62050	8	2.49E+06	111.686	68.2478	0.000
79	9	16019.4	2305.12	64800	10	3.61E+06	107.551	67.2122	0.000
80	9	10909.8	2378.26	25430	6	1.98E+06	92.061	59.3622	0.000
81	31	1187.01	298.249	581540	-1.01613	1.05E+07	40.9794	20.8335	0.048
82	31	609.654	150.378	94080	-5.35484	7.30E+06	61.29	10.4184	0.000
83	31	55236.2	2856.82	328550	3.70968	1.63E+07	128.118	46.4816	0.000
84	31	401.728	269.825	1.22E+06	-2.83871	7.68E+06	48.0145	21.4648	0.000
85	31	1651.73	450.989	1.03E+06	-6.67742	1.84E+06	103.318	35.7781	0.000
86	21	1333.35	2821.78	2030	9.90476	1.07E+06	119.059	41.5348	0.000
87	31	272667	3084.51	1.91E+06	-1.19355	7.51E+07	33.4111	68.5132	0.000
88	9	11621.4	504.713	32910	6.77778	4.32E+06	128.047	46.1289	0.000

89	20	8717.99	429.954	1.57E+06	1.35	2.10E+06	116.527	55.92	0.000
90	31	20010.9	1162.46	446304	-7.83871	2.18E+07	53.3544	44.8942	0.000
91	11	1425.1	153.513	784090	-1.27273	1.51E+07	41.6447	23.2727	0.000
92	9	1220.93	2239.7	823290	6	1.70E+06	105.503	29.0744	0.000
93	31	1074.3	177.379	143000	-1.93548	1.67E+07	34.6066	8.03419	0.000
94	31	138798	23018	33880	10	1.45E+07	103.491	59.3268	0.000
95	30	22610.5	15230.7	267990	10	3.34E+06	56.7079	83.9667	0.000
96	31	2314.35	641.982	121400	-0.90323	3.45E+06	70.2642	51.6468	-0.419
97	31	787.607	272.036	1.27E+06	-4.01613	6.84E+06	44.2808	14.3945	0.016
98	31	54551.5	268.208	910770	-3.25806	8.56E+07	53.4938	31.3245	-0.032
99	31	37839.1	26471.8	306830	10	4.17E+06	74.3181	70.9781	0.000
100	30	9930.23	4646.8	309500	-9.66667	1.45E+06	95.0792	45.5317	0.000
101	29	54492.3	394.598	770880	1.58621	9.88E+07	34.1169	29.4793	0.276
102	21	4003.18	2909.6	74430	2.2381	2.40E+06	73.2054	53.5324	0.000
103	25	2134.65	898.941	452860	10	3.75E+06	92.9557	12.9864	0.000
104	31	2079.83	1664.04	397300	-2.70968	3.67E+06	52.1192	45.4703	0.000
105	31	22688.5	2349.86	1.28E+06	1.25806	1.95E+07	33.2358	66.2539	0.161
106	31	43322.9	1064.31	298181	0.096774	5.50E+07	61.0897	44.1613	0.032
107	11	337691	3417.74	304387	8.27273	3.85E+07	50.9928	61.2409	0.000
108	31	33728.6	8520.86	91500	6.70968	9.67E+06	61.2171	38.5006	0.000
109	11	115127	1502.73	230340	6.36364	2.27E+07	56.8513	54.3591	0.000
110	9	1.56E+06	2823.27	1.69E+07	4.55556	1.48E+08	63.7616	73.3456	0.000
111	31	352.607	276.572	24670	-6.5	5.75E+06	31.4513	6.01194	-0.210
112	31	173444	9752.78	2.15E+06	-10	1.27E+07	77.3519	70.7787	0.000
113	31	2740.19	575.076	192530	-2.22581	6.54E+06	67.9585	38.6587	0.000
114	3	46752.6	1754.6	102136	-6	1.06E+07	51.2559	51.5	0.000
115	31	515.572	294.102	71620	-4.64516	3.69E+06	45.7418	27.1265	0.581
116	9	39272	3798.91	48800	7.66667	5.36E+06	125.961	56.7589	0.778
117	8	13869.2	10076.7	20120	10	1.99E+06	114.092	50.7887	0.000
118	31	255028	4205.72	1.22E+06	5.3871	3.18E+07	49.8827	49.6552	0.452
119	31	196702	12382.3	499515	6.25806	3.77E+07	37.7132	73.09	0.097
120	31	4590.41	559.58	64630	5.90323	1.54E+07	68.7962	21.5032	0.000
121	23	3935.98	239.825	2.38E+06	-5.47826	2.12E+07	27.7151	23.0043	-0.304
122	31	382.711	1247.46	17200	-8.77419	685419	155.558	19.249	0.000
123	31	63918.2	25270.7	411620	10	8.45E+06	60.9403	82.8774	0.000
124	31	40503.7	41171.4	39550	10	6.62E+06	68.726	62.0661	0.000
125	31	28652.2	672.759	183780	-8.93548	1.07E+07	53.8715	47.4955	0.000
126	5	5003.56	209.057	140600	-2.8	6.09E+06	145.718	26.888	0.000
127	11	2919.48	182.983	883590	-3.18182	2.96E+07	49.5604	26.9409	0.000
128	31	83204.9	1646.19	510890	2.8871	5.03E+07	63.1807	27.3484	-0.210
129	31	773.565	379.408	54390	-5.54839	3.06E+06	88.9808	24.6661	-0.290
130	31	11365.8	1721.57	155360	-6.45161	7.29E+06	77.2686	54.6606	0.000
131	31	117228	2321.53	769630	6.12903	5.07E+07	29.1456	51.7823	0.000
132	8	31799.4	594.427	469930	-9	4.34E+06	100.071	44.6763	0.000
133	17	924.923	275.381	197100	-4.70588	1.85E+07	30.0144	11.1476	-0.118
134	9	420007	1017.12	579350	6.55556	5.10E+07	83.9678	66.99	0.000
135	31	576437	16255	240880	10	5.71E+07	52.6106	86.501	0.000

136	31	4.75E+06	23536.7	9.16E+06	10	2.40E+08	19.0281	75.1703	0.000
137	31	5023.67	5184	175020	2.41935	3.02E+06	38.1001	87.1052	0.000
138	9	111058	623.6	414240	-9	2.32E+07	53.5047	38.2489	0.000
139	31	105271	3777.32	882050	8.64516	1.73E+07	47.7152	80.9206	0.000
140	15	30846.2	261.931	325490	-7	7.00E+07	70.699	21.6387	0.000
141	10	11643.7	283.389	527970	-2	1.54E+07	82.8952	23.461	-0.400
142	31	3044.65	542.23	743390	-4.3871	6.83E+06	74.9179	37.1216	0.000
143	26	13335.3	627.929	386850	-1.67308	9.36E+06	54.7658	26.9727	0.173

1 Dataset includes observations for 143 countries over maximum range of 31 years (1970-2000).
2 Countries not observed in all years of the dataset still provide efficiency in model estimation through unbalanced panel estimation techniques.

Appendix B: Random Effects Models

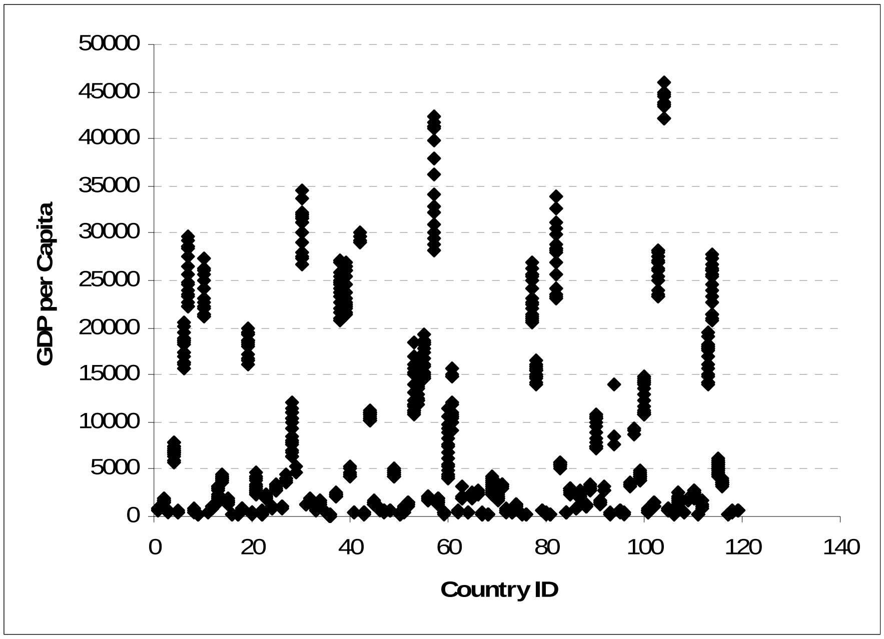
Table B:1: Random Effects Estimators for Panel Data Models Estimating the Effect of Openness on BOD and CO2 Emission Levels while Controlling for National Characteristics.

VARIABLE	***REGRESSAND = BOD*** ***(MODEL 1)***	***REGRESSAND = CO2*** ***(MODEL 2)***
GDP	42.9224* (13.8758)	19.2847* (2.7583)
GDP2	-0.00149 (0.000923)	-0.000306* (0.00008)
Trade	1287.0131* (366.226)	262.7237* (70.8675)
Polity	1731.4803 (2359.4646)	-742.8951** (423.0826)
Pop	0.00547* (0.000179)	0.00369* (0.00005)
Land	0.01327 (0.01185)	0.03739* (0.01311)
Urban	3618.7357* (1062.8450)	53.8731 (202.5192)
Disrupt	-808.7068 (6459.1326)	2642.835* (1256.2304)
Respond	-18.4651 (11.6275)	1.3538 (1.8806)
Respond2	0.00117 (0.000902)	0.000194* (0.00007)
ATrade	729.1924* (325.7277)	42.8767 (60.1491)
Haven	-0.1641* (0.05213)	-0.09638* (0.00846)
Constant	-357575.1* (54690.135)	-106143.5* (31521.364)
# Countries	N = 119	N = 143
Years	1980 – 1995	1970 – 2000
Hausman Test Statistic	254.83 12 df; p-value = 0.0000	97.85 12df; p-value = 0.0000

1 Standard errors provided in parentheses.
2 * indicates significance at the 5% level or better
3 ** indicates significance at the 10% level or better
4 The panel data in this study required the application of unbalanced panel estimation techniques.

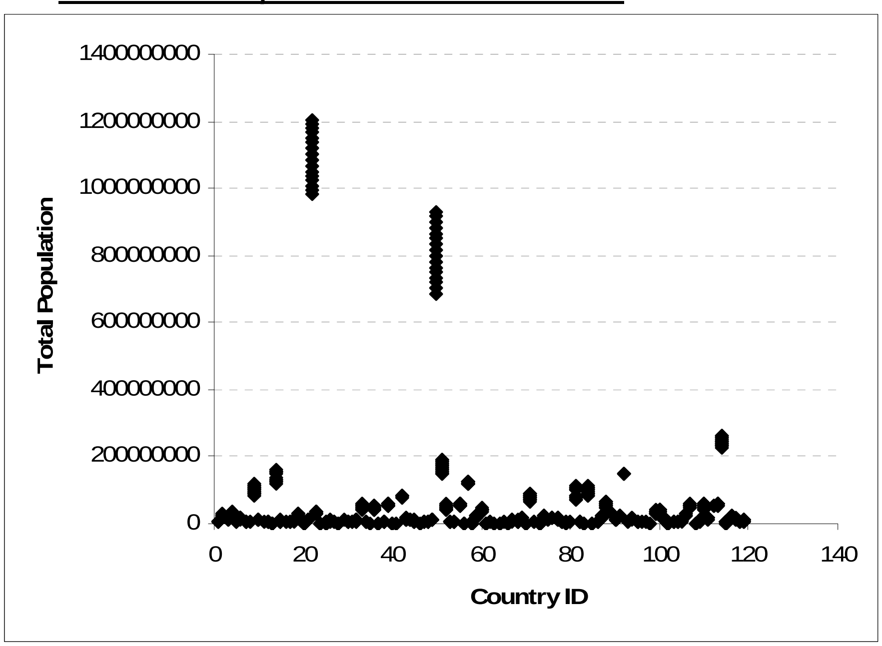
BOD Dataset Scatter Plots:

Figure B:1: Scatter Plot of GDP per Capita Observations Across Countries. Values shown are for the BOD Dataset: 1980-1995.



1 Max GDP per Capita Observation = $45,951. 95
2 Mean GDP per Capita Observation = $6,871. 53
3 Median GDP per Capita Observation = $2,091. 63

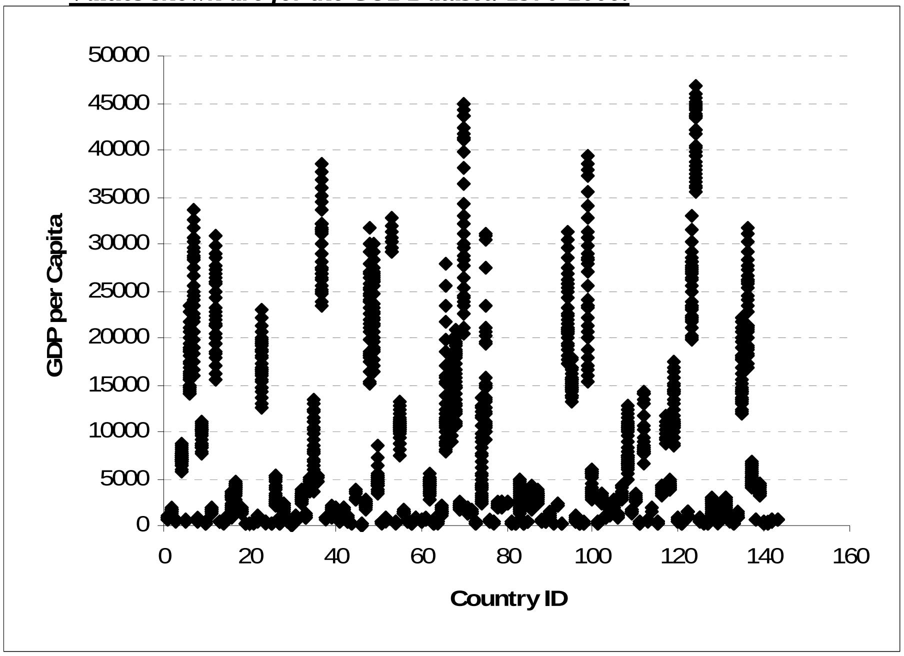
Figure B:2: Scatter Plot of Total Population Observations Across Countries. Values shown are for the BOD Dataset: 1980-1995.



1 Max Population Observation = 1,200,000,000
2 Mean GDP per Capita Observation = 48,616,678
3 Median GDP per Capita Observation = 9,994,000

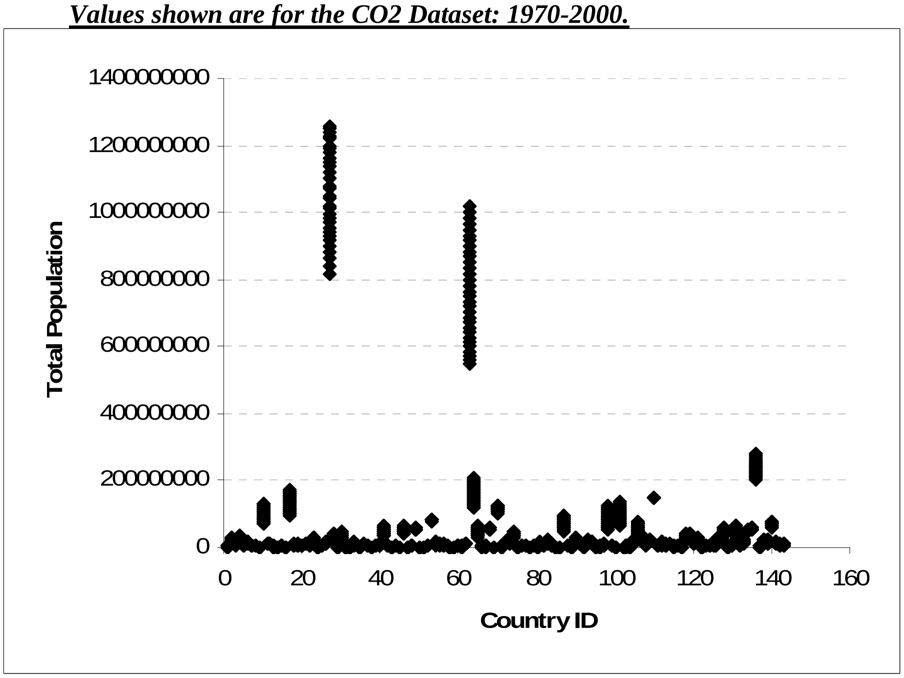
CO2 Dataset Scatter Plots:

Figure B:3: Scatter Plot of GDP per Capita Observations Across Countries. Values shown are for the CO2 Dataset: 1970-2000.



1 Max GDP per Capita Observation = $46,815. 50
2 Mean GDP per Capita Observation = $5,434.13
3 Median GDP per Capita Observation = $1,399.71

Figure B:4: Scatter Plot of Total Population Observations Across Countries. Values shown are for the CO2 Dataset: 1970-2000.



1 Max Population Observation = 1,260,000,000
2 Mean GDP per Capita Observation = 37,746,439
3 Median GDP per Capita Observation = 8,257,500