Testing the Environmental Kuznets Curve Hypothesis for CO_2 Emissions

What Can We Learn About the Pollution-Income Relationship and Pathways Toward Sustainable Development

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1. Introduction

Global temperatures are rising, glaciers are melting, and mass extinctions are ravaging the most biodiverse places on the planet. If temperatures rise 2°C above preindustrial levels by 2100, scientists say the damage will be irreversible.

According to the United States Environmental Protection Agency (EPA),

> "Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere […] The primary human activity affecting the amount and rate of climate change is greenhouse gas emissions from the burning of fossil fuels," (EPA, 2017).

Thus, climate change is largely attributable to the emissions-intensive development strategies of industrialized countries. Just from observing the trend in atmospheric CO_2 concentrations over the past 120 years, as seen in Figure 1, and the trend in global temperature anomaly over the same time frame, as seen in Figure 2, it is hard to deny that the trends seem related (Huang et al., 2007; Keeling et al., 2001). Additionally, there is evidence that the negative effects are being exacerbated by aggressive, and environmentally negligent, development strategies of the industrialized world.

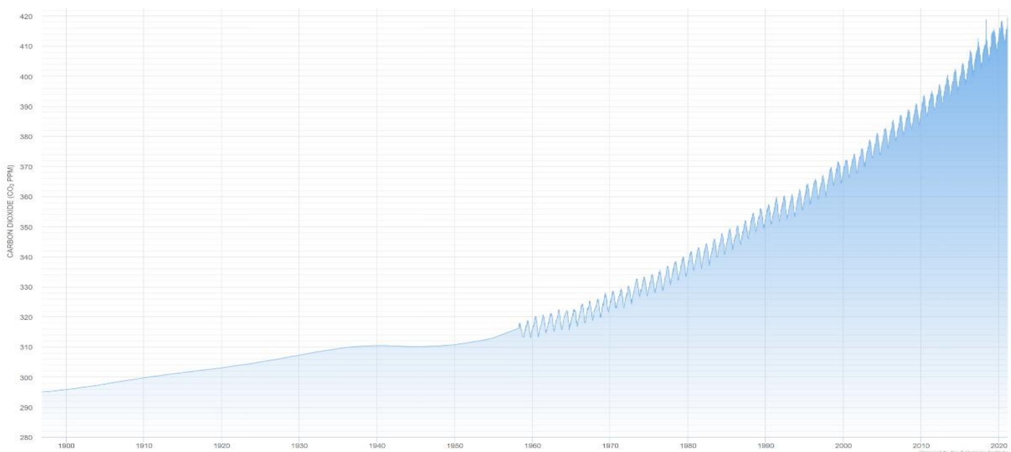

Figure 1: Carbon Dioxide Concentration (1900-2020) from https://www.co2levels.org/

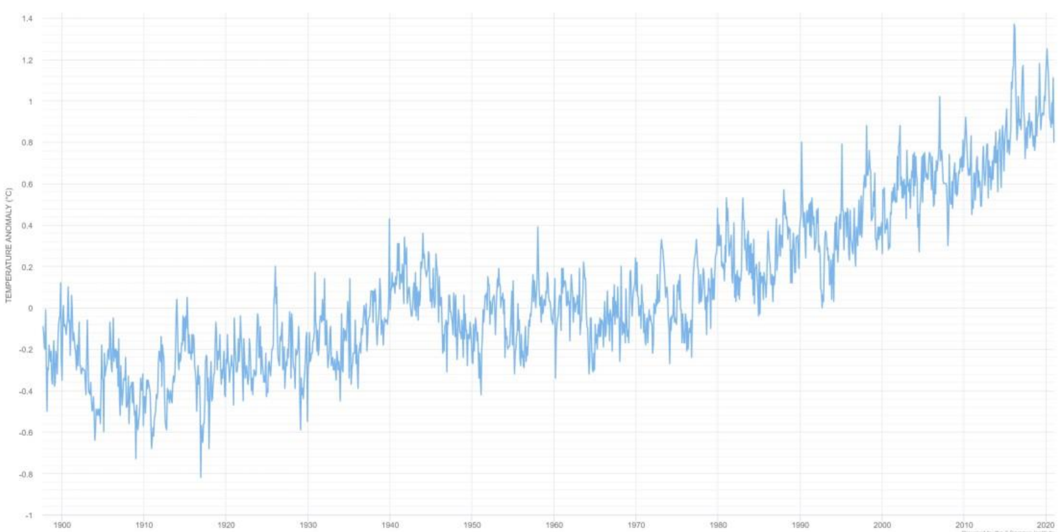

Figure 2: Global Temperature Anomaly (1900-2020) from https://www.temperaturerecord.org/

While climate change is clearly a pressing issue, developing countries face a disproportionately large amount of the negative effects. According to the International Panel on Climate Change (IPCC), "[r]egions at disproportionately higher risk include Arctic ecosystems, dryland regions, small island developing states, and Least Developed Countries," (IPCC, 2018). This indicates that, while developing countries are largely not to blame for the climate crisis, they are the ones suffering the most from the repercussions. The dichotomy that presents itself is that, in order to resist the negative effects of climate change, Least Developed Countries need to strengthen their economies. However, development itself has historically been a major driver of climate change.

At the global scale, many efforts are being made to combat climate change and to promote economic development in less developed nations. Finding solutions to these, and other, pressing international challenges motivated the creation of the United Nations' Sustainable Development Goals (SDGs). A call for the development of the SDGs was made at the United Nations Conference of Sustainable Development in Rio de Janeiro in 2012. After solidifying these goals, the *2030 Agenda for Sustainable Development* was adopted at the UN Sustainable Development Summit in September of 2015 (UN General Assembly, October 2015). The SDGs were at the Agenda's core.

Within the same year that the Sustainable Development Agenda was adopted, several other multilateral agreements were also adopted. These include:

- the *Sendai Framework for Disaster Risk Reduction* (UN General Assembly, March 2015), which outlines priorities and pathways toward disaster risk reduction (especially disasters which may be exacerbated by climate change,
- the *Addis Ababa Action Agenda on Financing for Development* (UN General Assembly, July 2015), which provides policy actions to finance Sustainable Development,
- the *Paris Agreement on Climate Change* (UNFCCC, December 2015), which is a legally binding international treaty to limit global warming.

Thus, it is evident that finding pathways toward sustainable development, and the urgency of climate action, are at the forefront of international conversations. Additionally, it is clear that efforts to combat climate change are being addressed at a global scale.

Despite clear evidence of action being taken to combat climate change and to promote economic development, in order to implement the most effective policies towards these goals, it is essential to have a deep understanding of how these variables interact. Thus, in an effort to better understand the relationship between environmental degradation and economic development, and in an effort to examine the best paths toward achieving SDGs, the goal of this thesis is to analyze the dynamics which underpin the pollution-income relationship. To do this, I will use the Impact, Population, Affluence, and Technology (IPAT) equation and the Environmental Kuznets Curve (EKC) Hypothesis, which are both frequently used in the field of environmental economics.[1]

1.1: The EKC Hypothesis for Local and Global Pollutants

The Environmental Kuznets Hypothesis suggests that as a country develops, environmental quality deteriorates until a certain level of development has been reached. At this point, environmental quality should begin to improve. The idea is that once societies have reached a threshold level of development, they will gain more utility from a cleaner environment than from further environmentally negligent development. Testing the EKC Hypothesis determines if there exists a nonlinear relationship between

[1] While the following section provides a brief overview of the EKC Hypothesis and the IPAT model, these models are discussed in detail in section 2.1 and 2.2 below.

economic development and environmental quality. Additionally, the testing the EKC Hypothesis seeks to discover if there exists a "turning point" level of economic development that can be reached, at which point environmental quality within a nation can be expected to improve. If a countries' pollution-income relationship is consistent with the EKC hypothesis, we would expect to see an inverted U-shaped relationship when emissions levels are graphed over income levels, as seen in Figure 3 below.

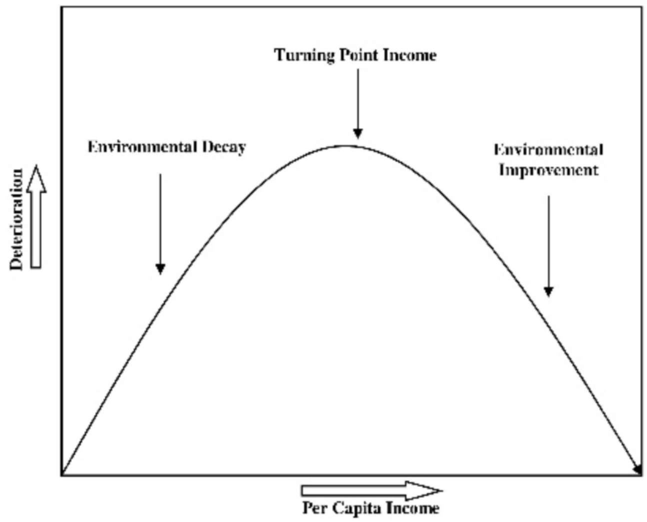

Figure 3: EKC Relationship from https://earthbound.report/2014/03/11/the-environmental-kuznets-curve/

Many previous EKC studies have found an EKC relationship in the case of local pollutants, such as SO_2 emissions; however, I will test if this relationship also holds for CO_2, the global pollutant most responsible for spurring the climate crisis. The implications of an EKC in CO_2 is different than for SO_2 because the negative effects CO_2 emissions are felt at a global scale and for a longer duration than the effects of local pollutants. The location and duration of the effects of these different types of pollutants can be summarized by Figure 4 (Bornstein, 2018). Thus, the existence of an EKC in CO_2 emissions would suggest that, rather than just gaining more utility from a cleaner local environment after a certain level of development has been reached, societies also gain more utility from a safer and cleaner world in the future. This makes CO_2 a particularly important pollutant to examine when determining the best approaches to Sustainable Development.

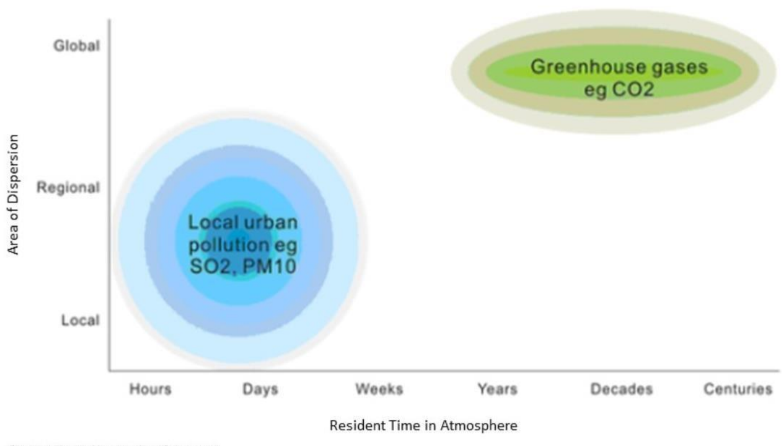

Figure 4: Effects of Local vs Global Air Pollutants from https://energyathaas.wordpress.com

1.2. The IPAT Model

Similar to the EKC Hypothesis, the IPAT model focuses on development indicators and their effects on the environment. Specifically, the IPAT model, estimates the elasticity of environmental impact to changes in development indicators (specifically, Population, Affluence, and Technology). It assumes the IPAT identity, seen in Equation 1 below, when taken in the log linear form, as shown in Equation 2 below, finds the elasticity of Impact to changes in Population, Affluence, and Technology.

$$I_i = \propto P_i^{\beta} A_i^{\gamma} T_i^{\delta} \varepsilon_i$$

Equation 1: IPAT Identity, from (Aguir Bargaoui, S., Liouane, N., & Nouri, F. Z., 2014)

$$lnI_i = \alpha_0 + \beta ln(P_i) + \gamma ln(A_i) + \delta \ln(T_i) + \mu_i$$

Equation 2: IPAT Equation Log Linear form, from (Aguir Bargaoui, S., Liouane, N., & Nouri, F. Z., 2014)

In my case, the Impact variable can be taken to be CO_2 emissions and the Affluence can be GDP per capita. Using the IPAT model then becomes very similar to testing the EKC Hypothesis; however, nonlinear effects of changes in GDP per capita are not controlled for. Using the IPAT model in this form assumes that a country's pollution-income relationship is linear and thus does not follow an EKC relationship.

I will use the IPAT model to determine the elasticity of CO_2 emissions to changes in Population, Affluence and Technology. Determining the elasticity of emissions to changes in these development indicators may help decision makers to decide whether policies aimed at changing population growth, affluence, or technology will be the most effective in emission reduction. I hope to determine if the EKC holds empirically when integrated into the framework of the IPAT equation and within the context of recent technology advancements. Additionally, I aim to use the most contemporary forms of panel data analysis to estimate these models. Advancements in panel data analysis methods have been made since the first EKC and IPAT studies, and these methods should yield the most consistent and unbiased results.

1.3. Hypotheses

Hypothesis 1:

> I hypothesize that the EKC will hold, but that the relationship between environmental degradation and income in developed and developing countries differs. Specifically, I expect that, relative to Developed Countries, Developing Countries gain more utility from a reduction in CO_2 emissions and thus have a lower turning point level of GDP per capita at which point we can expect environmental quality to begin to improve.
>
> I make this hypothesis because, as mentioned, Least Developed Countries are at a disproportionately high risk from the effects of climate change. Thus, I think it is reasonable to assume that these countries would gain more utility from reducing emissions than from further development. On the other hand, developed countries who are less impacted by the negative externalities associated with global pollutants may not gain the same level of utility from emissions reductions. In the context of environmental policy, this might indicate that the most effective policies to achieve SDGs differ between developed and developing countries.

Hypothesis 2:

> I hypothesize that the IPAT model will find that emissions are more elastic to changes in Affluence in developing countries than developed countries. This is because developed countries are already very reliant on the emissions-intensive means they have used to industrialize. Countries who still have a lot of developing to do may have cleaner development methods to choose from than countries who developed before environmentally conscious technology advancements. As a result, it might require a smaller increase in Affluence in these nations to spark a switch to cleaner forms of development than in countries who already have well established production practices.

Hypothesis 3:

> I hypothesize that an increase in renewable energy in a country's energy mix is associated with a reduction in emissions. Increasing access to energy in developing countries is a focus of the Sustainable Development Goals. As a result, if developing countries focus on implementing renewable forms of energy, they may be able to develop economically while also mitigating the harmful impacts of emissions intensive forms of energy generation.

1.4. Findings

EKC Findings

I find that the pollution-income relationship with respect to CO_2 emissions does differ between developed and developing countries. In fact, I find that the EKC Hypothesis seems to hold for developing countries, but not for developed countries. The pollution-income relationship that my three favored models find for developing countries are shown in Figure 5 below. The pollution-income relationship that my three preferred models find for developing countries are shown in Figure 6 below.

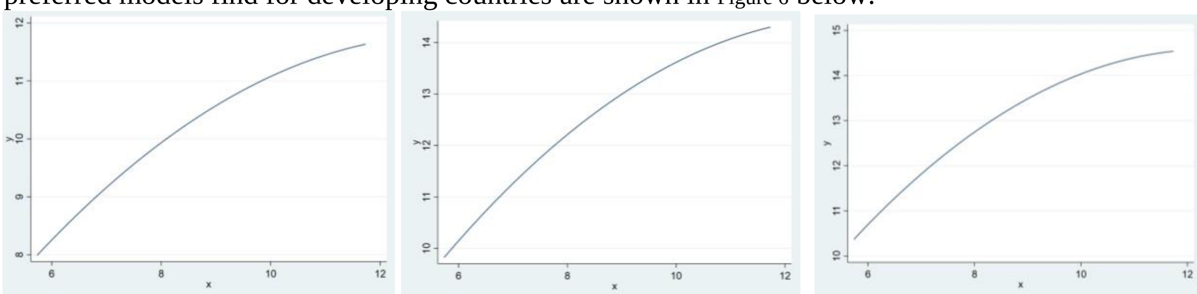

Figure 5:EKC Results Developing Countries Using CCEMG Estimator (Left), AMG Estimator (Middle), AMG-1 Estimator (Right))[1]

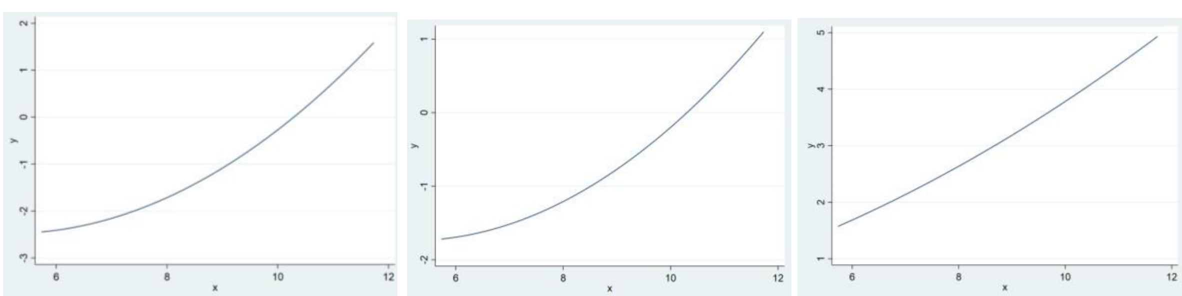

Figure 6: EKC Results Developed Countries (CCEMG Estimator (Left), AMG Estimator (Middle), AMG-1 Estimator (Right))

[1] For details on how these estimators are calculated and why they are used, see Data and Methodology Section 3.3.5.

These results suggest that the pollution-income relationship in developed countries follows a U-shaped path. On the other hand, the pollution-income relationship of developing countries appears to be an inverted U-shape, supporting the EKC hypothesis; however, the turning point levels of per capita income at which point emissions are expected to decrease in developing countries are high and out of range of experience in most cases. This suggests that at least in the near future, any increase in per capita income can be expected to increase emissions in both developed and developing countries.

IPAT Findings

In order to estimate the IPAT model, I use the same CCEMG and AMG estimators that I used to test the EKC hypothesis. I find that CO_2 emissions in both developed and developing countries are countries are more elastic to changes in population than to changes in per capita GDP. Further, emissions seem to be more elastic to changes in population in developed countries than in developing countries. These estimated elasticities range from 1.495-2.282 in developed countries, and from 0.810-1.722 in developing countries.

In terms of the elasticity of emissions to changes in affluence, there is discrepancy among my three favored models as to whether emissions in developed countries are more elastic to changes in affluence than in developed counties. These estimated elasticities range from 0.488-0.730 in developed countries, and from 0.445-0.641 in developing countries. The magnitude of these elasticities is relatively similar when looking at the results for developed and developing countries separately. As a result, no strong conclusion can be made on this point.

Also, the results of the IPAT model suggest that an increase in the share of primary energy that comes from renewable sources is associated with a statistically significant reduction in CO_2 emissions; however, the relationship between renewable energy share and CO_2 emissions in developing countries is not statistically significant.

Table 1: Elasticities of Emissions to changes in Population Affluence and Technology in Developed Countries

VARIABLES	**developed countries** CCEMG	**developed countries** AMG	**developed countries** AMG-1
lnGDP	0.730	0.534***	0.488***
lnpop	1.495**	2.282***	1.719***
renew	-0.0366	-0.0221*	-0.0220**

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Elasticities of Emissions to changes in Population Affluence and Technology in Developing Countries

VARIABLES	**developing countries** CCEMG	**developing countries** AMG	**developing countries** AMG-1
lnGDP	0.445***	0.602***	0.641***
lnpop	1.722***	0.810**	0.822**
renew	-4.087	-1.715	-0.122

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Implications and Thesis Structure

Hypothesis 1 is rejected in the sense that the EKC does not hold for all countries; however, the EKC results suggest that the pollution-income relationship for developed countries does differ from the one predicted for developing countries. Additionally, while determining the reason for these differences is beyond the scope of my analysis, the U-shaped pollution-income relationship found for developed countries may indicate that, as hypothesized, developed countries that are reliant on their CO_2-intensive development strategies are willing to neglect the negative impacts they will have globally in the long run. On the other hand, the inverted EKC pollution-income relationship found for developing countries may indicate that developing countries, who are most affected by the negative externalities of CO_2 emissions, will eventually gain more utility from reducing these emissions (though this turning point is high , and out of range of experience).

Hypothesis 2 cannot be confirmed given that my favored models show differing results as to the magnitude of elasticity of emissions to changes in per capita GDP.

Hypothesis 3 holds for developed countries. However, the lack of a statistically significant relationship between renewable energy share and CO_2 emissions in developing countries suggest that Hypothesis 3 cannot be confirmed for developing countries.

Overall, the different underlying relationship between emissions and development for developed and developing countries found in my results suggest that policy formation to progress toward SDGs should be different for developed and developing countries. Additionally, as previously mentioned, I hypothesize that the difference in the pollution-income relationship in developed and developing countries is due to the fact that CO_2 emissions do not impact high emitting countries the same way that SO_2 emissions and other local pollutants do.[1] Once a turning point level of per capita income is reached, a country that gains more utility from decreasing SO_2 emissions will not necessarily gain more utility from reducing their CO_2 emissions. Testing this hypothesis is beyond the scope of this Thesis, but is a topic for future research.

The rest of this Thesis is structured in the following way:

1. First, in the *Background and Literature Review* section, I provide an overview of the EKC and IPAT models and studies which have been conducted using these models in the past.
2. Next, in the *Data and Methodology* section, I describe the methods I will use, which mainly build upon what was done in the studies included my *Literature Review*. Additionally, I will describe my data which is made of three separate panels, one for developed countries, one for developing countries, and a panel combining these.
3. Finally, in the *Pre-Testing Results*, *Results,* and *Conclusion* sections, I will discuss my findings and the interpretation of my results.

2. Background and Literature Review

Among economists, the EKC and the IPAT models have been common approaches to empirically examine the relationship between economic development and environmental quality. In this section, I will provide background on the development of both models.

Over the course of this *Literature Review* I will first provide background on the EKC through examples of literature which empirically estimated the EKC relationship. I will then examine how the methods used to

[1] Much of my literature review suggests that an EKC has been confirmed for local pollutants, like SO_2 emissions, in developed countries; however, there is a lack of a consensus on if this relationship holds in developing countries. Additionally, there is a lack of a consensus on if an EKC can be found in developed or developing countries for global pollutants like CO_2 emissions.

estimate the EKC have changed as the econometric techniques used for panel data analysis have become more sophisticated in recent years.

Second, I provide background on the IPAT model. I will examine how the IPAT model has developed and been used in empirical work recently.

The literature review in this section serves as a base for my analysis, and much of the analysis I perform is based on what has been performed in these studies.

2.1 The Environmental Kuznets Curve

The EKC is named for its similarity to the Kuznets Curve which was developed by Simon Kuznets in 1955. Kuznets found that per capita income and income inequality seem to have an inverted U-shaped relationship (Kuznets, 1955). That is, as per capita income in a country increases, income inequality becomes more pronounced until a turning point level of per capita income is achieved. After this turning point is reached, income inequality begins to decrease. Graphically, this relationship can be seen in Figure 7 below.

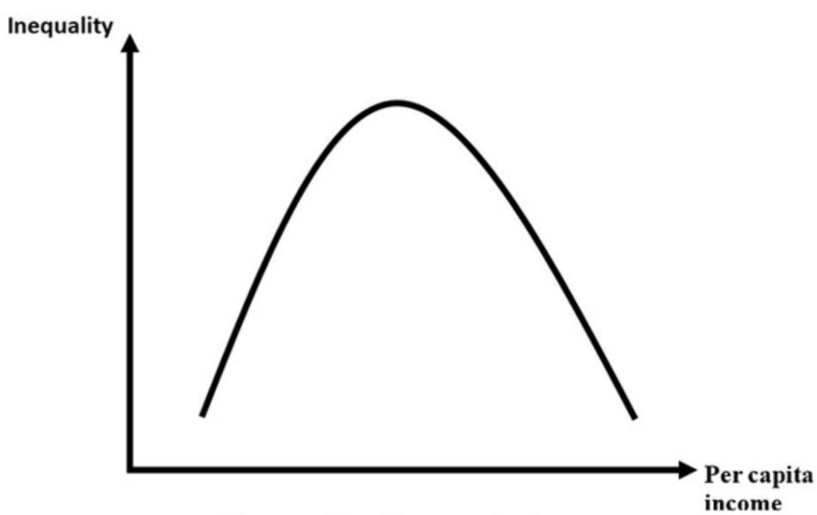

Figure 7: Kuznets Curve from, https://cpd.org.bd/is-inequality-temporary-pikettys-response-to-kuznets-false-optimism/

In the early to mid-1990s Gene Grossman and Alan Krueger conducted several studies which examined the relationship between economic growth and environmental quality (Grossman and Krueger, 1991; Grossman and Krueger, 1995). Their findings suggest that the relationship between certain local pollutant concentrations and per capita income follow an inverted U-shaped path.

The similarity between the relationship found by Grossman and Krueger, and Kuznets' findings about per capita income and income inequality, resulted in what known as the Environmental Kuznets Curve (EKC) Hypothesis. Specifically, the EKC Hypothesis suggests that as income within a country grows, so does environmental degradation, until a certain turning point level of income is reached. Once this turning point is reached, environmental quality improves. This relationship suggests that as countries develop, they eventually reach a point when they gain more utility from a cleaner environment than from additional emission-intensive development.

Understanding the pollution-income relationship is useful in exploring pathways toward sustainable development. Establishing the existence of an EKC relationship in developed countries could lead developing countries to the dangerous conclusion that their policies should be geared toward aggressive economic growth, without simultaneously implementing policies which seek to mitigate environmental damage. The assumption is that once a certain level of income is achieved, damage that was caused by environmentally negligent economic growth will begin to wither. Beckerman (1992) describes this dangerous interpretation of the EKC as a "grow first, then clean up" approach.

On the other hand, if the EKC cannot be validated empirically, it may make a stronger case for developing countries to place a larger focus on environmental protection when making decisions about development strategies. Otherwise, their development will exacerbate the climate crisis even further.

Since the flagship studies of Grossman and Krueger, EKC studies have used a variety of indicators[1] to proxy environmental quality and, while many studies establish an EKC relationship for local pollutants, there is still debate over the theoretical and empirical validity of the EKC relationship, especially with respect to global pollutants.

For example, in their EKC study, "Is the Environmental Kuznets Curve Still Valid: A Perspective of Wicked Problems", Chen, Hu, and van Tulder write that the "grow first then clean up approach "may only be applicable to local pollutants like urban wastes and water pollution. When it comes to pollution with transboundary impacts, especially global pollutants such as CO2, no country has sufficient incentive to regulate these emissions," (Chen, J., Hu, T. E., & van Tulder, R., 2019).

Since the flagship EKC studies by Gene Grossman and Alan Krueger in 1991, studies attempting to estimate the EKC have used a variety of techniques. As data analysis techniques have developed in recent years, different methods have estimated the EKC with varying levels of success. The following *Literature Review* outlines some of the strategies and findings of EKC studies since the seminal works of Grossman and Krueger.

2.1.1. Grossman and Krueger. (1995). Economic Growth and the Environment. *Quarterly Journal of Economics,* 110(2), 353–377.

In one of Grossman and Krueger's seminal EKC studies, "Economic Growth and the Environment," they examine the relationship between several environmental indicators and national per capita income. Specifically, they chose to study environmental indicators that were available in the Global Environmental Monitoring System (GEMS). These indicators included air pollutants (such as sulfur dioxide, smoke, and heavy particles), indicators of the oxygen regime in river basins (such as dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), and Nitrates), indicators of fecal contaminants in river basins (such as Fecal Coliform, and Total Coliform), and indicators of heavy metal concentrations in rivers (such as Lead, Cadmium, Arsenic, Mercury, and Nickel).

It is important to note that the indicators Grossman and Krueger use to proxy environmental quality are all local, rather than global, pollutants. Following from the discussion in the *Introduction* of this thesis, this means that the implications of Grossman and Krueger's results may differ from mine given that I am using CO_2 emissions, a global pollutant, to proxy environmental quality. Despite these differences, the work of Grossman and Krueger was integral in sparking interest in the study of the relationship between development and environmental quality. Additionally, the methodology used in all other EKC has been based work, thus, it is worth reviewing in this *Literature Review.*

To study the relationship between environmental quality and economic development, Grossman and Krueger pooled the GEMS data, which included observations from a number of monitoring stations in

[1] These include things such as a country's ecological footprint, SO_2 emissions, N_2O emissions, CH_4 emissions, CO_2 emissions, etc.

cities within 42 different countries. They used per capita GDP adjusted to international currency as their income variable. This GDP variable comes from the Penn World Table which provides a "large data table of internationally comparable estimates of real product-for gross domestic product (GDP) and its components," (Summers, R. and Heston A., 1988).

They employed a General Least Squares Random Effects model, as seen in Equation 3 below. This model estimates the relationship between concentration of emissions, measured in $\mu g/m^3$, and GDP per capita. Grossman and Krueger used annual levels of GDP in the cubic form. Including the cubic functional form of the GDP variable allows Grossman and Krueger to capture a non-linear pollution-income relationship. In addition, they include the cubic of the average of GDP over the previous three years as independent variables. They assert that including the cubic average of income controls for "permanent" levels of income, since recent income levels could have a determinant effect on levels of emissions. Additionally, including both of these income variables increases the statistical significance of their result.[1] Finally, they included a vector of control variables.[2]

Equation 3: Grossman and Krueger's EKC Model

$$(1) \qquad Y_{it} = G_{it}\beta_1 + G_{it}^2\beta_2 + G_{it}^3\beta_3 + \bar{G}_{it-}\beta_4 + \bar{G}_{it-}^2\beta_5 + \bar{G}_{it-}^3\beta_6 + X_{it}'\beta_7 + \epsilon_{it}$$

where Y_{it} is a measure of water or air pollution in station i in year t, G_{it} is GDP per capita in year t in the country in which station i is located, $\bar{G}_{it-}$ is the average GDP per capita over the prior three years, X_{it} is a vector of other covariates, and ϵ_{it} is an error term. The β's are parameters to be estimated.

While Grossman and Krueger's results varied depending on which indicator was used to proxy environmental quality, their largely suggest that for nearly all environmental indicators, in line with the EKC Hypothesis, once a certain level of per capita income was reached pollutant concentrations can be expected to decrease.

One specific model from the study which has been frequently replicated is the model which examines the relationship between SO_2 concentrations and income. This model is particularly interesting because, not only does it find an EKC relationship, Sulfur Dioxide is an indirect greenhouse gas. This means that it contributes to global warming through reactions with other compounds in the atmosphere (Satein, 2009).

Grossman and Krueger's SO_2 emissions regression results are shown in Table 3 below.

[1] See the bottom of Table 3.

[2] These included things like dummy variable to distinguish if a city's monitoring station was center city or suburban, a dummy variable to distinguish if a city was on a coastline, a dummy variable to distinguish if the land use around the monitoring station was industrial, commercial, residential, or unknown, a control variable for population density, a dummy variable to distinguish which monitoring system was used, etc.

Table 3: Grossman and Krueger's EKC Results for SO2

Variable	Sulphur Dioxide
Income (thousands)	− 7.37 (9.16)
Income squared	1.03 (1.11)
Income cubed	− 0.0337 (0.0384)
Lagged income	20.89 (9.76)
Lagged income squared	− 3.22 (1.26)
Lagged income cubed	0.117 (0.0461)
Coast	−12.72 (3.79)
Desert	—
Central City	3.06 (4.31)
Industrial	0.485 (5.26)
Residential	−11.11 (4.85)
Population Density (pop/sq mile)	1.14 (1.23)
Year	− 1.40 (0.218)
Variable	**Sulphur Dioxide**
P-value (income and lagged income combined)	< .0001
P-value (income only)	.852
P-value (lagged income only)	.096
Mean of Dependent Variable	33.24
σ^2_α	856
σ^2_ϵ	396
σ^2_y	1109
Sample size	1352

Grossman and Krueger's regression results would suggest that, as income in a country grows, environmental degradation caused by SO_2 emissions also grows until a certain turning point. The level of income at which this turning point occurs is presented in Table 4 below, and graphically in Figure 8. Specifically, they estimate that this turning point occurs when per capita GDP is $4,053.

Considering they use GDP per capita values from Robert Summers and Alan Heston's "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988," which includes per capita GDP values which range from less than $400 to over $20,000, the turning point is within the range of experience given Grossman and Krueger's dataset (Summers and Heston, 1991). In addition, Grossman and Krueger determine that the growth of SO_2 emissions is negative when per capita GDP is $10,000 and when it is $12,000, meaning that when a country's per capita income is at these levels, they are on the "downward sloping" section of the EKC. As a result, further economic progress should lead to improved environmental quality.

Table 4: Turning Point level of income for SO2 emissions EKC

Pollutant	Peak GDP	Derivative at $10,000	Derivative at $12,000
Sulphur Dioxide	$4,053 (355)	−5.295 (.780)	−3.065 (.910)

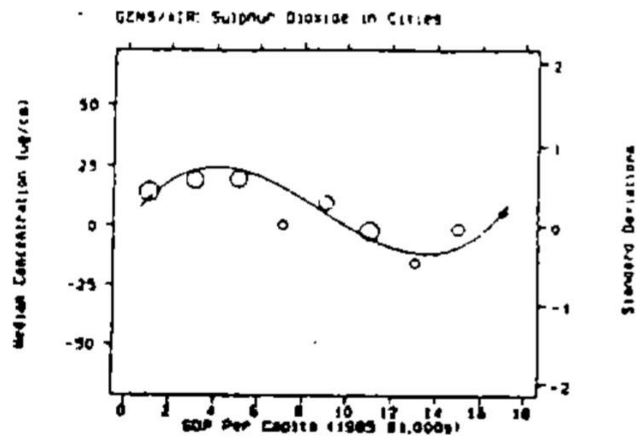

Figure 8: Sulfur Dioxide EKC Estimation by Grossman and Krueger

Since Grossman and Krueger's empirical estimation of the EKC, many other economists have followed their lead and have attempted to examine this relationship. Subsequent studies have used different econometric techniques, controlled for a variety of other variables, and have been met with a variety of results. The studies which have been conducted since Grossman and Krueger's have shown that different functional forms of the model may be more econometrically appropriate when studying the EKC. Additionally, different functional forms and the addition of different control variables may change the level of income that the model predicts needs to be achieved in order for environmental quality to be expected to improve.

The results of EKC studies which have used different panel data analysis methods to test the EKC Hypothesis motivate the rest of the *Literature Review* related to the EKC model.

2.1.2. Seldon and Song. (1994). Environmental Quality and Development: Is there a Kuznets Curve for Air Pollution Emissions? *Journal of Environmental Economics and Management,* 27(2), 147–162.

Thomas Seldon and Daqing Song are two economists who were intrigued by the findings of Grossman and Krueger. Seldon and Song set out to estimate the EKC in their 1994 study "Environmental Quality and Development: Is there a Kuznets Curve for Air Pollution Emissions?" Their analysis, contributed to the evolution of the EKC studies by specifying a slightly different model and paying particular attention to the effect of population density on emissions (focusing more heavily on the effects of population density than Grossman and Krueger). They claim that it is important to understand the effect that population growth has on the pollution-GDP relationship in order to assess what the future path of global pollution looks like under different emissions scenarios. Thus, the purpose of Seldon and Song's analysis differs slightly from that of Grossman and Krueger. Rather than testing to see if the EKC holds empirically, they are more interested in the implications it has when considering changes in other variables.

The model Seldon and Song use, which is slightly different than the one specified by Grossman and Krueger, is presented in Equation 4 below.

Equation 4: Seldon and Song's EKC Model

The focus of our analysis is on the relationship between per capita emissions, m, real per capita GDP, y, and population density, d,

$$m_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 y_{it}^2 + \beta_d d_{it} + \varepsilon_{it}, \qquad (1)$$

This model differs from the one used Grossman and Krueger in several ways:

1. First of all, Seldon and Song include population density as a variable of interest. Also, they do not control for the cubic in GDP or the average cubic of GDP.[1] This indicates that the relationship between pollution and income that they test is restricted to a quadratic form.
2. Secondly, Seldon and Song do not include the average of income from the past three years. This indicates that Seldon and Song do not assume that past levels of income affect emissions, as was assumed by Grossman and Krueger
3. Finally, the models used in Seldon and Song's analysis differs from what was used by Grossman and Krueger in the sense that Seldon and Song estimate a Pooled OLS version of the model, a Random Effects model, and a Fixed Effects model to test which method is most appropriate.

The data that Seldon and Song use is different than what was used by Grossman and Krueger, but covers a similar time frame. Seldon and Song's data cover four different pollutants: Sulfur Dioxide, Suspended Particulates, Oxides of Nitrogen and Carbon Monoxide. These data for pollutants are 3-year averages from 1973-1975, 1979-1981, and 1982-1984. Further, their data include 30 countries, 22 of which are considered high income, 6 of which are middle income, and 2 of which are low income. Thus, it is worth noting that Seldon and Song lack observations from developing countries.

The result of their models for SO_2 emissions are presented in Table 5below. Considering SO_2 emissions were also tested in both Grossman and Krueger's study, it is interesting to compare their findings.

[1] Note that Seldon and Song did estimate their model including higher order polynomial terms for the income variable, but found them to be insignificant at the 10% level or better, thus they restricted their model to the second order. See the t statistic for the cubic term in Seldon and Song's results table, Table 4.

Table 5: Results of Seldon and Song's Regression for SO2

Estimation Results for SO_2 Emissions[a]
(Standard Errors in Parentheses)

	Without population density			With population density		
	Cross section	Fixed effects	Random effects	Cross section	Fixed effects	Random effects
Constant[b]	423.94* (310.0)	−810.44	−148.41 (335.9)	480.76* (303.8)	−188.56	0.539 (348.6)
GDP per capita	−5.3092 (70.43)	385.78** (181.6)	201.26*** (73.85)	32.771 (71.25)	415.02** (182.6)	216.83*** (74.29)
(GDP per capita)^2	3.9764 (4.174)	−21.633*** (7.301)	−9.4216** (4.070)	1.4862 (4.254)	−23.826*** (7.518)	−10.534*** (4.114)
Population density	—	—	—	−120.77** (59.58)	−540.08 (472.8)	−155.53* (97.54)
Period effect (1979–1981 = 1)	−149.75 (162.6)	−11.022 (89.88)	−98.439* (58.37)	−165.45 (158.9)	36.612 (98.73)	−83.651* (58.87)
Period effect (1982–1984 = 1)	−260.57* (168.5)	−157.09* (107.4)	−257.27*** (64.87)	−254.66* (164.5)	−94.344 (120.2)	−236.31*** (65.93)
R^2	0.166	0.954	—	0.219	0.955	—
Homogeneity test (DF)	—	27.762 (22, 35)	—	—	25.146 (22, 34)	—
Hausman's χ^2 (DF)	—	—	6.241 (4)	—	—	5.193 (5)
t-statistic for cubic term	2.11	0.934	0.575	1.811	0.914	0.394
Turning point[c] (1985 U.S. Dollars)	(668)	8916	10,681	(−11,025)	8709	10,292
N	67	62	67	67	62	67

[a]Emissions are measured in kg × 10 per capita. Income is measured in thousands of 1985 U.S. Dollars. Density is measured as residents per hectare. One, two, or three asterisks indicate that a coefficient estimate is significantly different from zero at 10, 5, or 1% percent level, respectively.
[b]Constant terms for fixed-effect models include the mean of the estimated country effects.
[c]Turning points in parentheses indicate that curve is concave upward.

Seldon and Song note that when they run the models using a pooled cross-sectional approach, heteroskedasticity appears to be present. As a result, Random Effect and Fixed Effect approaches are more appropriate. The results of these models suggest that, similar to the findings of Grossman and Krueger, an inverted U-shaped relationship does exist between emissions and income.

What is interesting in the findings of Seldon and Song is that they find the turning point of GDP where environmental quality begins to improve to exceed $8,500 in all of the estimated models. This is contrary to the results of Grossman and Krueger which suggest that the turning point level of income for SO_2 emissions is less than $5,000. However, it is important to note that the countries in the datasets used by Seldon and Song differ from those of Grossman and Krueger, thus, different turning points might actually indicate that the pollution income relationship differs between different groups of countries, which may be in line with my first hypothesis.[1]

Additionally, extending beyond the analysis of Grossman and Krueger, Seldon and Song recognized that the turning point level of per capita income that they calculated had not been reached in most countries.

[1] If the pollution-income relationship differs between developed and developing countries, and Seldon and Song's dataset includes more developing countries than Grossman and Krueger's, the differences in their predicted turning points may actually just indicate a difference in the turning point level of GDP per capita for developed and developing countries.

Their estimates of greater than $8,500 per capita far exceeded the global average per capita GDP in 1985, the latest year in their dataset, which was reported at $3,766. As a result, their analysis also seeks to determine the implications of their models in terms of future pollution. They do so by using forecasts of population and per capita GDP to estimate when this turning point may occur.

They use population projections provided by the World Bank, and estimate a growth rate model to predict future per capita GDP. They then re-test their models under three different scenarios.

They consider a baseline scenario of GDP growth in addition to a scenario of fast GDP growth and one of slow GDP growth. Their findings of the expected year when peak emissions will be reached are presented in Table 6 below.

Table 6: Predicted Year Turning Point Will Occur

Sensitivity Analysis for Global Emissions Forecasts

Pollutant		Models without population density				Models with population density			
Model	GDP growth rate	Year of peak emissions	Percentage increase above 1986 level as of: 2000	Peak	2100	Year of peak emissions	Percentage increase above 1986 level as of: 2000	Peak	2100
		Sulfur dioxide (SO_2)							
Fixed-effects	Slow	2100[a]	17	247	247	2090	17	88	87
	Baseline	2085	16	354	287	2046	27	144	4
	Fast	2050	27	353	270	2026	44	144	−22
Random-effects	Slow	2100[a]	20	137	137	2100[a]	12	95	95
	Baseline	2100[a]	22	224	224	2061	13	140	107
	Fast	2061	30	231	156	2036	19	131	−1

These findings suggest that, in some cases, it may take until the next century for SO_2 emissions to peak. Thus, Seldon and Song urge that environmental regulations be considered in order to achieve this peak faster.

Overall, while the turning point found by Seldon and Song differs from that of Grossman and Krueger, the inverse U-shaped relationship in income and emissions still holds. This indicates that there may be some validity to the assumption that environmental quality improves after a certain level of income is reached. However, it is important to note that Seldon and Song, and Grossman and Krueger's studies analyzed pollutants which have local effects. Again, this means that the implications of their results may differ from mine which focus on CO_2 emissions; however, their studies laid the groundwork for other EKC studies and are thus important to examine in this *Literature Review*.

Their findings have spurred many other studies of the EKC relationships which use different environmental quality dependent variables-- such as CO_2 emissions[1] and ecological footprint[2] among others -- and control for other variables of interest -- such as oil prices,[3] trade openness,[4] and energy mix[5], among others. Additionally, the econometric validity of their models has been critiqued by other

[1] Shahbaz and Sinha (2019) provide a thorough survey of EKC studies which use CO_2 as the dependent variable of interest: https://www.emerald.com/insight/content/doi/10.1108/JES-09-2017-0249/full/pdf

[2] Destek and Sarkodie (2019) use ecological footprint as their dependent variable of interest https://www.sciencedirect.com/science/article/pii/S0048969718338907

[3] Esmaeili and Abdollahzadeh (2009) study the EKC relationship with oil prices as an independent variable https://www.sciencedirect.com/science/article/pii/S0301421508004229

[4] Fang, Huang, and Yang (2017) control for trade openness as a part of their EKC study focusing on Chinese cities. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/twec.12717

[5] Danish et al. (2017) control for the energy mix in tehir country specific EKC study which focuses on Pakistan. https://www.sciencedirect.com/science/article/pii/S0959652617306704?via%3Dihub

economists. As a result, the work of Grossman and Krueger and Seldon and Song inspired EKC studies which use more advanced panel data analysis methods in an effort to yield the most consistent and unbiased results.

2.1.3: Stern and Perman. (2003). *Evidence from Panel Unit Root and Cointegration Tests that the Environmental Kuznets Curve Does Not Exist. Australian Journal of Agricultural and Resource Economics,* 47(3), 325–347.

Despite the alignment between Grossman and Krueger, Seldon and Song's, and other EKC studies which find an inverted U-shaped relationship between pollution and income, especially for developed countries, there have been several more recent studies which question the validity of the relationship found in these studies. Beyond just discrepancies in the level of income at which the turning point in emissions occurs, some studied have failed to identify an inverted U-shaped pollution and income relationship at all when using different proxies for environmental quality or different econometric methods.

In order to test the cause of this misalignment in EKC studies, two economists, Stern and Perman, conducted several studies in the early 2000s which critique the empirical validity of EKC studies. They point out econometric flaws in the most commonly used methodologies. These flaws could lead to spurious results. That is, a relationship may appear to exist but in reality, it does not due to underlying assumptions of the model not being met. Further, Stern and Perman offer empirical methods which may be more appropriate to use to estimate the pollution-income relationship.

Stern's study "The Rise and Fall of the Environmental Kuznets Curve," claims that,

> "The EKC is an essentially empirical phenomenon, but most of the EKC literature is econometrically weak. In particular, little or no attention has been paid to the statistical properties of the data used […] and little consideration has been paid to issues of model adequacy such as the possibility of omitted variables bias. Most studies assume that, if the regression coefficients are nominally individually or jointly significant and have the expected signs, then an EKC relation exists. However, one of the main purposes of doing econometrics is to test which apparent relationships, or 'stylized facts,' are valid and which are spurious correlations," (Stern, 2004).

Stern's main critiques address the econometric techniques used for EKC studies. These include the failure to test for unit roots and cointegration. A time series variable that contains a unit root is a variable that is equal to its previous value plus a random shock. This means that the variable does not have the tendency to revert to the mean and it is considered to be nonstationary. If unit roots are present, researchers may be led to believe that a spurious regression is representative of a significant relationship

On the other hand, if a linear combination of multiple variables that each contain a unit root exists, these variables are considered to be cointegrated. Cointegration between these variables implies that a real, rather than spurious, long-run relationship exists between the variables; however, if cointegration is not present, inference from the regression does not apply.

David Stern and Roger Perman examine test for the presence of unit roots and cointegration in their study, "Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist," (2003). Considering the wealth of studies which claim the presence of the EKC holds for SO_2 emission concentrations and per capita income, Stern and Perman test for unit roots and cointegration using a data set constructed by ASL and Associates (1997), which includes SO_2 emissions from 1850-1990 for 74 countries. The equation Stern and Perman assume, which is a basic version of the model most commonly estimated in EKC studies, is presented in Equation 1 below.

Equation 5: Stern and Perman's Basic EKC Model

$$\ln\left(\frac{M}{P}\right)_{it} = \alpha_i + \chi_t + \delta_i t + \beta_{1,i} \ln\left(\frac{Y}{P}\right)_{it} + \beta_{2,i}\left[\ln\left(\frac{Y}{P}\right)\right]^2_{it} + \varepsilon_{it} \qquad (1)$$

where M is emissions, Y is constant price PPP GDP, P denotes a country's population, and t is a deterministic time trend. The variables are observed

Stern and Perman's unit root tests suggest that there is likely the presence of a unit root in all variables in their panel; however, the first difference of these variables is stationary. This implies the level variables are not stationary and instead are integrated of order 1, or I(1). They are considered stationary, or I(0), when differenced once.

With evidence that the variables are I(1), if they share a stochastic trend and no other integrated variables are missing from the model, the residual of the regression in equation (1) is stationary and the variables are cointegrated. Stern and Perman test for cointegration at an individual country level and in the panel as whole. Their country level test results suggest that cointegration is present in 35 of the 74 countries in the dataset. For the panel tests, Stern and Perman perform 7 different cointegration test, and five of the seven statistics are significant at the 5% level, indicating cointegration exits.

Stern and Perman then assert that the static EKC model that is commonly specified may be able to achieve consistent results[1], however, they are "possibly highly biased"[2] and inefficient[3]. Thus, in order to best estimate the EKC, Stern and Perman suggest estimating a dynamic, rather than a static, model. They estimate the following error correction model, shown in Equation 6 below, which intends to "not only yield information about long run relationships, but also estimates of short run dynamics and the speed of adjustment to equilibrium.":

Equation 6: Stern and Perman's Error Correction Model

$$\Delta\ln\left(\frac{M}{P}\right)_{it} = \alpha_i\left\{\ln\left(\frac{M}{P}\right) - \beta_{1,i}\ln\left(\frac{Y}{P}\right)_{it} - \beta_{2,i}\left[\ln\left(\frac{Y}{P}\right)\right]^2_{it}\right\} + \sum_{j=1}^{p-1}\chi_{ij}\Delta\ln\left(\frac{M}{P}\right)_{it-j} + \sum_{j=0}^{q-1}\delta_{ij}\Delta\ln\left(\frac{Y}{P}\right)_{it-j} + \sum_{j=0}^{r-1}\gamma_{ij}\Delta\left[\ln\left(\frac{Y}{P}\right)\right]^2_{it-j} + \mu_i + \eta_t + \varepsilon_{it} \qquad (2)$$

The results of this error correction model are shown in Table 5 below. The left-hand column are coefficients which are the "simple average of the individual country long run and error correction coefficient estimates from the model," (Stern and Perman, 2003). The center column includes the "pooled mean group estimates [which] are derived under the null that the long-run parameters are constant over the panel ($\beta 1i = \beta 1$ and $\beta 2i = \beta 2$) but permits dynamics, fixed effects and error variances to be heterogeneous over the panel" (Stern and Perman, 2003). The righthand column includes the results of a typical static fixed effect regression, for comparison. Their results for all three models do have coefficients which are consistent with the EKC hypothesis; however, Stern and Perman make note of the

[1] Consistency implies as the number of observations approaches infinity, the estimated parameter approaches the true parameter value.

[2] A biased estimator is one for with the expected value of the parameter does not equal the true value of the parameter.

[3] Inefficiency implies a high level of variance of an estimator, meaning estimators with smaller levels of variance are more efficient than ones with higher levels of variance.

difference in turning points between models. The different predicted turning points suggests there may be some econometric weaknesses in one or all of the models.

Table 7: Results of Stern and Perman's error correction model

Table 5 Dynamic Error Correction Model: unrestricted and restricted estimates for full panel

	Unrestricted model (mean group parameter estimator)	Pooled mean group estimator (homogeneous long-run coefficients)	Static fixed effects
Long-run parameter estimates			
ln (Y/P)	16.56 (1.30)	6.272 (17.25)	3.85 (3.67)
in $(Y/P)^2$	−0.89 (−1.30)	−0.326 (−15.22)	−0.17 (−2.70)
Error correction	−0.366 (−12.7)	−0.24 (−8.30)	na
Implied turning point (US$)	10 975	15 063	82 746
lnL	1828.19	1506.08	−1805.23

na, not applicable. *t* ratios in parentheses. *t* ratios for fixed effects based on robust standard errors. Truncation of maximum allowed lags, here set to three, chosen by a general to specific search procedure, beginning from a starting value of six.

While the previous analysis was performed on the panel including all 74 countries in Stern and Perman's dataset, they assert that we be able to gain insight by examining results for OECD and Non-OECD countries separately.[1]

Results of their re-estimation after separating their panel into OECD and Non-OECD countries are shown in Table 8 and Table 9 respectively. The results suggest that, while an EKC relationship may be found for OECD countries, the results for non-OECD countries find a monotonically increasing relationship between emissions and per capita income. This is because no turning point can be found for the unrestricted model and, despite a turning point level of per capita income being found in the pooled mean group estimator and the static fixed effect models, both turning points are out of sample. This suggests that finding an EKC relationship in some countries, does not mean the same underlying relationship exists across all countries.

Table 8: Stern and Perman's Dynamic Error Correction results for OECD Countries

Table 6 Dynamic Error Correction Model: unrestricted and restricted estimates for OECD countries only

	Unrestricted model (mean group parameter estimator)	Pooled mean group estimator (homogeneous long-run coefficients)	Static fixed effects
Long-run parameter estimates			
ln (Y/P)	19.78 (2.11)	34.59 (13.31)	12.84 (4.73)
in $(Y/P)^2$	−1.02 (−1.91)	−1.85 (−12.65)	−0.71 (−4.62)
Error correction:	−0.300 (−5.57)	−0.163 (−3.16)	na
Implied turning point (US$)	16 254	11 483	8453
lnL	923.22	843.00	−8.21

na, not applicable. *t* ratios in parentheses. *t* ratios for fixed effects based on robust standard errors. Truncation of maximum allowed lags, here set to three, chosen by a general to specific search procedure, beginning from a starting value of six.

[1] This is in line with one of the goals of my analysis, considering that I hope to examine how the pollution-income relationship differs between developed and developing countries. OECD countries in Stern and Perman's data set are likely very similar to the countries that I classify as developed. Non-OECD countries are likely in line with my developing countries.

Table 9: Stern and Perman's Dynamic Error Correction results for Non-OECD Countries

Table 7 Dynamic Error Correction Model: unrestricted and restricted estimates for non-OECD countries only

	Unrestricted model (mean group parameter estimator)	Pooled mean group estimator (homogeneous long-run coefficients)	Static fixed effects
Long-run parameter estimates			
ln (Y/P)	−1.56 (−0.23)	5.75 (11.91)	3.50 (2.73)
in $(Y/P)^2$	0.13 (0.31)	−0.28 (−9.95)	−0.15 (−1.89)
Error correction	−0.331 (−11.09)	−0.221 (−7.40)	na
Implied turning point (US$)	403 minimum	28 792	116 618
lnL	922.32	751.56	−1464.01

na, not applicable. *t* ratios in parentheses. *t* ratios for fixed effects based on robust standard errors. Truncation of maximum allowed lags, here set to three, chosen by a general to specific search procedure, beginning from a starting value of six.

While the EKC relationship may hold in some of the cases studied by Stern and Perman, the inconsistencies across different models and panels of different countries suggests weakness in the EKC Hypothesis and the methods which have been commonly used to test it. These results did not, however, deter other researchers from continuing to test the EKC Hypothesis and to develop the techniques used to estimate the EKC even further.

Stern and Perman's techniques are more advanced than the ones used in previous studies. Their pre-tests of the data, such as testing for unit roots and cointegration, and their attempts to correct for model misspecification are important developments in EKC analysis. These techniques are now conventionally used in EKC studies to ensure econometric validity.

2.1.4: Atasoy. (2017). Testing the Environmental Kuznets Curve Hypothesis Across the U.S.: Evidence from Panel Mean Group Estimators. *Renewable and Sustainable Energy Reviews, 77,* 731–747.

Although Stern and Perman's study uses more sophisticated methods of panel analysis, methods to estimate econometric models using macro-economic panels have developed even further since their study. In 2017, Burak Sencer Atasoy conducted a study, "Testing the Environmental Kuznets Curve Hypothesis Across the U.S.: Evidence from Panel Mean Group Estimators," which uses some of these more sophisticated methods. The progress which has been made in terms of regression techniques to examine large panels also suggests that some of the previous EKC studies that were conducted without these methods yielded inconsistent or biased results.

In addition to using more sophisticated methods, Atasoy's study differs from Stern and Perman's, Seldon and Song's, and Grossman and Krueger's, by using CO_2 as the proxy for environmental degradation. This is notable since CO_2 is a global pollutant. The negative effects of CO_2 emissions are not as immediate or local as for SO_2, thus it is more difficult to assume that a society would gain more utility from decreasing CO_2 emissions than from further economic development.[1]

To test the relationship between CO_2 emissions and personal income per capita, Atasoy's study uses a balanced panel of annual data which includes observations from all 50 U.S. states, ranging from 1960-

[1] Given that this CO_2 emissions is also the proxy that I use for environmental quality, the implications of Atasoy's study may give more insight into the implications of my results than those of Grossman and Krueger, Seldon and Song, and Stern and Perman.

2010. Additionally, Atasoy includes a variable to control for population growth rate, and one to control for energy consumption, both of which he hypothesizes have an effect on environmental quality. The model specification used by Atasoy is presented in Equation 7 below.

Equation 7: Atasoy's EKC Model

The EKC hypothesis is tested by using the specification below:

$$CO2_{it} = \lambda_i d_t + \alpha_{1i} GDPPC_{it} + \alpha_{2i} GDPPC^2_{it} + \alpha_{3i} EN_{it} + \alpha_{4i} POP_{it_i} + u_{it} \quad (4)$$

$$u_{it} = \theta f_t + \varepsilon_{it} \quad ,i = 1, 2, \ldots, N \text{ and } t = 1, 2, \ldots TN$$

where $CO2_{it}$ is the natural logarithm of CO_2 emissions per capita, GDPPC is the natural logarithm of personal income per capita, $GDPPC^2$ is the natural logarithm of personal income per capita squared, EN is the natural logarithm of energy consumption per capita, POP is the population growth rate, d_t and f_t represent observed and unobserved common effects, and ε_{it} is the error term. In this section, I test for cross-sectional dependence, unit root, cointegration, and slope homogeneity, respectively.

Unlike many earlier EKC studies, Atasoy tests for “cross-sectional dependence, unit roots, cointegration, and slope homogeneity.” The presence of cross-sectional dependence and unit roots, and the absence of cointegration and slope homogeneity, could contribute to biased or inconsistent results if Pooled OLS, Fixed Effect, or Random Effect estimators are used.[1] The results of Atasoy’s data pretests are presented in Table 10- Table 13 below. They suggest that his panel contains cross sectional dependence, unit roots, cointegration, and the slope parameters are heterogeneous.

Table 10: Atasoy's Cross Sectional Dependence Test Results

	Value
CD Test	30.14***
Bias Adjusted LM Test	298.5***

*, **, *** indicate that statistics are significant at the 10%, 5% and 1% level of significance, respectively. The null hypothesis is no cross-sectional dependence.

[1] The effects of the presence of cross-sectional dependence and unit roots, and the absence of cointegration and slope homogeneity are discussed in detail in the Methodology Section 3.3.1-3.3.4.

Table 11: Atasoy's Unit Root Test Results

First and Second Generation Unit Root Test Results.

	CIPS		Maddala-Wu	
	Intercept	**Intercept + trend**	**Intercept**	**Intercept + trend**
Lnco	−0.588	1.119	212.245***	114.153
Lny	−1.166	−1.534	318.493***	1.764
Lny2	−1.268	2.132	208.288***	2.255
Len	−0.832	2.122	278.001***	113.369
Pop	−0.343	−1.255	169.606***	70.355
	CIPS		**Maddala - Wu**	
	Intercept	**Intercept + trend**	**Intercept**	**Intercept + trend**
ΔLnco	−12.294***	−10.017***	325.717***	327.472***
ΔLny	−8.943***	−6.749***	659.901***	858.321***
ΔLny2	−8.816***	−6.185***	320.774***	339.939***
ΔLen	−11.930***	−10.111***	457.328***	468.894***
ΔPop	−8.635***	−6.039***	343.826***	402.635***

*, **, *** indicate that statistics are significant at the 10%, 5% and 1% level of significance, respectively. For the Maddala-Wu and CIPS tests the null hypothesis is nonstationarity.

Table 12: Atasoy's Cointegration Test Results

Pedroni Cointegration Test Results.

	Value	p-value
Panel-v	3.023	0.0013
Panel-rho	−2.201	0.0139
Panel-PP	−4.37	0
Panel-ADF	−4.828	0
Group-rho	0.209	0.5826
Group-PP	−3.07	0.0011
Group-ADF	−4.173	0

* The null hypothesis is no cointegration.

Table 5

Westerlund Durbin-Hausman Test Results.

	Value
DHg	3.54***
DHp	4.76***

*, **, *** indicate that statistics are significant at the 10%, 5% and 1% level of significance, respectively. The null hypothesis is no cointegration.

Table 13: Atasoy's Slope Homogeneity Test Results

Slope Homogeneity Test Results.

	Value
Swamy $\hat{S}$	2416***
$\tilde{\Delta}$	979***
$\tilde{\Delta}_{adj}$	1053***
$\hat{\Delta}$	110.81***
$\hat{\Delta}_{adj}$	2.35***

*, **, *** indicate that statistics are significant at the 10%, 5% and 1% level of significance respectively. The null hypothesis is slope homogeneity.

To account for the presence of cross-sectional dependence and unit roots, and the absence of cointegration and slope homogeneity, Atasoy uses the CCEMG and AMG estimators to estimate the EKC. These estimators are more appropriate than the more commonly used Fixed Effect, Random Effect, and Pooled OLS regressions since Fixed Effect and Random Effect regressions do not account for endogeneity which may be caused by heterogeneity.

The CCEMG estimator and AMG estimators appropriate in the case of Atasoy's data since they accounting for common factors which affect all countries in the panel, which cause cross sectional dependence. Both estimators are calculated by running country specific OLS regressions which are augmented to account for these factors. Parameters of the models are then cross-sectional averages of these individual regressions.

The CCEMG and AMG estimators differ, however, in how they attempt to control for common factors. The main difference between these estimators is that the CCEMG estimator attempts to blend out the effect of the common factors by including cross sectional averages of the independent and dependent variables in each country specific OLS regression. The AMG estimator, on the other hand, treats these common factors as a common dynamic process which can be estimated as its own variable. This variable is first estimated, and then each country specific OLS regression is augmented with this variable. [1]

This causes estimates to be inconsistent. In addition, AMG and CCEMG estimators are robust to cross sectional dependence, unlike the Pesaran and Smith's (1995) Mean Group (MG) estimator. Atasoy also estimates a second specification of the AMG estimator, AMG-I, which "augments the regression by imposing a unit coefficient on each group member in addition to the regular AMG estimator." Finally, despite the presence of cross-sectional dependence in his panel, Atasoy includes Pesaran's MG estimator for comparison.

Atasoy's results are presented in Table 14 below.

Table 14: Atasoy's Regression Results

MG, CCEMG and AMG Estimator Results.

	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-I	AMG-I
GDPPC	0.3614*	−0.0044	0.7767	1.0495*	0.6685***	0.7873***	0.7237***	0.8995***
	(0.2052)	(0.224)	(0.5585)	(0.6372)	(0.2181)	(0.271)	(0.1984)	(−0.0547)
GDPPC2	−0.0262***	−0.0023	−0.0472	−0.0604*	−0.0407***	−0.0501***	−0.0417***	−0.0547***
	(0.0098)	(0.0116)	(0.0318)	(0.0356)	(0.0107)	(0.015)	(0.0096)	(0.0103)
EN	0.8068***	0.8838***	0.7626***	0.8021***	0.8024***	0.7872***	0.7842***	0.7295***
	(0.0492)	(0.0482)	(0.0449)	(0.0425)	(0.0458)	(0.049)	(0.044)	(0.0414)
POP	0.0051*	0.0017	0.0017	0.0016	0.0025	0.0029	0.0018	0.0041**
	(0.0029)	(0.0024)	(0.0027)	(0.0025)	(0.0022)	(0.0022)	(0.0022)	(0.0019)
Constant	−10.112***	−10.11***	−2.267*	−4.978***	−11.403***	−11.679***	−11.709***	−11.839***
	(0.7719)	(0.7231)	(1.2964)	(1.8456)	(0.6899)	(0.666)	(0.7492)	(0.6755)
Trend		−0.006***		−0.008**		0.0019		0.0041*
		(0.0024)		(0.0036)		(0.003)		(0.0021)
The EKC Holds	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Turning Point	$989		$3743	$5931	$3687	$2584	$5869	$3722
Number of group specific significant trends		25		17		24		22
RMSE	0.047	0.0434	0.0322	0.0312	0.0411	0.0371	0.0446	0.0409

*, **, *** indicate that statistics are significant at the 10%, 5% and 1% level of significance respectively.

Atasoy's results suggest that "the AMG estimator strongly validates the EKC hypothesis with highly significant income per capita and income per capita squared coefficients under both specifications." On the other hand, the MG estimator and the CCEMG estimator "give mixed results. [They] reject the EKC

[1] The CCEMG, and AMG estimators are discussed in more detail in the Methodology Section 3.3.5.

hypothesis if a time trend is included. However, after removing the time trend it provides weak evidence in favor of the hypothesis."

In addition to these results, Atasoy also includes state specific results using the MG, CCEMG, and AMG estimators. His findings suggest that "The AMG estimator seems […] in favor of the [EKC] hypothesis in general. Accordingly, the EKC holds in 30 of the 50 states. […] The MG estimator generates similar results to the AMG estimator by proposing that the EKC holds in 22 […] The results of the CCEMG estimator draw a completely different picture. Accordingly, the EKC holds only in 10 states." Atasoy concludes that despite the different results depending on the estimator used, "there is evidence in favor of the EKC hypothesis for the U.S. economy as the EKC hypothesis is validated in 8 out of 10 specifications [used]." However, he does warn that state specific results should be interpreted with caution due to their sensitivity to method.

Atasoy's study relates to the analysis considering that I plan on performing data pretests to determine which estimators will yield the most consistent and unbiased results. Similar to Atasoy, I plan to test or cross-sectional dependence, unit roots cointegration, and slope homogeneity. After performing these tests, Atasoy determines that the CCEMG and AMG estimators are the most appropriate to use. My pretests, as seen in section 4.1-4.5, suggest that the CCEMG and AMG estimators are most appropriate in the case of my data as well. Additionally, he uses CO_2 emissions to proxy for environmental quality, which is what I plan on using as well. The question that this work raises is whether or not the EKC relationship that Atasoy's AMG estimator finds for CO_2 emissions in the US holds when using data from other countries.

2.1.5: EKC Literature Review Findings and Questions for Consideration

As in the case of Grossman and Krueger, Seldon and Song, and to some extent, Stern and Perman, the EKC hypothesis has largely been found to hold when using local air pollutants, such as SO_2 emissions, as a proxy for environmental degradation. Emissions of local air pollutants generally have negative local effects. These include things such as increased mortality and morbidity, respiratory distress, and a reduction in visibility (EPA, 2021). It then makes sense that, once a certain turning point level of per capita income is reached, societies gain more utility from reducing these local pollutants than they would from additional emissions-intensive development. The question then becomes, does this relationship still hold when considering global pollutants such as CO_2?

Since the local effects of CO_2 emissions are not as immediate or as severe as the effects of SO_2 emissions, societies may not gain more utility from reducing CO_2 emissions-intensive practices than they do from additional development. On the other hand, an increase in CO_2 emissions will have severe detrimental effects on the planet as a whole. If societies recognize this, perhaps a turning point level of income, at which point CO_2 emissions can be expected to decrease, does exist, as was suggested by Atasoy in the case of the US.

Reducing CO_2 emissions is a goal of sustainable development, thus it is the most interesting to study in the context of this Thesis. In addition, it is worth reiterating that while the negative externalities of CO_2 emissions have a disproportionately high effect on Least Developed Countries, developed countries have historically been responsible for the majority of these emissions. As a result, determining if the pollution-income relationship with respect to CO_2 emissions differs between developed and developing countries may yield interesting results.

2.2: The IPAT equation

While the EKC has been used frequently in environmental economics studies, the IPAT equation is another model which has been used to empirically estimate the effect of development on environmental quality. Paul Ehrlich and John Holden are largely attributed with developing the theoretical framework of the IPAT equation in their 1971 article, "Impact of Population Growth," (Ehrlirch and Holden, 1971). The basic version of the equation is written in the form I=PAT where I, a variable for environmental impact, is set equal to the product of population (P), affluence (A), and technology (T).

The IPAT equation was developed further by Thomas Dietz and Eugene Rosa in their 1994 paper, "Rethinking the Environmental Impacts of Population, Affluence, and Technology," into a form that allows for statistical analysis. The model of Dietz and Rosa takes the following form $I = aP^bA^cT^de$, "where I, P, A and T remain environmental impact, population size, per capita economic activity and impact per unit economic activity. Now a, b, c, and d are parameters and e a residual term. Data on I, P, A and T can be used to estimate a, b, e, d and e using standard statistical methods such as regression analysis and its kin," (Dietz and Rosa, 1994). This extension of the original IPAT formula is known as the "Stochastic Impacts by Regression on Population, Affluence, and Technology" (STIRPAT) model has been used in many empirical works since its development.

The model seeks to estimate how elastic environmental impact is to changes in population, affluence, and technology, and to determine which of these variables has the most significant effect on environmental quality. This model differs from the EKC since it places equal attention to the impact of population, affluence, and technology on environmental quality, rather than focusing solely on the impact of economic development. It is also worth noting that the basic version of the IPAT model assumes that economic development, or affluence, has a linear effect on environmental degradation. This would contradict the EKC assumption that economic development has a non-linear effect on environmental quality; however, the STIRPAT equation, allows us to extent this model to also control for non-linear impacts of the independent variables.

2.2.1: **Dietz and Rosa. (1997). Effects of Affluence on CO_2 Emissions.** ***Proceedings of the National Academy of Sciences of the United States of America,*** **94(1), 175-179.**

Rosa and Dietz's reformulation of the IPAT model allowed it to be used stochastic regression analysis. They demonstrate this in their 1997 study "Effects of Affluence on CO_2 Emissions."

In this study Dietz and Rosa use the following Equation 8 below to determine "the net effect of population and influence on impact," (Dietz and Rosa, 1997).

Equation 8: Dietz and Rosa's IPAT Equation

$$I_i = aP_i^bA_i^ce_i$$

Dietz and Rosa note that the "i" subscript indicates that these quantities may vary across units of observation. They also note that they exclude the "T" component of the typical IPAT model, allowing technology to be modeled in the residual *e* term. This is due to the fact that "[t]he technology term actually incorporates not only technology as it is usually conceived but also social organization, institutions, culture, and all other factors affecting human impact on the environment other than population and affluence," (Dietz and Rosa, 1997).

The formulation of Dietz and Rosa's IPAT model allows to test the hypothesis that the population and technology have effects that are not strictly linear in the logged form of the equation. That is, it allows

Dietz and Rosa to replace the assumed constant a, b, and c coefficients with other functions which would reflect a “thresholds and other nonproportional effects,” (Dietz and Rosa, 1997).

In order to utilize their extension of the IPAT model, Dietz and Rosa estimate the effects of affluence, population, and technology on CO_2 emissions. They use data from 111 nations in 1989. The variables they include are population size for P and GDP per capita for A. The whole equation is taken in the log form. Additionally, they test for the presence of nonlinearities in the a, b, and c coefficients by including polynomials in the quadratic form for the log population variable and the cubic form for the log of the affluence variable.

The nations included in their dataset are presented in the Table 15 below.

Table 15: Countries in Dietz and Rosa's Dataset

Algeria	Libya
Angola	Madagascar
Argentina	Malawi
Australia	Malaysia
Austria	Mali
Bangladesh	Mauritania
Belgium	Mauritius
Benin	Mexico
Bhutan	Mozambique
Bolivia	Morocco
Botswana	Nepal
Brazil	Netherland
Bulgaria	New Zealand
Burkina Faso	Nicaragua
Burundi	Niger
Cameroon	Nigeria
Canada	Norway
Central African Republic	Oman
Chad	Pakistan
Chile	Panama
China	Papua New Guinea
Colombia	Paraguay
Congo	Peru
Costa Rica	Phillippines
Cote d'Ivoire	Poland
Czechoslovakia	Portugal
Denmark	Rwanda
Dominican Republic	Saudi Arabia
Ecuador	Senegal
Egypt	Sierra Leone
El Salvador	Singapore
Ethiopia	Somalia
Finland	South Africa
France	Spain
Gabon	Sri Lanka
Germany	Sweden
Ghana	Switzerland
Greece	Syrian Arab Republic
Guatemala	Tanzania
Guinea	Thailand
Haiti	Togo
Honduras	Trinidad
Hungary	Tunisia
India	Turkey
Indonesia	Uganda
Iran	United Arab Emirates
Ireland	United Kingdom
Israel	United States
Italy	Uruguay
Jamaica	Union of Soviet Socialist Republics†
Japan	Venezuela
Jordan	Yugoslavia
Kenya	Zaire
Korea, South	Zambia
Kuwait	Zimbabwe
Lao People's Republic	

The results of Dietz and Rosa's regression is seen in Table 16 below.

.

Table 16: Dietz and Rosa's Regression Results

Table 2. Effects of population and affluence on 1989 CO_2 emissions of 111 nations

	Log–polynomial model		Log–linear model	
	Coefficient	SE	Coefficient	SE
Population				
Linear	1.123	0.058	1.149	0.060
Quadratic	0.063	0.026		
Affluence				
Linear	1.484	0.105	1.084	0.047
Quadratic	−0.152	0.026		
Cubic	−0.070	0.020		
Intercept	16.854	0.101	16.545	0.073
Coefficient of determination	0.931		0.891	

Dietz and Rosa note that while the quadratic term for the log of population is significant, this is likely due to the influence of China and India. When the model was rerun without these two nations, the coefficient of the quadratic of population lost its significance. On the other hand, the coefficients for all of the coefficients for the polynomial of the log of affluence remained relatively unchanged with the removal of China and India from the dataset.

The results of Dietz and Rosa indicate population has a significant positive effect on CO_2 emission, which "support[s] the ongoing concern with population as a driving force of environmental impacts," (Dietz and Rosa, 1997). Additionally, their results suggest that affluence has a significant effect on emissions which levels off at high levels of GDP. However, they note that this turning point is above $10,000 per capita. Since this level of affluence is well above the average level of per capita income in most of the nations in their dataset, this result suggests that the majority of nations will see increasing rather than decreasing levels of emissions with economic growth.

When Dietz and Rosa estimate their model without including the non-linear terms, they found that affluence and population have a significant and positive effect on CO_2 emissions, with elasticities greater than 1. They note that this result is in line with previous IPAT studies which estimated only the log-linear model. The inclusion of polynomial terms, however, suggests that economic growth to high levels of GDP may be able to decrease emissions. This finding is in line with the EKC Hypothesis

2.2.2: Wang et al. (2015). A Semi-Parametric Panel Data Analysis on the Urbanization-Carbon Emissions Nexus for OECD Countries. *Renewable and Sustainable Energy Reviews*, 48, 704–709.

One group of researchers who have used Dietz and Rosa's STIRPAT model more recently are Wang et al. in their 2015 study, "A semi-parametric panel data analysis on the urbanization-carbon emissions nexus for OECD countries." In this study, Wang et al. use the STIRPAT model to study the relationships between environmental impact, population, affluence, and technology in OECD countries; however, they also incorporate some elements of the EKC Hypothesis by including a quadric term for the percent of the population that lives in urban regions.[1] This was done with the purpose of "determining the effect of urbanization on carbon emissions," (Wang et al., 2015).

Wang et al. base their analysis on the model in Equation 9 below.

Equation 9: Wang et al.'s Parametric Model

$$\ln CE_{it} = \alpha_i + \beta_1 \ln A_{it} + \beta_2 \ln EI_{it} + \beta_3 UR_{it} + \beta_4 UR_{it}^2 + T_t + \varepsilon_{it} \qquad (2)$$

where CE_{it} is the amount of carbon dioxide emitted (in tons per capita) by country i in year t, A is the GDP per capita, EI is energy intensity and UR is the level of urbanization, regarded as a demographic factor. The explanatory variable coefficients to be estimated are represented by β_s', ε_{it} represents the random error, α_i represents the country-specific effect that is constant over time and the time-specific effect, T_t, could be considered as a proxy for each of the variables that change over time but are common across all countries.

In addition to this parametric regression model, Wang et al. also estimate a semiparametric model, which assumes that the functional form of the relationship between urbanization and environmental impact is unknown. Thus, this semi-parametric model takes the form of Equation 10 below.

Equation 10: Wang et al.'s Semi-Parametric Model

$$\ln CE_{it} = \alpha_i + \beta_1 \ln A_{it} + \beta_2 \ln EI_{it} + f(UR_{it}) + T_t + \varepsilon_{it} \qquad (3)$$

Wang et al.'s results can be seen graphically in Figure 9 below, and in Table 17 which follows. They find that in both the parametric and semiparametric models, energy intensity and affluence have a positive and statistically significant effect on carbon emissions. In addition, for the parametric fixed effect regression, the coefficients on the Urbanization variable indicate that an inverted U-shaped relationship exists between urbanization and carbon emissions. When the semiparametric model is estimated, the nonlinear relationship that is observed is even more dramatic. This difference can be seen in the figure below, where the graphical results of the urbanization-emissions relationship for the parametric fixed model are on the left, and the graphical results for the semiparametric model are on the right. It is clear that the semiparametric model results predict a more dramatic inverted U-shaped relationship than the parametric fixed effect model.

[1] Note that the nonlinear relationship with emissions that Wang et al. control for are in this urbanization variable, rather than in the GDP per capita variable which is conventional to use for EKC studies.

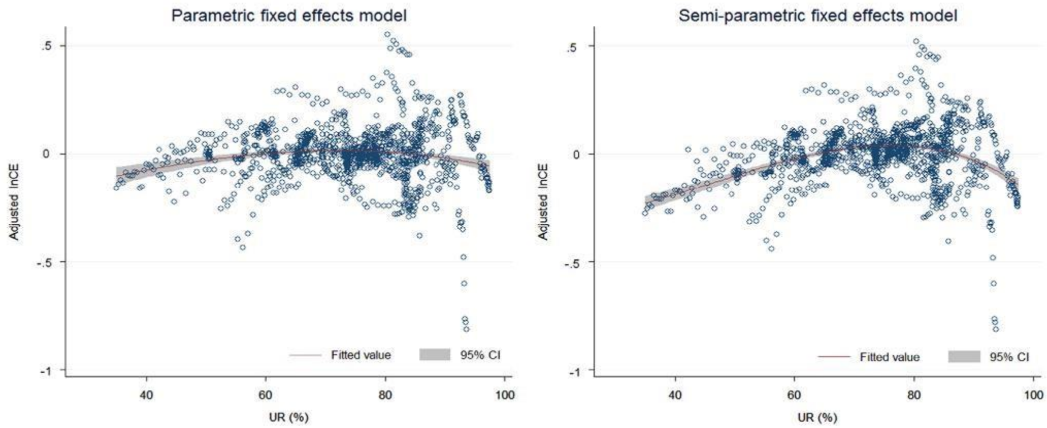

Fig. 2. Partial fits of urbanization and carbon emission nexus. Note: the points in each graph are estimated partial residuals for carbon emission. The maroon curves represent the fitted value for the adjusted effects of the other explanatory variables in the model, and 95% confidence bands are indicated by shaded areas.

Figure 9: Wang et al.'s Graphical Results

Table 17: Wang et al.'s Regression Results

Table 2
Estimation results for carbon emissions models.

Variable	Parametric model		Semi-parametric model	
	Coefficient (St. dev.)	*t*-statistic [*p*-value]	Coefficient (St. dev.)	*t*-statistic [*p*-value]
Constant	0.0155 (0.6083)	0.03 [0.980]		
ln*EI*	0.7884[a] (0.1616)	4.88 [0.000]	0.9180[a] (0.1368)	6.71 [0.000]
ln*A*	0.8268[a] (0.1436)	5.76 [0.000]	1.0308[a] (0.0597)	17.28 [0.000]
UR	0.0747[c] (0.0398)	1.88 [0.070]		
UR^2	−0.0005[c] (0.0003)	−1.92 [0.064]		
Country dummies	Yes		Yes	
Year dummies	Yes		Yes	
Adjusted R^2	0.8233		0.6111	
N	1279		1248	

Note: Cluster-robust standard errors in parentheses. Superscripts "a" and "c" denote statistical significance at the 1% and 10% level, respectively

Wang et al. determine that "[i]n general, energy intensity and income per capita are the main driving forces of increasing carbon emissions, while technical progress has decreased carbon emissions. The inverse U-shaped curve suggests that urbanization is both a problem and a solution in terms of carbon emissions. While carbon emissions tend to increase during the early stages of urbanization, there comes a point when carbon emissions begin to decrease as urbanization increases. After this point it appears that urbanization could become part of the solution to carbon emissions," (Wang et al., 2015).

2.2.3: **Usman and Hammar. (2020). Dynamic Relationship Between Technological Innovations, Financial Development, Renewable Energy, and Ecological Footprint: Fresh Insights Based on the STIRPAT Model for Asia Pacific Economic Cooperation Countries.** ***Environmental Science and Pollution Research International.*** **28,15519–15536.**

Following the analysis of Dietz and Rosa, many other economists have used the STIRPAT model to examine the effects of different variables on the environment. In fact, the stochastic equation used by Dietz and Rosa has been extended to allow for panel analysis.

Another pair of researchers who used the STIRPAT model to examine the effects of different variables on the environment are Muhammad Usman and Nesrine Hammar in their 2020 study, "Dynamic relationship between technological innovations, financial development, renewable energy, and ecological footprint: fresh insights based on the STIRPAT model for Asia Pacific Economic Cooperation countries." In this study, Usman and Hammar use modern panel regression techniques to estimate the STIRPAT model for Asian Pacific Economic Cooperation (APEC) countries. The methods they use are similar to the panel regression techniques used by Atasoy (2017) in his estimation of the EKC.

Specifically, Usaman and Hammar use a panel of data which includes variables for "technological innovation, financial development, economic growth, renewable energy consumption, […] population [and] ecological footprint for the Asian Pacific Economic Cooperation (APEC) countries over the period from 1990 to 2017," (Usman and Hammar, 2020).

Ecological footprint is a measure of the global hectares per person that a nation is responsible for. This is the variable Usman and Hammar use as a proxy for environmental degradation. It is measured in global hectares per person and was obtained from the Global Footprint Network. Usman and Hammar use population size from the World Development Indicators Dataset as their population variable, POP. To control for a country's level of affluence, Usman and Hammar use three different variables. First, they use an index of financial development of a nation which is "based on the nation's relative ranking regarding their depth, access, and efficiency of both particular financial markets and institutions (IMF 2019)," FD. Second, they include the percent of total energy use that is renewable, REC. The data for this variable also comes from the World Development Indicators Dataset. Finally, they include an economic growth variable, GDP, which is measured in constant 2010 US Billions of dollars, which was also obtained from the World Development Indicators Dataset.

To control for technology changes, Usman and Hammar create an index for technological innovation, TECH. TECH is assumed to take the following form where PAT which is the number of total patent applications, TMA which is the number of trademark applications, and GRA which is the total number of grants for direct applications: $TECH_{it}=\Theta_{0it}+\Theta_{1it}\, PAT_{it} + \Theta_{2it}\, TMA_{it} + \Theta_{3it}\, GRA_{it} +\mu_{it}$.

The model they estimate is presented in Equation 11 below.

Equation 11: Usman and Hammar's Model

$$\ln(EFP_{it}) = \Phi_{0it} + \Phi_{1it}\ln(TECH_{it}) + \Phi_{2it}\ln(FD_{it}) + \Phi_{3it}\ln(GDP_{it}) + \Phi_{4it}\ln(REC_{it}) + \Phi_{5it}\ln(POP_{it}) + \mu_{it} \quad (5)$$

Where Φ_0 represents the individual intercept term; Φ_1, Φ_2, Φ_3, Φ_4, Φ_5 express the elasticity of explanatory variables; lnEFP, lnTECH, lnFD, lnGDP, lnREC, and lnPOP show the natural logarithmic transformation of ecological footprint, technological innovations, financial development, economic growth, renewable energy utilization, and population size; and μ_{it} refers to the stochastic error term.

Similar to Atasoy (2017), Usman and Hammar first test for cross sectional dependence in their panel. Then, after having established cross-sectional dependence, they test for the presence of unit roots in their variables, and then test for cointegration in order to determine whether a long run causal relationship exists between the variables in their panel. Their results are presented below, and suggest that Usman and Hammar's panel contains cross-sectional dependence.[1] Their variables all fail to reject the null of no unit root in levels, with the exception of the variable for financial development; however, all variables are stationary in first difference. Their cointegration test confirms that cointegration, and thus a long run relationship, exists among the independent variables and the dependent variable in the panel.

Table 18:Usman and Hammar's Cross Sectional Dependence Test

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Table 2 Cross-sectional dependency analysis of the variables

Series	Breusch-Pagan LM		Pesaran Scaled LM		Bias-corrected Scaled		Pesaran CSD	
	Stats.	Prob.	Stats.	Prob.	Stats.	Prob.	Stats.	Prob.
lnEFP	855.725*	0.0000	46.4581*	0.0000	46.1617*	0.0000	5.992*	0.0000
lnTECH	2345.04*	0.0000	142.593*	0.0000	142.296*	0.0000	47.075*	0.0000
lnFD	1795.87*	0.0000	107.144*	0.0000	106.848*	0.0000	41.201*	0.0000
lnGDP	3061.66*	0.0000	188.851*	0.0000	188.554*	0.0000	55.075*	0.0000
lnREC	1155.27*	0.0000	65.7939*	0.0000	65.497*	0.0000	3.625*	0.0000
lnPOP	3098.95*	0.0000	191.257*	0.0000	190.961*	0.0000	42.834*	0.0030

*indicates a 1% level of significance

[1] Note that these tests are similar to what were performed by Atasoy (2017), and what I will perform in my analysis. Details on how these tests are performed and the implications of their results can be seen in the Methodology Sections 3.3.1-3.3.4.

Table 19: Usman and Hammar's Unit Root Test Results

Table 3 Second generation panel unit root outcomes

Series	CADF test		CIPS test		Breitung and Das test	
	Level	First Δ	Level	First Δ	Level	First Δ
Intercept						
lnEFP	− 1.699	− 3.261*	− 2.078	− 5.127*	0.192	− 4.795*
lnTECH	− 2.041	− 3.705*	− 2.199**	− 4.687*	1.967	− 3.134*
lnFD	− 2.529*	− 3.671*	− 3.156*	− 5.370*	0.554	− 4.472*
lnGDP	− 1.298	− 2.783*	− 2.016	− 3.259*	1.788	− 2.158**
lnREC	− 1.110	− 3.923*	− 1.466	− 5.073*	0.883	− 2.651*
lnPOP	− 1.722	− 2.161**	− 1.287	− 1.821**	1.604	− 2.001**
Intercept and trend						
lnEFP	− 2.320	− 3.244*	− 2.694**	− 5.189*	− 0.051	− 5.461*
lnTECH	− 2.435	− 3.668*	− 2.544	− 4.681*	− 0.366	− 4.610*
lnFD	− 2.745**	− 3.750*	− 3.222*	− 5.713*	− 1.461***	− 5.792*
lnGDP	− 2.277	− 3.000*	− 2.082	− 3.559*	− 0.480	− 2.891*
lnREC	− 2.451	− 3.926*	− 2.501	− 5.179*	0.960	− 3.033*
lnPOP	− 2.229	− 3.291*	− 1.705	− 1.826	0.950	− 2.331**

Table 20: Usman and Hammar's Cointegration Tests

Statistics	Values	Z-values	P values	Robust P values
G_τ	− 3.605*	− 4.024	0.000	0.000
G_a	− 5.777	4.463	0.999	0.968
P_τ	− 10.685***	− 1.104	0.135	0.088
P_a	− 5.260	2.907	0.998	0.878

* and *** indicate 1% and 10% level of significance

Having established these relationships, and in the presence of cross-sectional dependence, Usman and Hammar employ the AMG estimator and CCEMG estimator. The results of these estimators represent the long run elasticities of the independent variables in their model. These estimators are robust in the presence of cross-sectional dependence. Additionally, Usaman and Hammar estimate the model using the feasible generalized lease squares (FGLS) estimator, which is robust to CSD, serial correlation, and heteroskedasticity, but may be mis specified when the time dimension of the panel is greater than the cross sections. That is, when the number of years in the panel is fewer than the number of nations in the panel, which is the case in Usaman and Hammar's panel. Usaman and Hammar estimate the all three models for comparison. Their results are presented in Table 21 below.

Table 21: Usman and Hammar's Regression Results

Table 5 Results of long-run elasticity estimates

Series	FGLS		AMG		CCEMG	
	Coefficient	P value	Coefficient	P value	Coefficient	P value
lnTECH	0.0992**	0.0421	0.3491*	0.0010	0.7801**	0.0390
lnFD	− 0.0927*	0.0000	− 0.1045**	0.0430	− 0.1976	0.4570
lnGDP	0.5175*	0.0000	0.4592	0.7860	0.5598*	0.0000
lnREC	− 0.4274*	0.0000	− 0.5591**	0.0270	− 0.6318***	0.0610
lnPOP	0.4582*	0.0000	0.1945*	0.0000	0.0017	0.9180

*, **, and *** signify 1%, 5%, and 10% level of significance

The results of Usaman and Hammar suggest that an increase in renewable energy consumption and improvements in financial development will decrease ecological footprint, and thus improve environmental quality in the long run. On the other hand, population growth, economic development, and technology advancement will increase ecological footprint and further degrade the environment.

The final analysis performed by Usaman and Hammar is a causality test in order to determine the "flow of the relationships" (Usaman and Hammar, 2020) that are estimated by the AMG, CCEMG and FGLS models.[1] They note that this is important in order to make policy recommendations and to understand the true relationships between the variables of interest.

Usaman and Hammar use a Granger non-causality test which was proposed by Dumitrescu and Hurlinm (2012). This test "check[s] the causality direction in heterogeneous panels," (Usaman and Hammar, 2020). This test in particular accounts for cross sectional dependence and slope heterogeneity. The results of this test are presented in Table 22 below. Usaman and Hammar present two test statistics, W-bar and Z-bar. They note that "W-bar statistics utilized mean test statistics while Z-bar test statistic is applied to analyze the standard normal distribution," (Usaman and Hammar, 2020). Additionally, they note that an underlying assumption of the test is that the variables follow a stationary process, thus they are all transformed by first differencing in order to fit this assumption before the test is performed. Their results are presented below.

Table 22: Usman and Hammar's Granger Causality Test Results

Table 6 Results of pairwise Dumitrescu Hurlin Panel Causality Tests

Null hypothesis	W-Stat.	Zbar-Stat.	Prob.	Inference
lnFD ⇎ lnEFP	6.39848*	6.81838	0.0000	FD ↔ EFP
lnEFP ⇎ lnFD	4.80778*	4.22857	0.0000	
lnTECH ⇎ lnEFP	4.78317*	3.58426	0.0000	TECH → EFP
lnEFP ⇎ lnTECH	2.36941	0.53411	0.6826	
lnGDP ⇎ lnEFP	4.98682*	4.52006	0.0000	GDP ↔ EFP
lnEFP ⇎ lnGDP	3.80035*	2.58838	0.0096	
lnPOP ⇎ lnEFP	5.89577*	5.99993	0.0000	POP ↔ EFP
lnEFP ⇎ lnPOP	8.17854*	9.71648	0.0000	
lnREC ⇎ lnEFP	3.66776**	2.37252	0.0177	REC ↔ EFP
lnEFP ⇎ lnREC	4.97147*	4.49507	0.0000	
lnTECH ⇎ lnFD	4.46514*	3.67072	0.0002	TECH ↔ FD
lnFD ⇎ lnTECH	3.51602**	2.12547	0.0335	
lnGDP ⇎ lnFD	5.44391*	5.26424	0.0000	GDP ↔ FD
lnFD ⇎ lnGDP	4.67343*	4.00984	0.0000	
lnPOP ⇎ lnFD	6.46584*	6.92805	0.0000	POP → FD
lnFD ⇎ lnPOP	2.63478	0.69073	0.4897	
lnREC ⇎ lnFD	4.00532*	2.92210	0.0035	REC → FD
lnFD ⇎ lnREC	2.78349	0.93284	0.3509	
lnGDP ⇎ lnTECH	6.37261*	7.82115	0.0000	GDP → TECH
lnTECH ⇎ lnGDP	2.34186	0.91744	0.7631	
lnPOP ⇎ lnTECH	6.07268*	6.28795	0.0000	POP ↔ TECH
lnTECH ⇎ lnPOP	7.78554*	9.07663	0.0000	
lnREC ⇎ lnTECH	1.90096	− 0.50400	0.6143	TECH → REC
lnTECH ⇎ lnREC	3.51841**	2.12936	0.0332	
lnPOP ⇎ lnGDP	6.86270*	7.57416	0.0000	POP ↔ GDP
lnGDP ⇎ lnPOP	16.4765*	23.2263	0.0000	
lnREC ⇎ lnGDP	2.00574	− 0.33340	0.7388	GDP → REC
lnGDP ⇎ lnREC	4.49726*	3.72301	0.0002	
lnREC ⇎ lnPOP	5.25647*	4.95907	0.0000	REC ↔ POP
lnPOP ⇎ lnREC	5.86590*	5.95129	0.0000	

*, and ** denote 1%, and 5% significance level. The symbol ⇎ shows does not Granger cause, while ↔ symbolizes as bidirectional causality and symbol → shows the unidirectional causal relationship

[1] Note again that the details on the CCEMG and AMG estimators are in the Methodology Section 3.3.5.

These results suggest that there is “bidirectional causality linkage between EFP and FD, between GDP and EFP, between POP and EFP, between REC and EFP, between TECH and FD, between GDP and FD, between GDP and TECH, between POP and TECH, between POP and GDP, and between REC and POP in case of APEC countries.” Additionally, they “discovered the unidirectional causality association from TECH to EFP, from POP to FD, from REC to FD, from GDP to TECH, from TECH to REC, and from GDP to REC,” (Usaman and Hammar, 2020).

Usaman and Hammar’s STIRPAT study uses advanced panel regression technique, allowing them to study more than one year of data as was done by Dietz and Rosa. Further, their use of the Dumitrescu and Hurlinm Granger Non-Causality test allows them to make policy suggestions. It is important to note, however, that, unlike Dietz and Rosa, Usaman and Hammar fail to test for nonlinear relationships between their variables. This suggests that their study neglects a possible EKC relationship between degradation.

2.2.4: STIRPAT Literature Review Findings and Questions for Consideration

The theoretical framework of the STIRPAT model is useful when considering pathways toward sustainable development due to its estimation of the elasticity of environmental impact to changes in population, affluence, and technology. Further, when controlling for higher order affluence terms, the EKC Hypothesis can be tested simultaneously. This was seen in the study of Dietz and Rosa. Similar to the results of Seldon and Song and Stern and Perman, however, Dietz and Rosa find an EKC turning point that is well above a level of per capita income that has been reached by most countries. This suggests that, at least for some period of time, further economic development will lead to additional environmental degradation.

Additionally, as was seen in the study Usman and Hammar, more sophisticated forms of panel data analysis, such as the CCEMG and AMG estimators instead of Pooled OLS, Fixed Effect and Random Effect estimators, may be more appropriate when estimating the STIRPAT model due to cross sectional dependence, unit roots and cointegration.

From the STIRPAT *Literature Review*, it seems as if it is there is a lack of evidence toward an EKC relationship between pollution and income for levels of income close to what most countries are at currently, as suggested by the high turning point found in Dietz and Rosa’s study. However, since the STIRPAT model estimates the elasticity of environmental impact to changes in other factors, such as population and technology, some policy implications can follow. Additionally, the cross-sectional dependence, unit root, and cointegration tests performed by Usman and Hammar reinforce the findings of Atasoy (2017) that the CCEMG and AMG estimators will be most appropriate when using panels of this sort.

3: Data and Methodology

The *Literature Review* portion of this thesis covered examples of studies which had the goal of quantifying the effects of human activity on environmental degradation through the use of the EKC and the IPAT models. It is worth noting that the most basic form of these two models seem to oppose each other. The IPAT model assumes that the effect of a change in economic growth (or affluence, A) on pollution (or impact, I) is linear. On the other hand, the EKC is based on the hypothesis that environmental degradation and economic growth have a nonlinear relationship.

As we have seen, however, Dietz and Rosa's STIRPAT model can be extended to include a quadratic relationship to GDP growth, and thus allows me to test the validity of the EKC hypothesis while also determining the long run elasticity of environmental impact to changes in population, economic development, and technology advancements. Additionally, if the EKC fails to hold, the STIRPAT model can be easily adjusted to the basic form, only considering a linear relationship between income and emissions. In either case I will then be able to interpret the results and infer which policy choices may be the most effective in making progress toward sustainable development at a global scale.

3.1: Model and Data Selection

In total, there are 55 countries included in my dataset. Of these, 33 are developing and 22 are developed.[1] All data are annual and include observations for all countries from 1980-2016. The data will be separated into three panels. One panel will include all 55 countries, one panel will include only developing countries and the one panel will only include developed countries.

Table 23 lists all countries included in the dataset.

[1] These are classified based on the United Nations country classification lists provided in their World Economic Situation and Prospects report (UN, 2020).

Table 23: Countries Included in My Dataset

	Developing Countries		Developed Countries
1	Algeria	1	Austria
2	Argentina	2	Belgium
3	Bangladesh	3	Bulgaria
4	Brazil	4	Canada
5	Chile	5	Cyprus
6	China	6	Denmark
7	Colombia	7	Finland
8	Ecuador	8	Greece
9	Egypt	9	Hungary
10	Hong Kong	10	Iceland
11	India	11	Ireland
12	Indonesia	12	Japan
13	Islamic Republic of Iran	13	Luxembourg
14	Israel	14	Norway
15	Malaysia	15	Poland
16	Mexico	16	Portugal
17	Morocco	17	Romania
18	Oman	18	Spain
19	Pakistan	19	Sweden
20	Peru	20	Switzerland
21	Philippines	21	United Kingdom
22	Qatar	22	United States
23	Republic of Korea		
24	Saudi Arabia		
25	Singapore		
26	South Africa		
27	Sri Lanka		
28	Thailand		
29	Trinidad and Tobago		
30	Turkey		
31	United Arab Emirates		
32	Venezuela		
33	Vietnam		

I will then estimate the following models which combines the most essential elements of the STIRPAT and EKC models presented in my *Literature Review*. The first model, shown in Equation 12 below, controls for a cubic relationship between income per capita and CO_2 emissions. The second EKC model, shown in Equation 13, controls for a quadratic relationship. Both will be estimated in an effort to estimate the true underlying relationship between the variables. One functional form may be more fitting than the other, so both will be estimated for comparison.

Equation 12: Cubic EKC Model

$$\ln CO_{2it} = \beta_0 + \beta_1[\ln GDP_{it}] + \beta_2[\ln GDP_{it}]^2 + \beta_3[\ln GDP_{it}]^3 + \beta_4[\ln POP_{it}] + \beta_5[Renew_{it}] + \beta_6 + u_{it}$$
$$u_{it} = \Theta f_t + \varepsilon_{it}$$

Equation 13: Quadratic EKC Model

$$\ln CO_{2it} = \beta_0 + \beta_1[\ln GDP_{it}] + \beta_2[\ln GDP_{it}]^2 + \beta_3[\ln POP_{it}] + \beta_4[Renew_{it}] + \beta_5 t + u_{it}$$
$$u_{it} = \Theta f_t + \varepsilon_{it}$$

Using both of these functional forms, I will be able to test the Environmental Kuznets Hypothesis and determine which of these functional forms is most appropriate given my data. Further, I can rerun the model using the following functional form, as seen in Equation 14 below, which follow the most basic form of the STIRPAT model, to estimate how elastic CO_2 emissions are to changes in Population, Affluence, and Technology.

Equation 14: STIRPAT Model

$$\ln CO_{2it} = \beta_0 + \beta_1[\ln GDP_{it}] + \beta_2[\ln POP_{it}] + \beta_3[Renew_{it}] + \beta_4 t + u_{it}$$
$$u_{it} = \Theta f_t + \varepsilon_{it}$$

I now turn to a discussion of the variables that I chose to include in my models and the sources I obtained these data from.

Dependent Variable:

Impact, I

The dependent variable, $\ln CO_{2\,it}$, is the natural log of per capita CO_2 emissions for country *i* in time period *t*. This variable is a proxy for environmental degradation and impact. This is not one of the pollutants included in the original studies of Grossman and Krueger, yet it has been used more recent EKC studies such as Atasoy's (2017) study.

This pollutant is important to study in the context of Sustainable Development since reducing CO_2 emissions is essential to make progress toward SDGs. As mentioned, however, there is debate over the existence of an EKC for global pollutants, like CO_2 emissions. This may be because the negative effects of CO_2 emissions are felt at more of a global than a local scale, disproportionately affecting Least Developed Countries. This may prevent countries most responsible from these emissions from gaining more utility from decreasing these emissions after a certain level of development has been reached, as was seen in the case of SO_2 emissions when studied by Selden and Song, and Grossman and Krueger.

The data for per capita CO_2 emissions were downloaded from the World Development Indicators dataset which is made publicly available by the World Bank (The World Bank, 2019).[1] This variable is measured in metric tons of CO_2 emissions of per capita. This was then multiplied by population data which were also downloaded from World Development Indicators dataset (The World Bank, 2019) in order to transform it to a level variable rather than the per capita form.

While many EKC studies examine the effect of changes in a per capita income variable on a per capita emissions variable, the IPAT model keeps pollution (or impact) and population separate in order to estimate the elasticity between population and impact. I follow this methodology in my analysis.

[1] https://data.worldbank.org/indicator/EN.ATM.CO2E.PC

The scatter plots in Figure 10 and Figure 11 below show how the logged value of per capita emissions have changed in both the developed and the developing countries over from 1980-2016.[1] Note that this shows a generally flat to decreasing trend in emissions for developed countries in Figure 10, and a generally flat to increasing trend in emissions for developing countries in Figure 11.

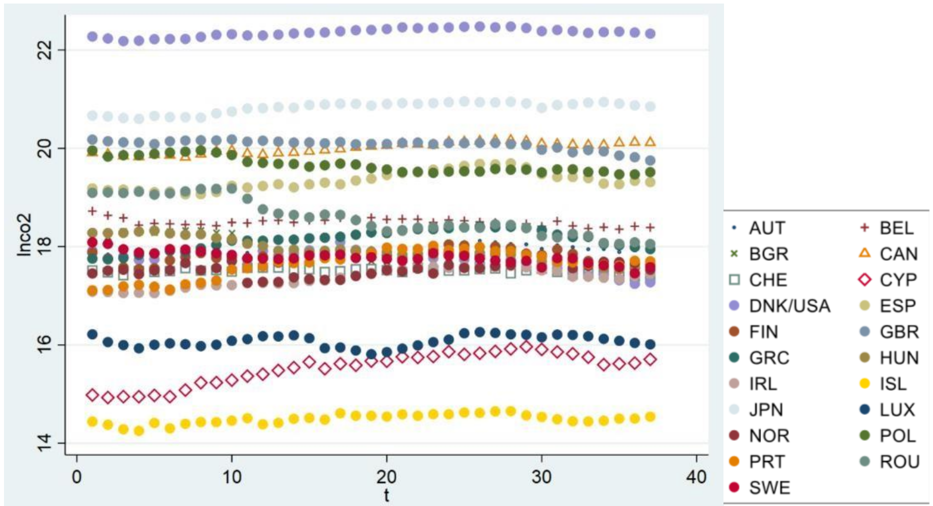

Figure 10: Developed Countries CO_2 Emissions Over Time

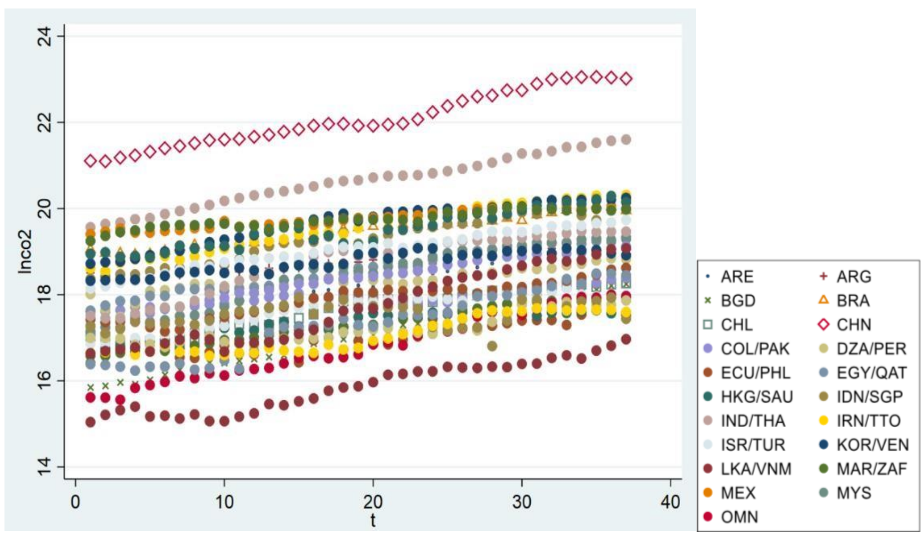

Figure 11: Developing Countries CO_2 Emissions Over Time

[1] Note that t in the x axis of the scatter plot represents the number of years since 1980.

Independent Variables:

Population, P

The variable for population, $\ln POP_{it}$, is the natural log of population in country *i* and time period *t*. These data were downloaded from the World Development Indicators dataset (The World Bank, 2019).[1]

Population is a variable of interest in my model since the IPAT model estimates the elasticity of impact to changes in population, affluence and technology. In addition, many EKC studies, like the one performed by Grossman and Krueger and Selden and Song, use population as a control variable.

The scatter plots in Figure 12 and Figure 13 below show how population has changed in both the developed and the developing countries from 1980-2016.[2] Note that this shows a generally increasing trend in population for both developed countries, as seen in Figure 12, and developing countries, as seen in Figure 13.

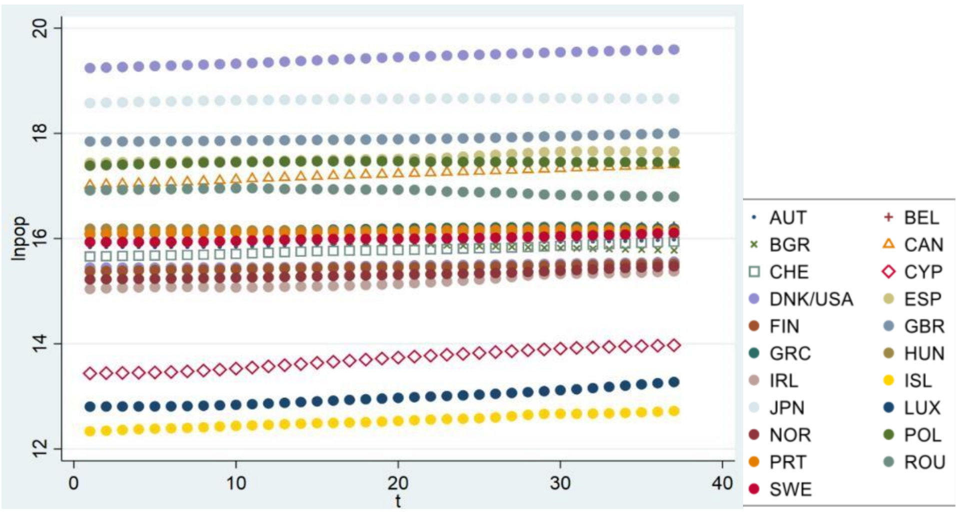

Figure 12: Developed Countries Population Over Time

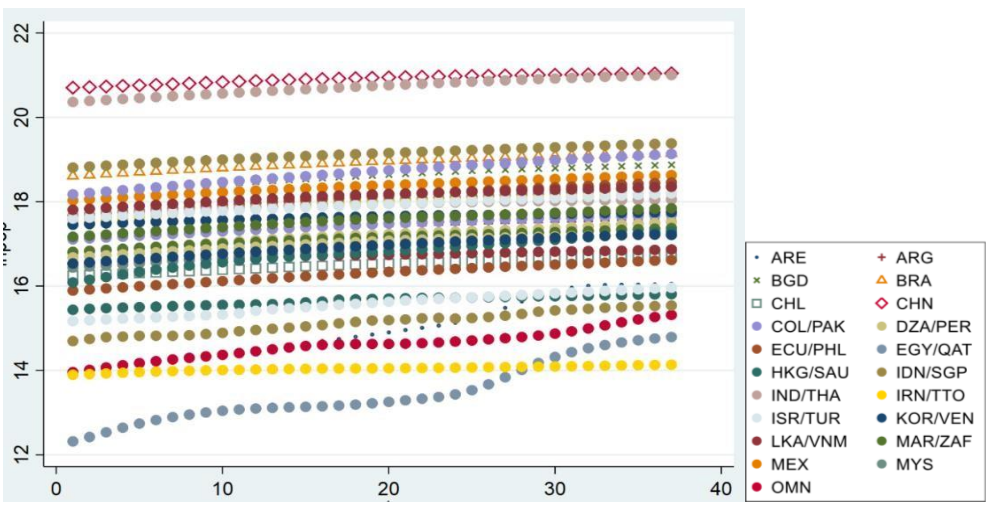

Figure 13: Developing Countries Population Over Time

[1] https://data.worldbank.org/indicator/EN.ATM.$CO2$E.PC

[2] Note that t in the x axis of the scatter plot represents the number of years since 1980.

Affluence, A

The variable I will use for economic development and affluence, $\ln GDP_{it}$, is the natural log of per capita GDP adjusted for purchasing power parity in country *i* and time period *t.*

For this variable, I use data that is made publicly available in the IMF's World Economic Outlook Database for PPPGDP by country.[1] This variable is measured in billions of dollars and corrected for purchasing power parity. It "is calculated by dividing a country's nominal GDP in its own currency by the PPP exchange rate," (International Monetary Fund, 2020). I will adjust this variable to be in per capita terms by dividing it by population data which was downloaded from the World Development Indicators dataset (The World Bank, 2019).[2]

The GDP data is based on a series which "has been linked to produce a consistent time series to counteract breaks in series over time due to changes in base years, source data and methodologies," (The World Bank, 2019). Thus, no transformations to a common base year were needed.

The scatter plots in Figure 14 and Figure 15 below show how per capita GDP has changed in both the developed and the developing countries from 1980-2016.[3] This trend is increasing in both developed countries, as seen in Figure 14, and developing countries, as seen in Figure 15. This increasing trend is not surprising, however, given that I use nominal, rather than real, GDP.

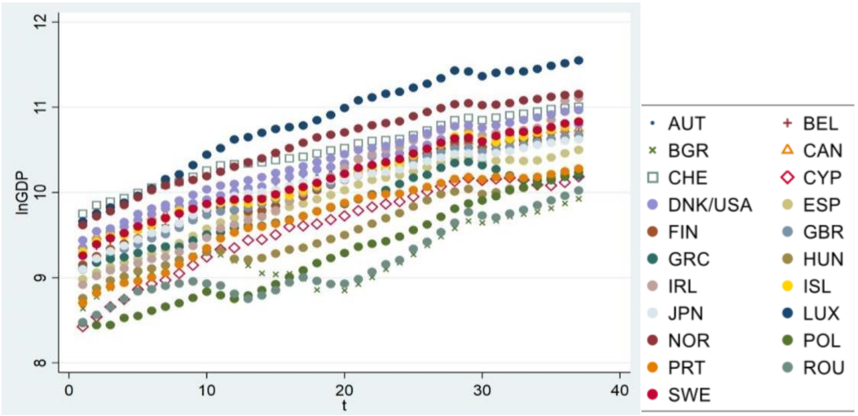

Figure 14: Developed Countries GDP Over Time

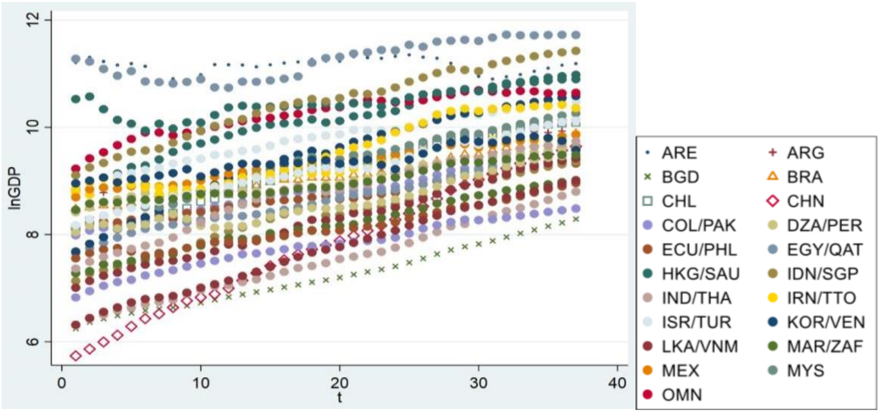

Figure 15: Developing Countries GDP Over Time

[1] https://www.imf.org/external/pubs/ft/weo/faq.htm

[2] https://data.worldbank.org/indicator/EN.ATM.CO2E.PC

[3] Note that t in the x axis of the scatter plot represents the number of years since 1980.

Technology, T

In some STIRPAT models, the technology variable is excluded from the regression under the assumption that it is not possible to find an adequate proxy for this variable. The assumption then is that the error term will largely capture the effect of technology advancements.

My analysis will remain in line with this approach by including a time trend variable, t, in the model; however, I will include a variable to partial out some of the effect from advancements in renewable energy generation. The variable $Renew_{it}$ is the share of primary energy consumed in country *i* and time period *t* that comes from renewable forms of energy. These data were downloaded from bp's "Statistical Review of World Energy" dataset (bp, 2020).[1]

The scatter plots in Figure 16 and Figure 17 below show how the primary share of energy that comes from renewable forms of energy has changed in both the developed and the developing countries from 1980-2016.[2] Note that there a large portion of both developed and developing countries whose share of primary energy that comes from renewable sources is at or near zero. On the other hand, there are two developed countries, Iceland (ISL) and Norway (NOR) whose share of primary energy that comes from renewable sources has been above 50% since 1980. Additionally, this variable seems to have an increasing trend in the past 10 years, especially in developed countries.

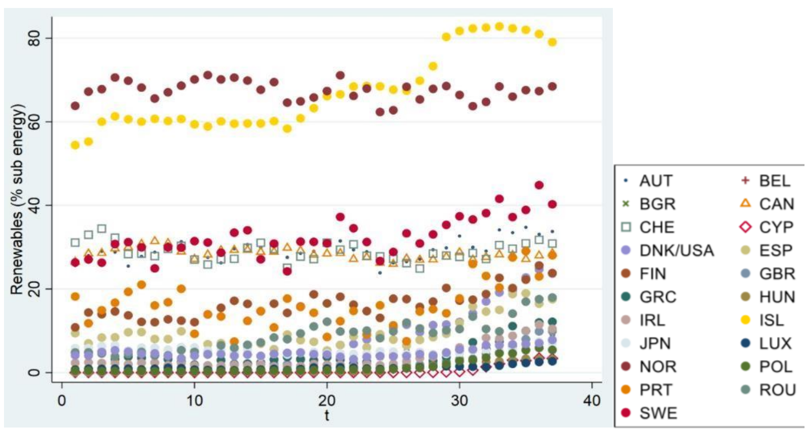

Figure 16: Developed Counties Share of Primary Energy Use that is Renewable Over Time

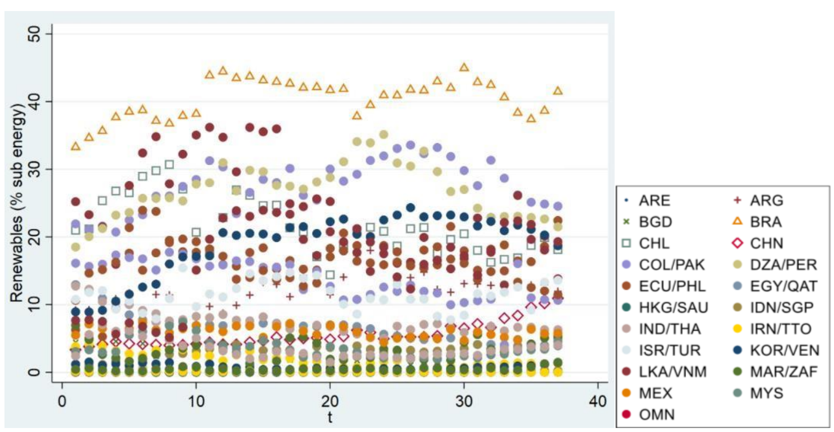

Figure 17: Developing Counties Share of Primary Energy Use that is Renewable Over Time

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[1] https://www.bp.com/en/global/corporate/energyeconomics/statistical-review-of-worldenergy/downloads.html

[2] Note that t in the x axis of the scatter plot represents the number of years since 1980.

The assumption is that the effects of technology advancements on emissions which are not attributable to renewable forms of energy generation will be picked up by the constant term, β_0, or in the error term, u_{it}.

Additional Controls to Test EKC Hypothesis

Studies have been conducted which extend the STIRPAT model and include control variables other than ones related to population, affluence, and technology. In order to test the EKC hypothesis, I include the squared and cubed versions of the income variable in my model.

While only the squared version is needed to test the EKC hypothesis, many EKC studies also include a cubed income variable to control for a potential N shaped, or reverse N shaped, relationship between pollution and income. As a result, I will test both the cubic and quadratic functional forms of the model for comparison.

Common Correlated Effects

Finally, the f_t variable represents unobserved common effects in time *t*. If unobserved common shocks affect all countries in the panel, they may will create cross sectional dependence and slope heterogeneity, yielding inconsistent or biased results when using pooled OLS, Fixed Effect, or Random Effects estimators. Given the presence of these types of common effects in Atasoy (2017) and Usaman and Hammar's (2020) studies, I have a suspicion that they will also be present in my data. As a result, I will test for them before estimating my models.

My models will each be estimated three times. Once for all 55 countries in my panel (Panel 1), once for the developing countries in the panel (Panel 2), and once for the developed countries in the panel (Panel 3). Countries in dataset are classified as either developed or developing based on the 2020 country classification lists provided by the United Nations in their World Economic Situation and Prospects Report (UN, 2020)

3.2: Descriptive Statistics and a Preliminary Look at the Data

Table 24 provides descriptive statistics for the variables of interest in all three panels in the dataset.

Table 24: Panel 1 Descriptive Statistics (Full Panel)

Panel	Variable	Obs	Mean	Std. Dev.	Min	Max
Panel 1 (All Countries)	GDP capita	2035	19949.076	19397.514	310.187	124024.55
	$CO2$	2035	3.398e+08	1.007e+09	1547474	1.029e+10
	pop	2035	80472575	2.116e+08	223632	1.379e+09
	RenewableEnergyShare	2035	.249	1.519	0	21.674
Panel 2 (Developing Countries)	GDP capita	1221	15778.104	20242.232	310.187	124024.55
	$CO2$	1221	3.022e+08	9.613e+08	3410310	1.029e+10
	pop	1221	1.134e+08	2.637e+08	223632	1.379e+09
	RenewableEnergyShare	1221	.058	.138	0	1.517
Panel 3 (Developed Countries)	GDP capita	814	26205.534	16160.451	4562.266	103708.84
	$CO2$	814	3.963e+08	1.070e+09	1547474	5.790e+09
	pop	814	31130056	60211984	228138	3.229e+08
	RenewableEnergyShare	814	.536	2.368	0	21.674

The descriptive statistics of the logged versions of the variables, with the exception of the variable for the share of energy that comes from renewable sources which was kept in its original form since it is a percent, are presented in Table 25 below. These log-transformed variables are the ones which will be used in the estimation of all models. In addition to allowing me to estimate elasticities between the variables of interest, which is a goal of the IPAT model, using the logged form of the variables is also conventional in EKC studies.[1] As mentioned by Stern and Perman, using the logged version of the variables assumes that, while emissions levels may vary over countries for a specific income level, their elasticities do not.

Table 25: Panel 1 (Full Panel) Descriptive Statistics

Panel	Variable	Obs	Mean	Std. Dev.	Min	Max
Panel 1 (All Countries)	ln$CO2$	2035	18.305	1.499	14.252	23.055
	lnGDP	2035	9.433	1.054	5.737	11.728
	lnpop	2035	16.766	1.738	12.318	21.044
	RenewableEnergyShare	2035	11.484	15.219	0	82.835
Panel 2 (Developing Countries)	ln$CO2$	1221	18.366	1.344	15.042	23.055
	lnGDP	1221	9.062	1.118	5.737	11.728
	lnpop	1221	17.219	1.668	12.318	21.044
	RenewableEnergyShare	1221	8.802	10.547	0	44.945
Panel 2 (Developed Countries)	ln$CO2$	814	18.213	1.701	14.252	22.479
	lnGDP	814	9.99	.623	8.426	11.549
	lnpop	814	16.087	1.615	12.338	19.593
	RenewableEnergyShare	814	15.507	19.635	0	82.835

Correlation matrices of the variables of interest are presented in Table 26 below. These suggest that, in developed countries, GDP per capita is negatively correlated with emissions, with a correlation of -0.039, whereas in developing countries GDP per capita is positively correlated with emissions, with a correlation of 0.038. This would suggest that there is reason to test the hypothesis that the pollution-income relationship differs between developed and developing countries.

Additionally, these correlations may suggest that, if an EKC relationship exists, developing countries are on the “upward sloping” portion of the EKC, and thus additional per capita GDP will be associated with additional emissions. On the other hand, developed countries may be on the “downward sloping” portion of the EKC and additional per capita GDP will be associated with a reduction in emissions. Testing these ideas motivates the analysis presented in the *Results* section.

It is also interesting to note from these correlation coefficients that, in case of both developed and developing countries, population is positively correlated with emissions. In fact, of all the variables included in my model, population has the strongest correlation with emissions. For developed countries population and emissions have a correlation coefficient of 0.968, which indicates a strong positive correlation. For developing countries, population and emissions have a correlation coefficient of 0.672. While this correlation is not as strong as for developed countries, it still suggests a rather strong positive correlation between the variables. This may be evidence of other development indicators which have a stronger effect on the pollution-income relationship than income

[1] This was seen in the studies of Stern and Perman, and Atasoy in my *Literature Review* section.

Table 26: Correlation Matrices for Panel 1, Panel 2, and Panel 3

Matrix of correlations (All Countries)

Variables	(1) lnco2	(2) lnGDP	(3) lnPOP	(4) renew
(1) lnco2	1.000			
(2) lnGDP	-0.011	1.000		
(3) lnpop	0.771	-0.542	1.000	
(4) renew	-0.266	0.062	-0.131	1.000

Matrix of correlations (Developed Countries)

Variables	(1) lnco2	(2) lnGDP	(3) lnPOP	(4) renew
(1) lnco2	1.000			
(2) lnGDP	-0.039	1.000		
(3) lnpop	0.968	-0.116	1.000	
(4) renew	-0.364	0.323	-0.344	1.000

Matrix of correlations (Developing Countries)

Variables	(1) lnco2	(2) lnGDP	(3) lnPOP	(4) renew
(1) lnco2	1.000			
(2) lnGDP	0.038	1.000		
(3) lnpop	0.672	-0.620	1.000	
(4) renew	-0.114	-0.293	0.259	1.000

A preliminary look at the data is provided in Figure 18 and Figure 19 below. Figure 18 plots the pollution-income relationship for developed countries in the dataset. By tracing out the data for individual countries, it seems reasonable to believe that that the relationship between income and pollution generally follows some form of an inverted U-shaped path. This seems to be in favor of the EKC hypothesis.

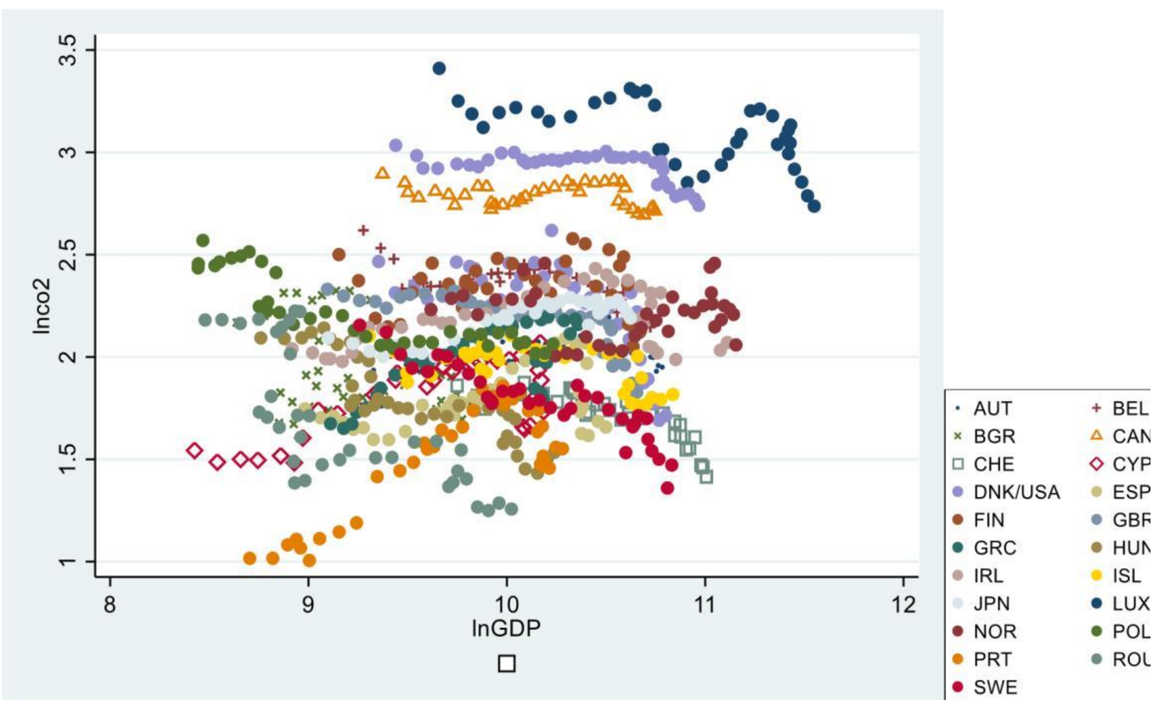

Figure 18: Pollution-Income Relationship in Developed Countries

Figure 19 plots the pollution-income relationship of the developing countries in the dataset. Again, tracing the relationship for individual countries, it seems like the relationship is generally trending upward. This suggests that if an EKC relationship does exists, these countries are still on the upward sloping part of the EKC and have not yet reached their "peak." This is also in line with expectations, since we expect developed countries to need to implement more production processes, which tend to be emissions intensive, in order to develop their economies.

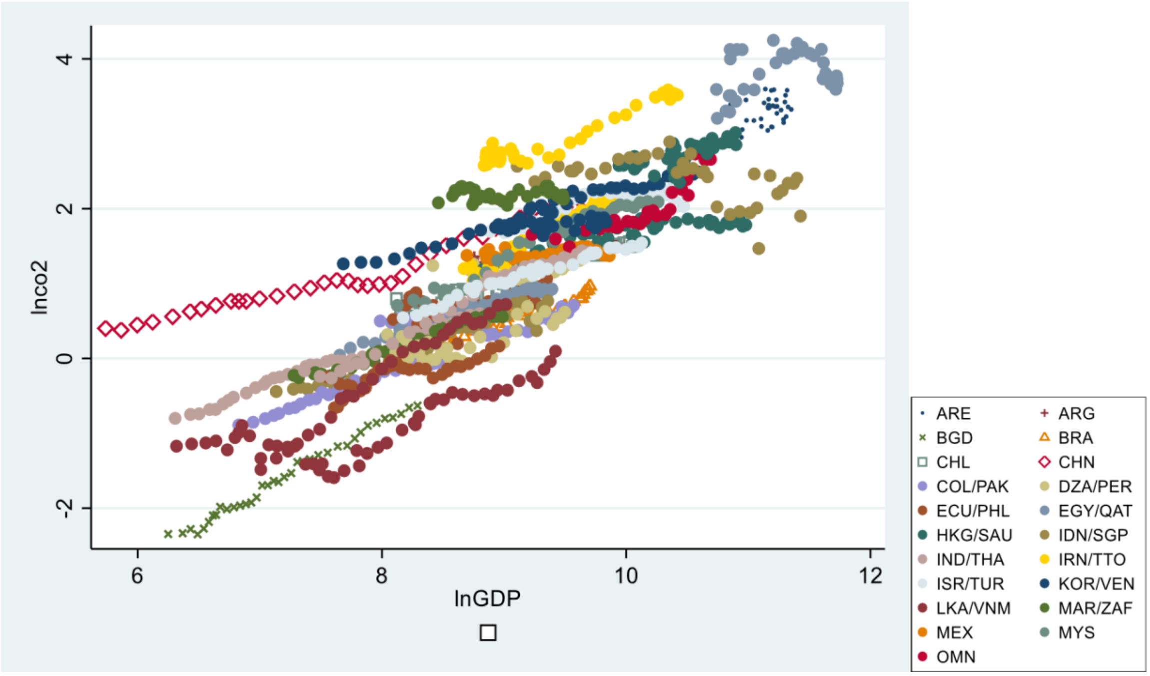

Figure 19: Pollution-Income Relationship in Developing Countries

Some Examples:

It may be interesting to examine the pollution-income relationship of some countries in more detail. The figures below plot the pollution-income relationship of 4 developed countries (Luxembourg, Canada, The United States and Belgium), and 4 developing countries (Bangladesh, Brazil, Mexico, and China).

What is interesting is that, for the selected developed countries, an inverted U-shaped relationship does seem to exist. For the selected developing countries, on the other hand, the pollution-income relationship appears to be monotonically increasing. Additionally, the shapes of the curves and the "turning points" in all countries seem rather different. This might suggest that, while the EKC appears to hold in one country, it may not hold across a panel which includes many countries. My analysis will also determine if, after controlling for factors such as changes to population, technology, and common correlated effects, these relationships persist.

Developed Countries:

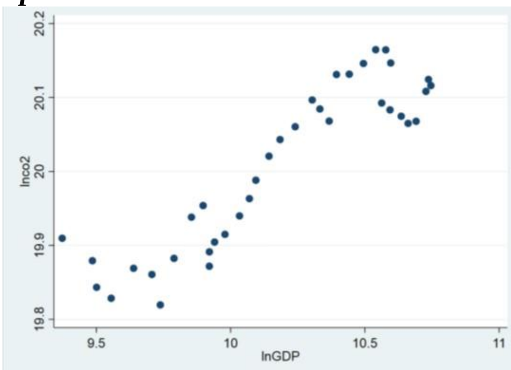

Figure 20: Canada Pollution-Income Relationship

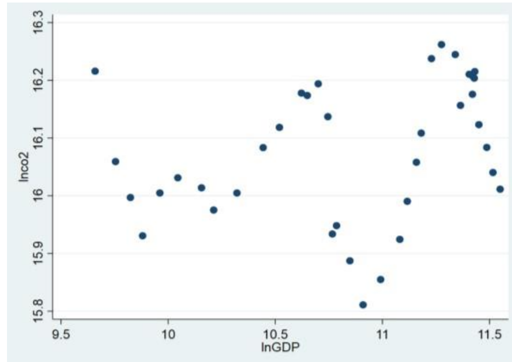

Figure 21: Luxembourg Pollution-Income Relationship

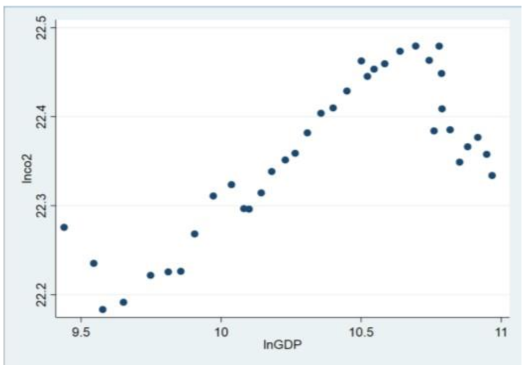

Figure 22: USA Pollution-Income Relationship

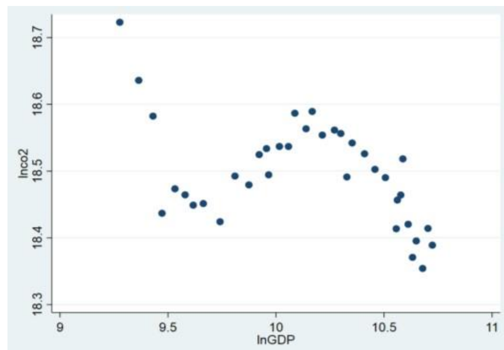

Figure 23: Belgium Pollution-Income Relationship

Developing Countries:

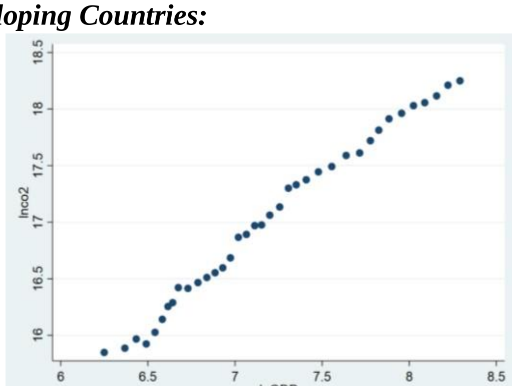

Figure 24: Bangladesh Pollution-Income Relationship

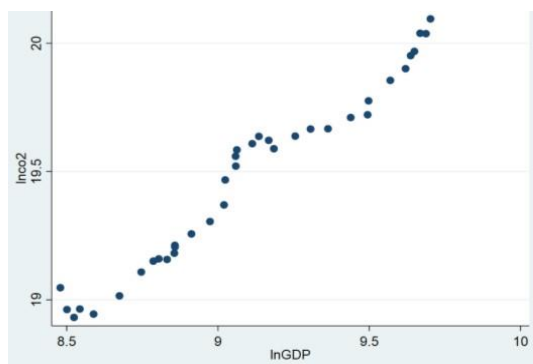

Figure 25:Brazil Pollution-Income Relationship

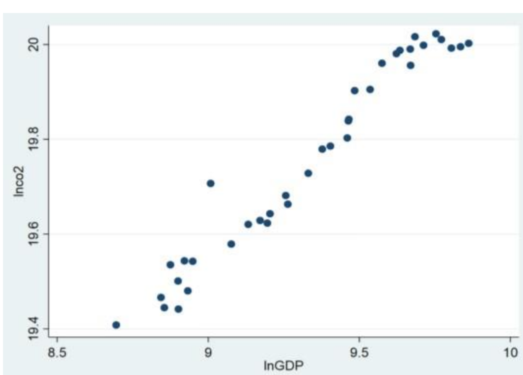

Figure 26: Mexico Pollution-Income Relationship

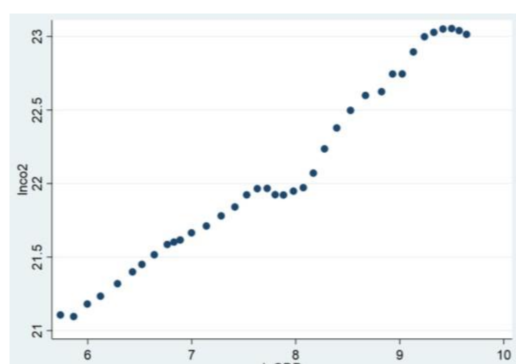

Figure 27: China Pollution-Income Relationship

3.3: Methods

While some of the preliminary looks at the data may seem to favor an EKC relationship in developed countries, and suggest the lack of an EKC in developing countries, this may change once other factors are controlled for and when using appropriate panel data analysis methodologies. Acknowledging the warnings of Stern and Perman, and taking advantage of the developments that have been made in panel regression analysis in recent years, the methodology I use will be similar to what was carried out by Atasoy (2017) in testing the EKC hypothesis, and Usaman and Hammar (2020) in their STIRPAT study. Specifically, I will use CCEMG and AMG estimators which are robust to cross-sectional dependence in the panel.

In an effort to address econometric issues that are typically associated with panel regressions, I will also consider the warnings discussed in "Environmental Kuznets Curve: A Manual," (Lin-Sea Lau, Cheong-Fatt Ng, Siew Pong Cheah, and Chee-Keong Choong, (2019 | Panel Data Analysis (stationarity, cointegration, and causality)).

3.3.1: Cross-Sectional Dependence Test

In order to address the warnings bought up by Lau et al. and Stern and Perman, I will first test for cross-sectional dependence (CSD) in all three of my panels. CSD is caused by the presence of common shocks which have "heterogeneous impacts across countries" (Lau et al., 2019, pp.108) and, as Lau et al. point out, is likely present in panels of macroeconomic data. Despite CSD's likely presence, Lau et al. mention that early EKC studies assumed cross-sectional independence. The assumption of independence is problematic since if these common shocks "are correlated with the regressors, which is usually the case, both the standard homogeneous estimators for panel data (FE, RE, or FD) and the heterogeneous MG estimator are inconsistent," (Henningsen, A. et al., 2019). Thus, in order to ensure consistent results for my estimates, I will test for CSD using the Pesaran (2004) CD test.[1]

The Pesaran (2004) CD test averages the "pairwise correlation coefficients of the OLS residuals obtained from the [Augmented Dickey Fuller] regressions for each variable in the panel," (Lau et al., 2019). The CD statistic that the test calculates is presented below in Equation 15. The CD statistic follows an "asymptotically two-tailed standard normal distribution," and the null hypothesis is cross-sectional independence. The test statistic, $\hat{p}_{ij}$ "is the sample estimate of the pair-wise correlation of the residuals obtained from the OLS," (Lau et al., 2019).

Equation 15: Cross Sectional Dependence Test Statistic

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}\right) \sim N(0,1) \quad i,j = 1,2,3,\ldots,N$$

3.3.2: Unit Root Tests

Next, following the warnings of Stern and Perman, I will test for the presence of unit roots and cointegration in all three of my panels. This is important since if unit roots are present in the panel, the results of Pooled OLS, Fixed Effect, and Random Effects regressions may be spurious. Some commonly used panel unit root tests are LLC and IPS tests that were developed by Levin, Lin, and Chu (2002) and Im, Pesaran and Shin (2003), respectively; however, both of these tests assume cross-sectional

[1] Note this is the same test that was used by Atasoy (2017) and Usman and Hammar (2020), as seen in the *Literature Review* section.

independence. As a result, if the Pesaran (2004) CD test rejects the null of no CSD, it is more appropriate to use the augmented CIPS unit root test developed by Pesaran (2007) which does not assume cross-sectional independence.

The null hypothesis of the CIPS unit root test is that there is no unit root in the panel. This is tested against the alternative hypothesis that one variable contains a unit root. The CIPS test statistics, as described by Usaman and Hammar (2020), are presented in Equation 16 below. Additionally, the test requires the selection of maximum lag length. Maximum lag length for this test can be chosen according to $4(T/100)^{2/9}$ Bartlett kernel width. In my case, $4(T/100)^{2/9} = 4(37/100)^{2/9} \approx 3$.

Equation 16: CIPS Unit Root Test

$$CIPS = N^{-1} \sum_{i=1}^{N} \theta_i(N, T) \quad (11)$$

Where the parameter $\theta_i(N, T)$ refers to CADF statistics that can be replaced as:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (12)$$

CADF test statistics is denoted as follows:

$$\Delta Y_{it} = \pi_i + \theta_i y_{i,t-1} + \gamma_i \overline{y}_{t-1} + \Psi_i \Delta \overline{y}_t + \mu_{it} \quad (9)$$

Putting the lag term in Eq. 9 results the subsequent Eq. 10 is calculated as follows:

$$\Delta Y_{it} = \pi_i + \theta_i y_{i,t-1} + \gamma_i \overline{y}_{t-1} + \sum_{j=0}^{p} \Psi_{ij} \Delta \overline{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{i,t-j} + \mu_{it} \quad (10)$$

Where $\overline{y}_{t-j}$ and $\Delta y_{i,t-j}$ show lagged level averages and the first difference operator of each cross-section. The CIPS panel

3.3.3: Cointegration Tests

If unit roots are present, I will then test for cointegration. In their EKC study, Galeotti et al. (2006) state that "the existence of unit root in the log of per capita CO_2 and GDP series, in addition to the absence of unit root in the linear combination among these variables, are prerequisites in order for the notion of EKC to be statistically and economically meaningful," (Moosa, 2017). Cointegration amongst the integrated of order 1, or I(1), variables ensures that the linear combination of these of the variable is not I(1). Thus, in the presence of unit roots, cointegration is necessary to estimate long run elasticities between the variables of interest.

While several panel cointegration tests exist, some commonly used tests such as Pedroni (1999, 2004) and Kao (1999) are not robust to CSD (Lau et al., 2019). As a result, I will use the Westerlund (2005) panel cointegration test which is robust to CSD. The null hypothesis of the Westerlund cointegration test is that there is no cointegration. This is tested against the alternative hypothesis that the variables are cointegrated in all panels, and thus share a long-run relationship.

3.3.4: Slope Homogeneity Tests

Finally, I will test for slope homogeneity. While Fixed Effect, Random Effect, and pooled OLS estimators allow for heterogeneous intercepts across units of observations, these estimators assume that slope coefficients are homogeneous across individuals. This assumption may not be appropriate, and thus I will follow the method used by Atasoy (2017) to test for slope homogeneity. Atasoy uses the slope homogeneity test developed by Pesaran and Yamagata (2008).

The null hypothesis of the test is that $\beta = \beta_i$ for all i. This is tested against the alternative that $\beta_i \neq \beta_j$ "for a non-zero fraction of pairwise slopes for i ≠ j." (Pesaran and Yamagata, 2008). The test statistic that is derived is presented in Equation 17 below.

Equation 17: Slope Homogeneity Test Statistics

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right).$$

$$\tilde{S} = \sum_{i=1}^{N} \left(\hat{\boldsymbol{\beta}}_i - \tilde{\boldsymbol{\beta}}_{\mathrm{WFE}}\right)' \frac{\mathbf{X}_i' \mathbf{M}_\tau \mathbf{X}_i}{\tilde{\sigma}_i^2} \left(\hat{\boldsymbol{\beta}}_i - \tilde{\boldsymbol{\beta}}_{\mathrm{WFE}}\right),$$

As stated by Atasoy (2017), "S and Δ are the test statistics, X is the matrix containing explanatory variables in deviations from the mean, β_{WFE} is weighted fixed effects estimators (the weights are constructed using $\tilde{\sigma}_i^2$ and k denotes the number of regressors."

This test is appropriate when the cross-sectional time dimension and the cross-sectional dimension of the panel are large, which is the case in my full panel. If the resulting values of the tests statistics exceed their respective critical values, the null hypothesis of slope homogeneity is rejected and Fixed Effect, Random Effect, and Pooled OLS estimation is invalid due to the underlying assumption of slope homogeneity.

3.3.5: CCEMG and AMG Estimators

In the presence of slope heterogeneity and cross-sectional dependence, Pesaran's Common Correlated Effects Mean Group (CCEMG) estimator and Eberhart and Teal's Augmented Mean Group (AMG) estimator are robust to cross-sectional dependence and slope heterogeneity. As a result, both of these models are estimated.

CCEMG:

According to Eberhart (2012), the CCEMG estimator allows for the estimation of models which induce "cross-section dependence from unobserved shocks which affect all countries in the data set differently. This "issue is comparable to the transmission bias problem in micro production function models, whereby inputs […] are correlated with (from the econometrician's perspective) unobserved productivity shocks," (Eberhart, 2012). In order to correct for this, the CCEMG estimator uses a "simple but powerful augmentation of the group-specific regression equation: apart from the regressors […] and an intercept this equation now includes the cross-section/panel averages (for the entire panel […]) of the dependent and independent variables […] Together these can account for the unobserved common factor […] and given the group-specific estimation the heterogeneous impact […]is also given. The coefficients […] are again averaged across panel members, where different weights may be applied."

Further explained by Usaman and Hammar, the CCEMG estimator is calculated as follows.

$$\Delta Y_{it} = \alpha_{1i} + \beta_i Z_{it} + \Phi_i \overline{Y}_{it} + \eta_i \overline{Z}_{it} + \pi_i W_t + \mu_{it} \qquad (18)$$

Where, Y_{it} and Z_{it} show the observables, β_i represents each unit slope, α_i shows the heterogeneous constant factor of an individual unit, W_t shows the unobserved common factors, and μ_{it} indicates the random error term.

$$CCEMG = \frac{1}{N}\left(\sum_{i=1}^{n} \widehat{\eta}_i\right) \qquad (19)$$

Where, $\widehat{\eta}_i$ the term shows the individual cross-sectional coefficient estimated from Eq. 18.

AMG:

According to Eberhart (2012), the AMG estimator is calculated in three steps:

"(i) A pooled regression model augmented with year dummies is estimated by first difference OLS and the coefficients on the (differenced) year dummies are collected. They represent an estimated cross-group average of the evolution of unobservable TFP over time. This is referred to as 'common dynamic process'.
(ii) The group-specific regression model is then augmented with this estimated TFP process either (a) as an explicit variable, or (b) imposed on each group member with unit coefficient by subtracting the estimated process from the dependent variable […] the regression model includes an intercept, which captures time-invariant fixed effects (TFP level).
(iii) […] the group-specific model parameters are averaged across the panel."

Further explained by Usaman and Hammar (2020), the AMG estimator is calculated in two steps, and is estimated as follows.

AMG First-Stage:

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta Z_{it} + \gamma_i G_t + \sum_{t=2}^{T} \Psi_i \Delta F_t + \mu_{it} \qquad (16)$$

AMG Second-Stage:

$$\widehat{\beta}_{AMG} = N^{-1} \sum_{i=1}^{N} \widehat{\beta}_i \qquad (17)$$

Where Δ indicates the operator of first difference; Y_{it} and Z_{it} indicate the dependent and explanatory variables; α_i shows the intercept term of individual cross-section; β_i indicates the coefficients of the specific country; G_t denotes the unobserved (latent) common factor with heterogeneous dynamic; Ψ_i indicates the time dummy coefficient (dynamic common process); $\widehat{\beta}_{AMG}$ denotes that AMG estimator for mean group, and finally the term μ_{it} represents the stochastic error term.

3.3.6: Dumitrescu and Hurlinm Granger Non-Causality Test results

In line with the analysis performed by Usaman and Hammar, I will implement the Dumitrescu and Hurlinm (D-H) Granger Non-Causality Test in order to test the direction of flow of the variables in my model, and to comment on the policy implications of my results.

This test accounts for cross-sectional dependence and slope heterogeneity. It is represented in the following form:

$$Y_{it} = \beta_i + \sum_{k=1}^{q} \delta_i^k Y_{i,t-k} + \sum_{k=1}^{q} \eta_i^k X_{i,t-k} + \mu_{it} \quad (20)$$

Where Y and X are two variables that follow the stationarity property for particular cross-sections in T time periods. The parameters β_i and $\eta_i = \left(\eta_i^1, \eta_i^2, \eta_i^3, \ldots\ldots\ldots\ldots \eta_i^k\right)$ are assumed to be fixed in all time periods. The null (H_0) and alternative (H_1) hypothesis is represented as follows:

$$H_0 : \eta_i = 0 \qquad for \forall i \quad (21)$$

$$H_1 : \left\{ \begin{matrix} \eta_i = 0 & forall & i = 1,2,\ldots\ldots\ldots\ldots\ldots, N_1 \\ \eta_i \neq 0 & forall & i = N_1 + 1, 2, \ldots\ldots\ldots N \end{matrix} \right\} \quad (22)$$

Wald test statistics is required to test the H_0 and H_1 hypothesis, which is shown as follows:

$$W_{N.T}^{HNC} = N^{-1} \sum_{i=1}^{N} W_{i,T} \quad (23)$$

Where $W_{i,\ T}$ denotes the individual test of Wald statistics for the unit of the individual cross-section.

4. Pre-Testing Results

4.1: Cross-Sectional Dependence Test Results

First, I test for cross sectional dependence in my panels. The results are shown in Table 27, Table 28, and Table 29. The results suggest that the null hypothesis of cross-sectional independence is rejected in all three panels.

Table 27: Panel 1 (All Countries) Cross-Sectional Dependence Test

```
xtcd test on variables lnco2 lnGDP lnGDP2 lnGDP3 lnpop renew
Panelvar: ID_1
Timevar: year
```

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
lnco2	85.887	0.000	37.00	0.37	0.72
lnGDP	214.623	0.000	37.00	0.92	0.92
lnGDP2	214.875	0.000	37.00	0.92	0.92
lnGDP3	215.054	0.000	37.00	0.92	0.92
lnpop	176.918	0.000	37.00	0.75	0.95
renew	30.356	0.000	37.00	0.13	0.43

```
Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1)
       P-values close to zero indicate data are correlated across panel groups
```

Table 28: Panel 2 (Developing Countries) Cross-Sectional Dependence Test

```
xtcd test on variables lnco2 lnGDP lnGDP2 lnGDP3 lnpop renew
Panelvar: ID_1
Timevar: year
```

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
lnco2	123.785	0.000	37.00	0.89	0.89
lnGDP	124.748	0.000	37.00	0.89	0.90
lnGDP2	125.015	0.000	37.00	0.89	0.90
lnGDP3	125.218	0.000	37.00	0.90	0.90
lnpop	137.965	0.000	37.00	0.99	0.99
renew	2.845	0.004	37.00	0.02	0.39

```
Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1)
       P-values close to zero indicate data are correlated across panel groups
```

Table 29: Panel 3 (Developed Countries) Cross-Sectional Dependence Test

```
xtcd test on variables lnco2 lnGDP lnGDP2 lnGDP3 lnpop renew
Panelvar: ID_1
Timevar: year
```

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
lnco2	11.488	0.000	37.00	0.12	0.53
lnGDP	88.677	0.000	37.00	0.96	0.96
lnGDP2	88.73	0.000	37.00	0.96	0.96
lnGDP3	88.781	0.000	37.00	0.96	0.96
lnpop	41.645	0.000	37.00	0.45	0.90
renew	51.247	0.000	37.00	0.55	0.61

```
Notes: Under the null hypothesis of cross-section independence, CD ~ N(0,1)
       P-values close to zero indicate data are correlated across panel groups
```

4.2: Panel Unit Root Test Results

The results of the panel unit root tests for all three panels are presented in

Table 30, Table 31, and Table 32, below. The results for all variables in both levels and first difference are presented. The results for Panel 1, in

Table 30, suggest that for the level value of all variables, the null hypothesis of no panel unit root fails to be rejected at the 5% significance level in all cases, except for the population variable. When considering the first difference of the variables, however, all are stationary at the 1% significance level, with the exception of the population variable. This suggests that all variables except for the population variable are I(1).

The results for Panel 2, in Table 31, suggest that for the level value of all variables, the null of no panel unit roots fails to be rejected at the 5% significance level in all cases except for the emissions and population variables. When considering the first difference, all variables are stationary at the 1% significance level except for the population variable. This suggests that all variables in the panel of developing countries, besides the population variable, are I(1).

The results for Panel 3, in Table 32, suggest that for the level value of all variables, the null of no panel unit root fails to be rejected at the 5% significance level in all cases except for the variables representing population and the share of primary energy that comes from renewable energy. When considering the first difference, all variables are stationary at the 5% significance level ort better. This suggests that all variables in the panel of developed countries are I(1).

Table 30: Panel 1 (All Countries) Panel Unit Root Test

	Panel Unit Root Test (Variables at Levels)	Panel Unit Root Test (Variables at First Difference)
ln$CO2$	-2.215**	-5.391***
lnGDP	-1.888	-3.808***
lnGDP2	-1.775	-3.706***
lnGDP3	-1.695	-3.629***
lnPopulation	-2.409***	-1.909
RenewableEnergyShare	-1.800	-4.524***

*** p<0.01, ** p<0.05, * p<0.1

Table 31: Panel 2 (Developing Countries) Panel Unit Root Test

	Panel Unit Root Test (Variables at Levels)	Panel Unit Root Test (Variables at First Difference)
ln$CO2$	-2.428***	-5.629***
lnGDP	-2.094*	-4.197***
lnGDP2	-1.929	-4.117***
lnGDP3	-1.787	-4.047***
lnPopulation	-2.381***	-1.790
RenewableEnergyShare	-1.945	-4.426***

*** p<0.01, ** p<0.05, * p<0.1

Table 32: Panel 3 (Developed Countries) Panel Unit Root Test

	Panel Unit Root Test (Variables at Levels)	Panel Unit Root Test (Variables at First Difference)
ln$CO2$	-1.750	-5.310***
lnGDP	-1.623	-3.720***
lnGDP2	-1.533	-3.698***
lnGDP3	-1.450	-3.681***
lnPopulation	-2.245***	-2.199**
RenewableEnergyShare	-2.414***	-5.054***

*** p<0.01, ** p<0.05, * p<0.1

4.3: Panel Cointegration Test Results

Since most variables contain a unit root and are non-stationary, in order to determine if a long run trend between these variables exists, cointegration must be present. Thus, I now test for cointegration using the Westerlund panel cointegration test.

The results of the Westerlund panel cointegration test are presented in Table 33. In all three panels, the null hypothesis of no cointegration is rejected, thus the results suggest that cointegration is present.

Table 33: Panel Cointegration Test

Westerlund Test:	**Panel 1 (All Countries)**	**Panel 2 (Developing)**	**Panel 3 (Developed)**
Variance Ratio	-5.1817***	-3.9790***	-3.3197***

*** p<0.01, ** p<0.05, * p<0.1

4.4: Slope Homogeneity Test Results

Having established unit roots and cointegration, I can assume that a long run relationship between the variables exists. With this relationship established, I now test for slope heterogeneity in the panels. In the presence of slope heterogeneity, generalized least squares regressions (such as the Pooled OLS, Fixed Effect, and Random Effect regressions used by Grossman and Krueger, Seldon and Song, and many other EKC researchers) will yield inconsistent results.

The results of slope homogeneity tests are presented in Table 34 below. These results suggest that the null hypothesis of slope homogeneity is rejected in all three panels.

Table 34: Slope Homogeneity Test

	Panel 1 (All Countries)	**Panel 2 (Developing)**	**Panel 3 (Developed)**
Δ	50.083***	33.085***	35.140***
Δ_{adj}	55.620 ***	36.742***	39.025***

4.5: Implications of the Data Pre-Testing Results

The results of the pre-tests suggest that there is cross sectional dependence in the data. This may be due to "common shocks" which affect all countries in the panel. If these common shocks are correlated with the regressors, they will cause correlation between the error terms of different countries and thus cause inconsistent and biased results of generalized least squares regressions. We need to take this into account when estimating our model.

The pre-test results also suggest that most of the variables of interest are non-stationary, but are cointegrated. This is good in our case since it means that a long run relationship between the variables likely exists.

Finally, a slope homogeneity test suggests that the slope coefficients are heterogeneous. This again suggests that generalized least squares estimators are not appropriate to use given the nature of my data panel. Instead, it would be more appropriate to use the CCEMG and AMG estimators that were used by Usman and Hammar (2020) and Atasoy et al (2017), which are robust to cross sectional dependence and slope homogeneity.

The CCEMG and AMG estimators control for common shocks which may be causing cross sectional dependence and slope homogeneity by running an OLS regression for each country in the panel separately. Both estimators then use these country-specific OLS results to estimate the "common shocks," augment the OLS regression results to account for them, and then take the average the coefficients for each country specific OLS. More details of the estimation process are provided in the methodology section above.

5. Results

5.1: Determining EKC Functional Form and Estimating Results for Full Panel

All Tables in this *Results* section provide estimates using both Pesaran's Common Correlated Effects Mean Group (CCEMG) estimator and Eberhart and Teal's Augmented Mean Group (AMG) estimator. The results for the AMG estimator are presented in both of its forms: in the basic form (AMG) with the 'common dynamic process' estimated separately so that it represents the evolution of the variable, and the alternate version (AMG-1) where the "estimator is implemented by imposing the 'common dynamic process' with unit coefficient (by subtracting it from the dependent variable)," (Eberhart, 2012). Also note that robustness tests of the EKC models can be found in section 8.4 of the Appendix.

Full Panel

I start out with the results for the full panel, which includes both developed and developing countries. Then I analyze results for developed and developing countries separately to test my hypothesis that the pollution-income relationship differs between these groups.

First, using the full panel of countries, I determine which functional form of the EKC model is most appropriate. As was shown in the *Literature Review* section, the EKC is typically estimated by controlling for either a cubic or a quadratic relationship between income and emissions. I will determine which of these forms is most appropriate in the case of my data by estimating both.

Third Order GDP Effects

I first control for a cubic income variable. The results to this model are presented in Table 35 below. They suggest that the three income variables (lnGDP, lnGDP2, and lnGDP3) are not jointly significant when using the CCEMG and AMG estimators. While the AMG-1 estimator does find a jointly significant relationship, the lack of significance in the other two estimators suggests that third order form of the income variable is unnecessary.

Table 35: EKC Results Using Cubic Functional Form and Panel 1 (All Countries)

VARIABLES	**full panel** CCEMG	**full panel** AMG	**full panel** AMG-1
lnGDP	158.8	187.8	183.9
	(140.1)	(131.1)	(129.3)
lnGDP2	-14.08	-17.09	-16.77
	(12.70)	(11.82)	(11.64)
lnGDP3	0.416	0.522	0.514
	(0.385)	(0.356)	(0.350)
lnpop	0.216	0.952	0.903
	(0.997)	(0.661)	(0.638)
renew	-2.032	-1.104	-1.075
	(1.469)	(0.862)	(0.862)
t	0.000237	0.00830	0.00625
	(0.0177)	(0.0118)	(0.0116)
f		1.195***	
		(0.207)	
Constant	-617.2	-687.9	-671.9
	(518.7)	(484.9)	(478.5)
Observations	2,035	2,035	2,035
Number of ID_1	55	55	55
Test for joint significance lnGDP, lnGDP2, lnGDP3 (Prob>chi2)=	0.4213	0.0978	0.0042
Turning Point(s)	N/A	N/A	N/A

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Considering the lack of statistical significance in the results of the cubic model, I re-estimate the model controlling for a quadratic relationship between income and emissions. These results are presented in Table 38. They suggest that the income variables (lnGDP and lnGDP2) are jointly significant when using any of the three estimators.

Second Order GDP Effects

Given the significance of this this functional form, I will analyze these results further by determining if an EKC relationship is present. To determine if the EKC relationship is present in the quadratic model, there are three possibilities for the signs of the coefficients to consider. Letting β1 be the coefficient on lnGDP and β2 be the coefficient on lnGDP2, the following are possible:

i. $\beta_1 > 0 \; and \; \beta_2 > 0,$ reveals a U-shaped relationship
ii. $\beta_1 > 0 \; and \; \beta_2 < 0$ reveals an inverted U-shaped relationship, and thus an EKC relationship is present
iii. $\beta_1 < 0 \; and \; \beta_2 > 0$ reveals a U-shaped relationship

The signs of the coefficients in the results of the quadratic functional form are in line with case (ii), and thus support the presence of the EKC. However, it is important to also examine the magnitude of these coefficients when interpreting the results. The turning point level of per capita GDP at which emissions in country should be expected to decrease can be found by plugging the coefficient values into the following "turning point" equation, as presented in Equation 18 below, where $\beta 1$is the coefficient on lnGDP and $\beta 2$ is the coefficient on lnGDP2:

Equation 18: Turning Point Equation for Quadratic EKC Model

$$Turning\ Point = \exp\{\frac{-\beta_1}{2 * \beta_2}\}$$

Examining the results of all three estimators, the lowest turning point level of income is predicted is $93,195.36 which is predicted by the CCEMG estimator. While this is within the range of experience, given that the maximum level of per capita income in the panel is $124,024.55, the mean level of per capita income for countries in the full panel is $19,949.

Histograms of the level of income of developed and developing countries from 1980-2016 are provided in the dataset are provided in Figure 28 below. This shows that in nearly all countries in nearly every year, per capita GDP lies to left of $75,000. In fact, it can be seen that the majority of the observed levels of GDP per capita in both developed and developing countries over the past year has remained under $50,000. Very few observations surpass a level of $100,000. This high turning point, and the much higher turning points predicted by the AMG and AMG-1 estimators, suggest that most countries are still on the "upward sloping" portion of the EKC, and an increase in economic growth in the near future is associated with an increase in emissions.

Table 36: EKC Results Using Quadratic Functional Form and Panel 1 (All Countries)

VARIABLES	**full panel** CCEMG	**full panel** AMG	**full panel** AMG-1
lnGDP	3.055	1.001	1.452
	(1.858)	(1.197)	(1.144)
lnGDP2	-0.133	-0.0186	-0.0408
	(0.0959)	(0.0631)	(0.0596)
lnpop	0.932	1.370**	1.066*
	(0.793)	(0.642)	(0.580)
renew	-2.131	-0.967	-0.935
	(1.563)	(0.791)	(0.742)
t	0.00496	-0.00218	-0.000273
	(0.0182)	(0.0123)	(0.0101)
f		0.858***	
		(0.158)	
Constant	-9.676	-12.33	-8.995
	(20.73)	(10.04)	(8.639)
Observations	2,035	2,035	2,035
Number of ID_1	55	55	55
Test for joint significance lnGDP, lnGDP2 (Prob > chi2)	0.0154	0.0001	0.0000
Turning point	$93,195.36	$4.941e+11	$53,985,122

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

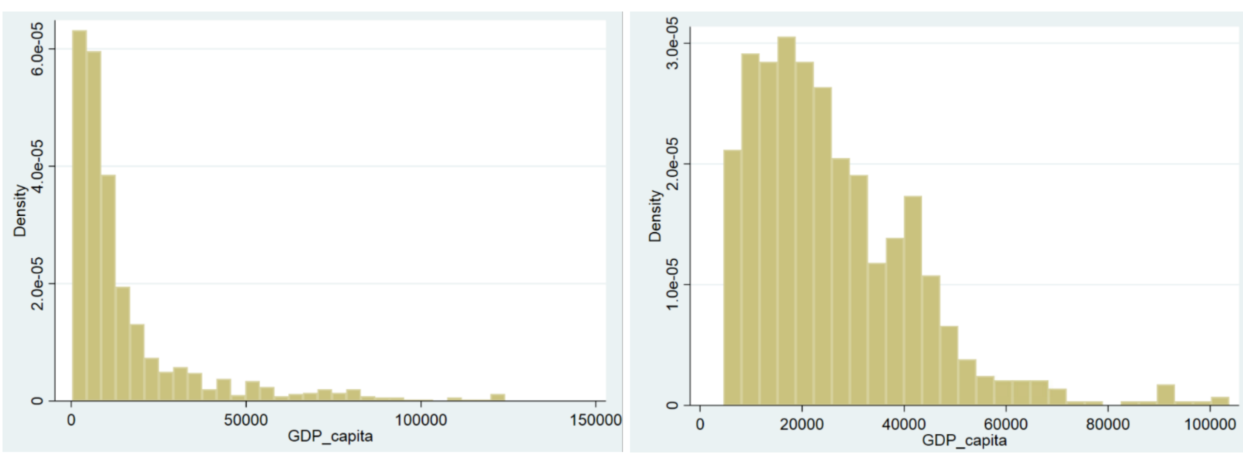

Figure 28: GDP per Capita in Developing (Left) and Developed Countries (Right)

The relationship predicted by these models is graphed in Figure 29 below, with the range of the graph being restricted to values of lnGPD that are present in the panel. Specifically, I plot the following equation, where β1 be the coefficient on lnGDP and β2 is the coefficient on lnGDP2:

Equation 19: Pollution-Income Relationship

$$y = \beta_1 x + \beta_2 [x]^2$$

I restrict the range of these plots to be between 5.737 and 11.728. This is because, as seen in the descriptive statistics in Table 25 of the *Data and Methodology* section 3.2, the minimum value for the natural log of GDP in any country and any year between 1980 and 2016 in my dataset is 5.737, and the maximum value is 11.728. Thus, any turning point out of this range is out of the range of experience for my data.

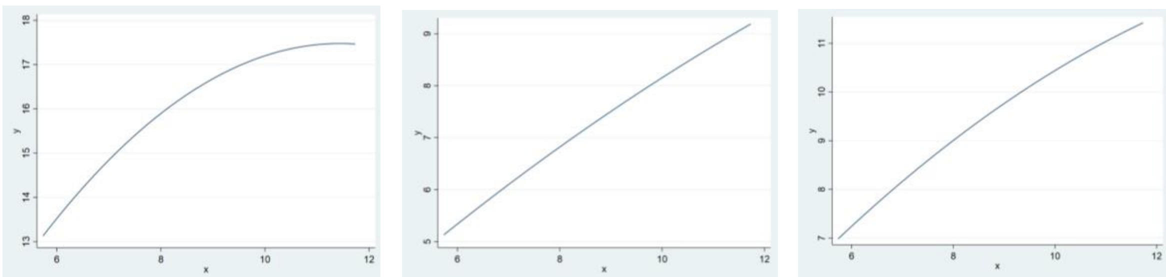

Figure 29: EKC Results for All Countries Using CCEMG Estimator (Left), AMG Estimator (Middle), and AMG-1 Estimator (Right)

5.2: Estimating the EKC for Developed and Developing Countries Separately

Since the quadratic functional form of the CCEMG and AMG estimators provided significant results when analyzing the full panel of countries, I will use this functional form to test my hypothesis that the income-pollution relationship differs between developed and developing countries. While the results using the full panel seem to suggest that the true result of an increase in per capita income is an increase in emissions for nearly all countries in the dataset, this may not necessarily hold when developed and developing countries are examined separately.

Combined Model with Different GDP Effects by Country Type

To begin testing this hypothesis, I will first interact the income variables (lnGDP and lnGDP2) with a binary variable which assigns a value of 1 to developed countries and a value of 0 to developing countries. I then interact both income variables with a second binary variable which assigns a 1 to developing countries and a value of 0 to developed countries. I rerun the regression from in Table 38, but replace the income variables with these new interaction terms. This allows the pollution-income relationship to differ between developed and developing countries.

The results are presented in Table 37. They suggest that the pollution-income relationship does differ between developed and developing countries. Both income variables for developing countries and developed countries are jointly significant, yet the sign of the coefficients on the first and second order terms for developed countries are opposite what they are for developing countries.

Examining the signs of the coefficients, the results for developed countries follow case (iii) above ($\beta_1 < 0$ $and\ \beta_2 > 0$). These signs suggest that the relationship between pollution and emissions is Ushaped. When plugging the coefficients into the turning point equation, a local minimum is found for all three estimators. This minimum is below the minimum level of per capita GDP in any country in our dataset, and is thus out of the range of experience. This essentially means that the minimum cannot be interpreted in a meaningful way and that all three estimators predict a monotonic increase in emissions from an increase in per capita income in developed countries.

The results for developing countries, on the other hand, are more in line with the results of using the full panel. The signs of the coefficients follow case (ii) above ($\beta_1 > 0$ and $\beta_2 < 0$), and again suggest the presence of an ECK relationship; however, the predicted turning points are high again. The turning points predicted by the AMG and AMG-1 estimators are well out of range of experience. The CCEMG estimator predicts a turning point of $33,106 per capita, but even this is high considering the data for developing countries. The mean level of GDP per capita in developing countries is $15,778.104, less than half of the predicted turning point value. This again suggests that, in most countries, any increase additional GDP per capita will likely result in increased levels of emissions.

Table 37: EKC Results Using Quadratic and Allowing Different Slope for developing Count

VARIABLE	CCEMG	AMG	AMG-1
developed_lnGDP	-0.171	-0.450	-0.305
	(1.610)	(0.457)	(0.418)
developed_lnGDP2	0.0251	0.0376	0.0292
	(0.0812)	(0.0240)	(0.0224)
developing_lnGDP	2.844***	1.147	1.421
	(0.981)	(1.117)	(1.048)
developing_lnGDP2	-0.137**	-0.0407	-0.0536
	(0.0548)	(0.0589)	(0.0543)
lnpop	1.584	1.333**	0.996*
	(1.078)	(0.644)	(0.580)
renew	-3.767	-0.986	-0.886
	(2.879)	(0.832)	(0.710)
t	0.0129	-0.00345	-0.00120
	(0.0213)	(0.0120)	(0.0100)
f		0.860***	
		(0.156)	
Constant	-3.190	-10.25	-6.057
	(25.08)	(10.16)	(8.681)
Observations	2,035	2,035	2,035
Number of ID_1	55	55	55
Test for joint significance of developed_lnGDP, developed_lnGDP2 (Prob>chi2)=	0.0021	0.0000	0.0000
Test for joint significance developing_lnGDP, developing_lnGDP2 (Prob>chi2)=	0.0009	0.0263	0.0032
Developed Turning Point	30.44 (min)	401.74 (min)	185.89 (min)
Developing Turning Point	$33,106.90	$1,294,634.30	$576,080.31

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Separate Models for Developed and Developing Countries

Now that there is reason to believe that the pollution-income relationship differs between developed and developing countries, I re-estimate the model using the panel for developed countries and the panel for developing countries separately.

Developed Countries

The results for developed countries are presented in Table 38 below. They reinforce what was found in the previous table. Specifically, the results suggest that the pollution-income relationship is U-shaped, with the income variables being jointly significant.

When the coefficients are plugged into the turning point equation, a local minimum is found. Again, in all cases this minimum is well below the mean level of per capita in income in developed countries. As a result, these minimums do not have a meaningful interpretation. Using the coefficients, I plot the shape of the pollution-income relationship predicted by all three model. These are shown Figure 30 below. These figures only cover the range of lnGDP included in the dataset, thus ignoring the parts of the relationship that are out of the range of experience.

Table 38: EKC Results Using Quadratic Function Form and Panel 3 (Developed Countries)

VARIABLES	**developed countries** CCEMG	**developed countries** AMG	**developed countries** AMG-1
lnGDP	-0.963	-0.676	0.135
	(2.889)	(1.185)	(1.013)
lnGDP2	0.0936	0.0656	0.0243
	(0.147)	(0.0616)	(0.0538)
lnpop	1.452	2.623***	1.729**
	(0.930)	(0.729)	(0.704)
renew	-0.0415**	-0.0277***	-0.0247***
	(0.0210)	(0.0104)	(0.00770)
t	0.0208**	-0.00372	0.000652
	(0.00874)	(0.00553)	(0.00583)
f		0.934***	
		(0.162)	
Constant	54.71	-23.36*	-12.84
	(36.85)	(12.95)	(11.21)
Observations	814	814	814
Number of ID_1	22	22	22
Test for joint significance lnGDP, lnGDP2 (Prob>chi2)=	0.0000	0.0000	0.0000
Turning point (local minimum)	171.41251	172.69639	.06251459

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

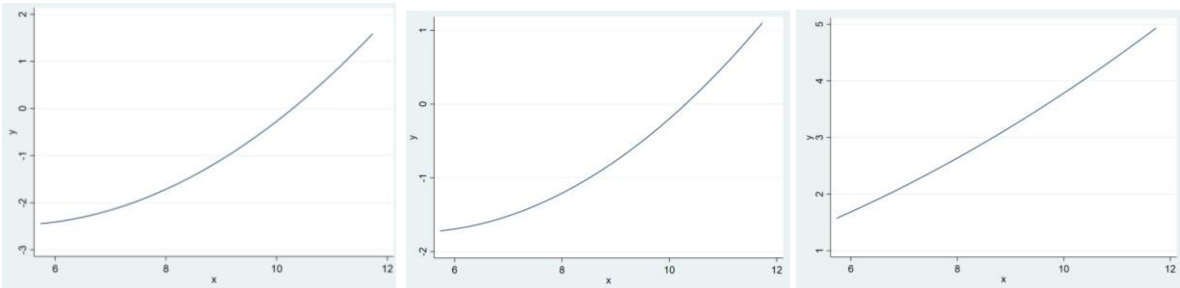

Figure 30: EKC Results for Developed Countries Using CCEMG Estimator (Left), AMG Estimator (Middle), and AMG-1 Estimator (Right)

Developing Countries

The results of the re-estimation of the model using only the panel of developing countries are presented in Table 39.

These results are in line with what was to be expected given the results of the model which used interaction terms to allow for different slopes of the income variables for developed and developing countries. Specifically, we again find that the signs of the coefficients are supportive of an EKC relationship; however, all three estimators predict turning points which are high and out the range of experience in the data.

The predicated pollution-income relationship is again plotted, in Figure 31, below using the estimated coefficients. Considering these plots are only over the range of lnGDP included in the dataset, we see that none of the turning points predicted by the estimators fall within this range. Again, this suggests that, for most countries, any additional growth in GDP now, and in the near future, will be associated with an increase in emissions in developing countries.

Table 39: EKC Results Using Quadratic Functional Form and Panel 2 (Developing Countries)

VARIABLES	**developing countries** CCEMG	**developing countries** AMG	**developing countries** AMG-1
lnGDP	2.186	1.778	2.352
	(1.899)	(1.527)	(1.651)
lnGDP2	-0.0825	-0.0670	-0.0949
	(0.105)	(0.0834)	(0.0874)
lnpop	0.0997	0.513	0.373
	(1.382)	(0.914)	(0.882)
renew	-3.005	-2.074	-1.271
	(2.165)	(1.732)	(0.986)
t	0.0123	-0.000574	-0.000170
	(0.0302)	(0.0200)	(0.0167)
f		0.873***	
		(0.212)	
Constant	6.154	-0.793	-0.712
	(24.12)	(13.42)	(12.91)
Observations	1,221	1,221	1,221
Number of ID_1	33	33	33
Test for joint significance lnGDP, lnGDP2, (Prob > chi2)	0.0249	0.0163	0.0034
Turning point (local maximum)	$571,609.79	$577,587.44	$241,905.27

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

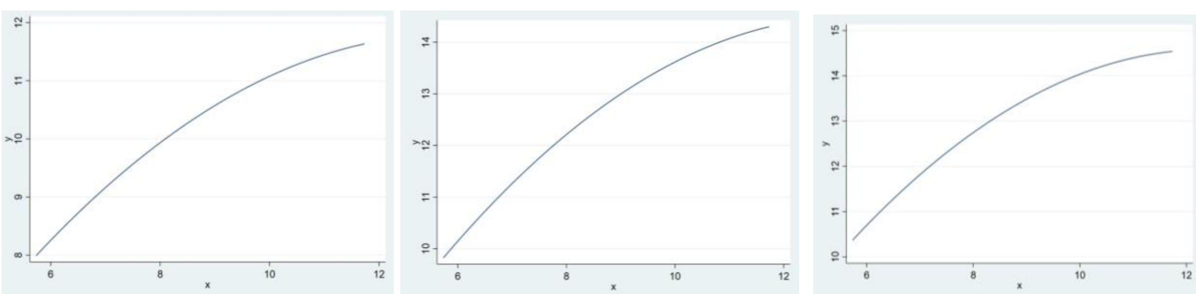

Figure 31: EKC Results for Developing Countries Using CCEMG Estimator (Left), AMG Estimator (Middle), and AMG-1 Estimator (Right)

5.3: Country Specific Results

Besides being able to control for differences in pollution-income relationship between groups of countries, such as developed versus developing, the CCEMG and AMG estimators allow for the estimation of country-specific effects.

The full results of these Country Specific Results can be found in the Appendix; however, the results are summarized in the following tables. Table 40 includes the countries and turning points for which all three estimators find an EKC relationship between emissions and per capita income. Of the 19 Countries in this table, 13 are developing. Table 41 includes a list the of countries for which all three estimators find a U-shaped relationship between emission and per capita income. Of the 14 countries in this table, 6 are developing and 8 are developed. Table 42 includes the countries for which there is discrepancy between the relationship found amongst the three estimators. Of the 22 countries in this table, 14 are developing and 8 are developed.

It is worth noting that, similar to the results of Atasoy et al. (2017), the country specific results are rather sensitive to changes between models, and thus should be interpreted with caution. When examining the findings of each estimator, the CCEMG estimator finds an EKC relationship in 26 of the 55 countries, the AMG estimator finds an EKC relationship in 29 of the 55 countries., and the AMG-1 estimator finds an EKC relationship in 31 of the 55 countries. For the regressions that do predict an EKC relationship, predicted turning points are indicated. It is worth noting, however, that several of the country specific regression results predict a turning point that is too large to even fit in the cell. In the case of several others, the turning point is far above the country's average level of per capita income. For regressions that find a U-shaped relationship, no turning points are included since plugging the regression coefficients into the turning point equation would find local minimums, which do not have a meaningful interpretation.

Table 40: Country Specific Results Finding EKC Relationship

	Country	**CCEMG Shape**	**AMG Shape**	**AMG-1 Shape**	**CCEMG Turning Point**	**AMG Turning Point**	**AMG-1 Turning Point**
Developing Countries (13)							
1	Bangladesh	EKC	EKC	EKC	$16.90	$206.88	$4,819.90
2	Colombia	EKC	EKC	EKC	$16,383.39	$14,906.65	$12,353.21
3	Ecuador	EKC	EKC	EKC	$4,907.31	$6,511.19	$8,445.66
4	Egypt, Arab Rep.	EKC	EKC	EKC	$7,835.02	$21,415.30	$35,702.13
5	Hong Kong, China	EKC	EKC	EKC	$15,152.16	$12,754.53	$14,382.10
6	Indonesia	EKC	EKC	EKC	$7,900.20	$10,635.27	$10,480.62
7	Iran, Islamic Rep.	EKC	EKC	EKC	$27,383.61	$31,333.59	$47,666.22
8	Israel	EKC	EKC	EKC	$34,379.70	$106,940.94	$107,087.31
9	Oman	EKC	EKC	EKC	$20,690.60	$0.00	$10,526.08
10	Peru	EKC	EKC	EKC	$4,659.95	$6,485.44	$7,309.92
11	Qatar	EKC	EKC	EKC	$59,264.71	$65,496.78	$72,073.30
12	Turkey	EKC	EKC	EKC	(too large)	$443,366.11	$1,964,155.90
13	Vietnam	EKC	EKC	EKC	$14,152.57	$9,509.98	$4,444.88
Developed Countries (6)							
14	Belgium	EKC	EKC	EKC	$18,159.85	$169,508.02	$15,631.45
15	Cyprus	EKC	EKC	EKC	$39,973.10	(too large)	$9,893,960.05
16	Finland	EKC	EKC	EKC	$17,556.81	$81,001.70	$28,761.57
17	Greece	EKC	EKC	EKC	$39,412.60	$39,688.78	$38,951.66
18	Iceland	EKC	EKC	EKC	$114,152.65	$232,768.25	$787,640.70
19	United Kingdom	EKC	EKC	EKC	(too large)	(too large)	(too large)

Table 41: Country Specific Results Finding U-Shaped Relationship

	Country	CCEMG	AMG	AMG-1	CCEMG	AMG	AMG-1
			Developing Countries (6)				
1	Algeria	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
2	Brazil	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
3	China	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
4	Korea, Rep.	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
5	Philippines	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
6	Trinidad and Tobago	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
			Developed Countries (8)				
7	Austria	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
8	Bulgaria	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
9	Japan	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
10	Norway	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
11	Poland	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
12	Romania	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
13	Spain	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A
14	United States	U-shaped	U-shaped	U-shaped	N/A	N/A	N/A

Table 42:Country Specific Results with Mixed Shape and Turning Point Estimates

	Country	CCEMG Shape	AMG Shape	AMG-1 Shape	CCEMG Turning Point	AMG Turning Point	AMG-1 Turning Point
			Developing Countries (14)				
1	Argentina	U-shaped	EKC	EKC	N/A	$28,581.90	(too large)
2	Chile	U-shaped	EKC	U-shaped	N/A	$3,160.86	N/A
3	India	EKC	U-shaped	U-shaped	$1,342.90	N/A	N/A
4	Malaysia	U-shaped	EKC	EKC	N/A	$107,982.48	$71,627,113. 48
5	Mexico	U-shaped	EKC	EKC	N/A	$43,108.71	(too large)
6	Morocco	U-shaped	EKC	EKC	N/A	$67,874.24	$59,026.37
7	Pakistan	U-shaped	U-shaped	EKC	$12.28	N/A	(too large)
8	Saudi Arabia	EKC	U-shaped	U-shaped	$57,072.35	N/A	N/A
9	Singapore	EKC	EKC	U-shaped	$45,205.26	$3,254.33	N/A
10	South Africa	U-shaped	EKC	EKC	N/A	$122,484.22	(too large)
11	Sri Lanka	EKC	EKC	U-shaped	$12,527.63	(too large)	N/A
12	Thailand	U-shaped	EKC	U-shaped	N/A	$54,337.53	N/A
13	United Arab Emirates	U-shaped	EKC	EKC	N/A	$64,609.50	$63,621.59
14	Venezuela, RB	EKC	U-shaped	U-shaped	$7.82	N/A	N/A
			Developed Countries (8)				
15	Canada	EKC	U-shaped	U-shaped	$24,210.14	N/A	N/A
16	Denmark	U-shaped	EKC	EKC	N/A	$381,367.60	(too large)
17	Hungary	U-shaped	U-shaped	EKC	N/A	N/A	(too large)
18	Ireland	U-shaped	EKC	EKC	N/A	(too large)	$541,398.12
19	Luxembourg	EKC	U-shaped	U-shaped	$50,072.29	N/A	N/A
20	Portugal	U-shaped	EKC	U-shaped	N/A	(too large)	N/A
21	Sweden	U-shaped	U-shaped	EKC	N/A	N/A	$24,910.51
22	Switzerland	U-shaped	EKC	EKC	N/A	$121,525.25	$179,226.94

5.4: Log-Linear STIRPAT Results

Considering that the results from the EKC regressions above largely suggest that, at least for the near future, there is a monotonically increasing relationship between emissions and per capita income, it makes sense to also run the linear STIRPAT model which does not control for an EKC relationship. The coefficients from this model can then be interpreted as elasticities.

Full Panel

The results of this STIRPAT model are presented in Table 43 below. These results suggest that, when using the CCEMG estimator, a 1% increase in population is associated 1.363% increase in per capita emissions and a 1% increase in per capita GDP is associated with a 0.619% increase in per capita emissions. The results of both AMG estimators are similar to the results of the CCEMG estimator. For the AMG estimator, a 1% increase in per capita GDP is associated with a 0.602% increase in emissions and a 1% increase in population is associated with a 1.323% increase in emissions. For the AMG-1 estimator, a 1% increase in per capita GDP is associated with a 0.631% increase in emissions and a 1% increase in population is associated with a 1.345% increase in emissions. The coefficients for the share of primary energy that comes from renewable sources and the time trend variable, which is supposed to pick up for the effects of technology advancement, do not yield significant results.

Table 43: STIRPAT Linear Model for Panel 1 (All Countries)

VARIABLES	**full panel** CCEMG	**full panel** AMG	**full panel** AMG-1
lnGDP	0.619***	0.602***	0.631***
	(0.0725)	(0.0601)	(0.0611)
lnpop	1.363***	1.323***	1.345***
	(0.437)	(0.305)	(0.288)
renew	-2.236	-0.709	-0.267
	(1.601)	(0.888)	(0.533)
t	0.00890	-0.00447	-0.00399
	(0.00936)	(0.00622)	(0.00560)
f		0.812***	
		(0.140)	
Constant	8.038	-8.052	-8.761*
	(14.29)	(5.202)	(4.939)
Observations	2,035	2,035	2,035
Number of ID_1		55	55

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.5: Log-Linear STIRPAT for Developed and Developing Countries Separately

Considering that the EKC results seemed to suggest that the pollution-income relationship does differ between developed and developed countries, it makes sense to test this hypothesis when using the linear STIRPAT model as well. I test this in the same way that I did for the quadratic EKC model, by first using the entire panel, but allowing different slope estimates for developed and developing countries.

These results are presented in Table 44. The suggest that, in all the case of all three estimators, emissions are more elastic to changes in per capita income in developing countries than developed countries. Additionally, the results suggest that elasticity of emissions to changes in income are similar in developed and developing countries. This is evident by the similarity in the magnitude of the developed_lnGDP and the developing_lnGDP coefficients.

We can examine this in more detail by analyzing the results of the regression using the separate panels for developed and developing countries. That analysis follows.

Table 44: STIRPAT Results Allowing Different Slope Coefficients for Developed and Developing

VARIABLES	CCEMG	AMG	AMG-1
developed_lnGDP	0.330***	0.213***	0.192***
	(0.0794)	(0.0437)	(0.0431)
developing_lnGDP	0.350***	0.358***	0.408***
	(0.0748)	(0.0662)	(0.0689)
lnpop	1.887***	1.208***	1.222***
	(0.626)	(0.308)	(0.294)
renew	-3.073	-0.713	-0.236
	(2.314)	(0.893)	(0.540)
t	0.00804	-0.00561	-0.00559
	(0.0109)	(0.00604)	(0.00561)
f		0.797***	
		(0.140)	
Constant	5.013	-5.761	-6.325
	(14.86)	(5.240)	(5.019)
Observations	2,035	2,035	2,035
Number of ID_1	55	55	55

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Developed Countries

The results of the linear STIRPAT model when considering only developed countries separately are presented in

Table 45. These suggest that, for the CCEMG model 1% increase in population is associated 1.495% increase in per capita emissions and a 1% increase in per capita GDP is associated with a 0.73% increase in per capita emissions. The coefficients for the share of primary energy that comes from renewable sources and the time trend variable do not yield significant results when using the CCEMG estimator. For the AMG estimator, a 1% increase in per capita GDP is associated with a 0.534% increase in emissions and a 1% increase in population is associated with a 2.282% increase in emissions. The coefficient of the share of primary energy that comes from renewable sources is significant in this case. It indicates that a

1% increase in the share of primary energy that is renewable is associated with a 0.0221% reduction in emissions. For the AMG-1 estimator, a 1% increase in per capita GDP is associated with a 0.488% increase in emissions and a 1% increase in population is associated with a 1.719% increase in emissions. A 1% increase in the share of primary energy that is renewable is associated with a 0.0220% reduction in emissions.

Table 45: STIRPAT Linear Model Using Panel 3 (Developed Countries)

VARIABLES	**developed countries** CCEMG	**developed countries** AMG	**developed countries** AMG-1
lnGDP	0.730***	0.534***	0.488***
	(0.126)	(0.0689)	(0.0738)
lnpop	1.495**	2.282***	1.719***
	(0.685)	(0.776)	(0.468)
renew	-0.0366	-0.0221*	-0.0220**
	(0.0229)	(0.0113)	(0.0102)
t	0.00694	0.00193	0.00371
	(0.0121)	(0.00545)	(0.00455)
f		1.106***	
		(0.155)	
Constant	14.44	-21.87*	-12.89
	(22.71)	(12.43)	(7.867)
Observations	814	814	814
Number of ID_1	22	22	22

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The signs of these elasticities are in line with intuition, especially after analyzing the results of the quadratic STIRPAT-EKC models; however, the magnitudes of the coefficients are interesting. It is worth noting that emissions are highly elastic to changes in population, with an elasticity greater than 1 in all cases. Additionally, emissions are elastic to changes in per capita GDP, with a positive elasticity; however, this elasticity is relatively inelastic compared to the elasticity of emissions to changes in population given that the magnitude of the lnGDP coefficient is smaller than that of the lnPOP coefficient in all cases. It is interesting since population has a seemingly more prominent effect on emissions.

Developing Countries

Finally, as presented in

Table 46, when using the linear STIRPAT model to examine developing countries alone, the results of the CCEMG model suggest that a 1% increase in population is associated 1.722% increase in per capita emissions and a 1% increase in per capita GDP is associated with a 0.445% increase in per capita emissions. The results using the AMG estimator suggest that a 1% increase in per capita GDP is associated with a 0.602% increase in emissions and a 1% increase in population is associated with a 0.810% increase in emissions. For the AMG-1 estimator, a 1% increase in per capita GDP is associated with a 0.641% increase in emissions and a 1% increase in population is associated with a 0.822% increase in emissions. Similar to the results in Table 45, when using the panel of all countries, the coefficients for the share of primary energy that comes from renewable sources and the time trend variable do not yield significant results.

Table 46: STIRPAT Linear Model Using Panel 2 (Developing Countries)

VARIABLES	**developing countries** CCEMG	**developing countries** AMG	**developing countries** AMG-1
lnGDP	0.445***	0.602***	0.641***
	(0.116)	(0.0893)	(0.0840)
lnpop	1.722***	0.810**	0.822**
	(0.606)	(0.359)	(0.386)
renew	-4.087	-1.715	-0.122
	(3.729)	(1.965)	(0.635)
t	0.00751	-0.0112	-0.0136
	(0.0136)	(0.00937)	(0.00882)
f		0.802***	
		(0.196)	
Constant	3.654	0.0152	-0.378
	(13.90)	(6.326)	(6.706)
Observations	1,221	1,221	1,221
Number of ID_1	33	33	33

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Similar to the results for developed countries, the signs of the elasticities estimated by the STIRPAT model for developing countries are in line with intuition. It is worth noting, however, that while emissions remain highly elastic to changes in population, with an elasticity greater than 1 in the case of the CCEMG estimator, and greater than 0.8 in the case of both AMG estimators, this elasticity is not as high as was predicted for developed countries. Additionally, emissions remain elastic to changes in per capita GDP, but not as elastic as they are to changes in population, as was the case for developed countries.

To further investigate the policy implications of the STIRPAT model results, we can follow a methodology similar to what was carried out by Usaman and Hammar (Usman and Hammar, 2020). Specifically, we can use Granger Causality tests. The results of these tests are presented in the following section.

5.6: ***Dumitrescu and Hurlinm Granger Non-Causality Test results***

Figure 32, Figure 33, and Figure 34 below summarize the results of the D-H Granger Non-Causality test. Full results can be found in the Appendix. The results suggest that when considering the entire panel, represented in Figure 32, every independent variable that is included in STIRPAT model granger-causes emissions. Additionally, there is a bidirectional causal relationship between from population and GDP and between emissions and the share of energy that is renewable. On the other hand, there is a unidirectional causality identified from population to the share of energy that is renewable, from GDP to the share of primary energy that is renewable, from population to emissions, and from GDP and emissions.

When considering the Panel 2 which includes only developing countries from the full panel, represented in Figure 33, all independent variables in the STIRPAT model except for GDP granger cause emissions. In fact, no causal relationship in either direction is identified between GDP and emissions. Additionally, there is no causal relationship identified between GDP and the share of primary energy that comes from renewable sources. On the other hand, there is a bidirectional causal relationship between population and GDP and between emissions and the share of energy that is renewable. A unidirectional causal relationship is identified from GDP to the share of primary energy that is renewable, from population to the share of primary energy that is renewable, and from population to emissions.

Finally, when considering Panel 3 which includes only the developed countries from the full panel, represented in Figure 34, all independent variables in the STIRPAT model granger-cause emissions. Additionally, there is a bidirectional causal relationship between population and GDP, emissions and the share of energy that is renewable, emissions and GDP, and between GDP and the share of primary energy that is renewable. On the other hand, there is a unidirectional causality identified from population to the share of energy that is renewable and from population to emissions.

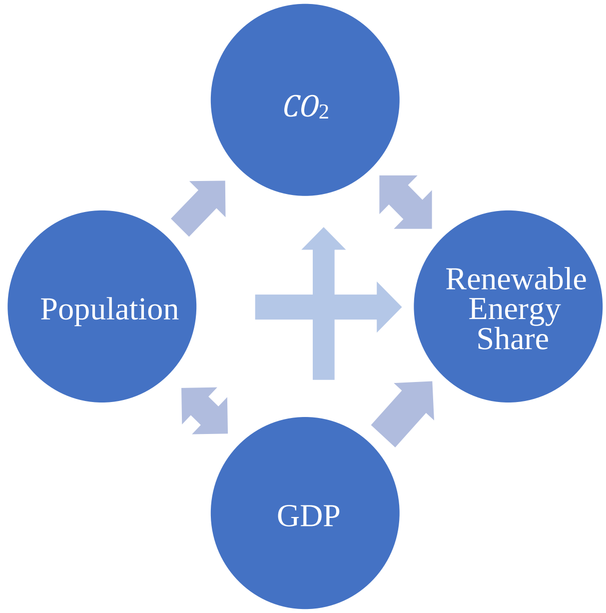

Figure 32: D-H results for Panel 1 (All Countries)

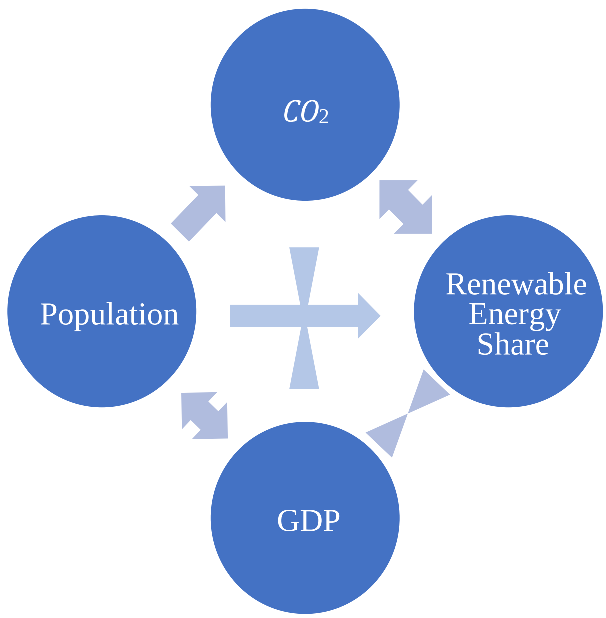

Figure 33: D-H Results for Panel 2 (Developing Countries)

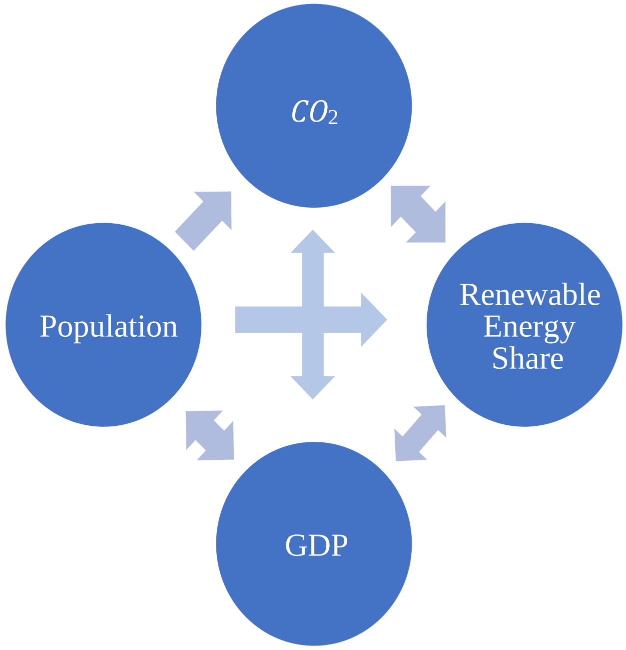

Figure 34: D-H Results for Panel 3 (Developed Countries)

6. Conclusion

This analysis is able to shed some light on the debate over the validity of the EKC when considering global pollutants, such as CO_2, by using more contemporary panel data analysis techniques than have been used previously and by testing the EKC Hypothesis for developed and developing countries separately. In addition, the linear STIRPAT and the Dumitrescu and Hurlinm Granger Non-Causality test results can be used to derive some policy implications for pathways toward sustainable development.

First of all, when analyzing the results of the EKC, I determine that the most appropriate functional form is the one which uses the quadratic form of the income variable. Further, the results suggest that a turning point level of per capita income at which point CO_2 can be expected to decrease may exist; however, the turning point level of per capita income predicted by all three estimators is high. In fact, the turning point is out of the range of experience for two of the three estimators. This indicates that, at least in the near future, any increase in per capita income will be associated with more emissions.

When considering estimating the EKC for developed and developing countries separately, it is evident that the pollution-income relationship does differ between these groups. The results suggest that an EKC may exist for developing countries but, again, the predicted turning points are very high. On the other hand, no predicted turning point exists for developed countries.

Considering that the many studies find an EKC relationship for SO_2 emissions in developed countries (as was seen in the studies of Grossman and Krueger, Seldon and Song, and to some extent, Stern and Perman), the lack of an EKC in my results for CO_2 emissions may suggest that developed countries gain different levels of utility from reductions in local pollutants and global pollutants. The negative externalities of local pollutants, like SO_2, emissions are more immediately and locally felt than they are for global pollutants, like CO_2 emissions. As mentioned, the negative effects of climate change place Least Developed Countries at a disproportionately high risk. This may indicate that developed countries are so reliant on their CO_2-intensive development strategies that they are willing to neglect the negative impacts they will have globally in the long run. On the other hand, Least Developed Countries who are feeling the effects of the CO_2 emissions the most will eventually gain more utility from reducing these emissions.

The country-specific EKC results should to be interpreted with caution considering their sensitivity to changes between estimators. It is worth noting, however, that the country-specific results suggest that, even though a common EKC may not be confirmed for developed or developing countries in general, specific countries many have an EKC relationship in CO_2 emissions. The reason some countries appear to have an EKC in CO_2 emissions and others do not is a topic for future research.

The results of the linear STIRPAT model suggest that in the case of both developed and developing countries, CO_2 emissions are more elastic to changes in population than to changes in per capita GDP. The linear STIRPAT model results also suggest that an increase in the percent of primary energy that comes from renewable sources only has statistically significant effect on CO_2 emissions in developed countries. Additionally, while CO_2 emissions in both developed are very elastic to changes in population, CO_2 emissions in developed countries tend to be more elastic the changes in population than in developing countries.

Finally, the most interesting finding of the D-H Granger Non-Causality test results is that per capita GDP does not Granger cause CO_2 emissions in developing countries. This suggests that, even though the EKC results predict an EKC in developing countries, despite the high turning point levels of per capita GDP, there actually might not be a causal link between the two variables.

To summarize, the results of my analysis suggest that it is hard to identify an EKC relationship in CO_2 emissions. While no definitive reason can be identified from my research, I hypothesize that it is due to the fact that CO_2 emissions do not impact high emitting countries the same way that SO_2 emissions and other local pollutants do. Thus, a country that gains more utility from decreasing SO_2 emissions might not necessarily gain more utility from reducing their CO_2 emissions.

Additionally, my analysis suggests that the relationship between income and pollution does seem to be fundamentally different in developed countries and developing countries. This is evident in the different shapes of the pollution-income relationship predicted by the EKC model. As a result, policy should be approached differently in both groups. Given the lack of evidence for a common EKC relationship in the developed countries, and in an effort to reduce global CO_2 emissions, it is more important than ever to implement policies aimed at increasing the perceived utility of carbon neutral alternatives. Also, the results of the linear STIRPAT model for developed countries suggest that an increase in the primary share of energy that comes from renewable sources decreases emissions, which only work to support this conclusion.

My results also suggest that development in Least Developed Countries should not rely on the "grow first, then clean up" approach (Beckerman, 1992). Given the high predicted EKC turning points and the lack of a causal link between per capita GDP and emissions, additional economic growth in developing countries, without counter balancing environmental policies to offset negative externalities, can be expected to only cause more emissions in the near future. Environmentally negligent development strategies will only lead to an increase in emissions and thus Development will not be Sustainable.

7. References

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8. Appendix
8.1: CCEMG Country Specific Results

The CCEMG estimator finds an EKC relationship in 26 of the 55 countries. These countries, and their turning points are indicated in the furthest column to the right. Additionally, the column indicates if the AMG-1 estimator finds a "U-shaped" pollution-income relationship for a country. The turning points displayed for these countries are local minimums.

Country		Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]	Shape and Turning Point
United Arab Emirates								
	lnGDP	-5.92813	28.52657	-0.21	0.835	-61.8392	49.98292	U-shaped
	lnGDP2	0.276783	1.291162	0.21	0.83	-2.25385	2.807414	$ 44,755.77
	lnpop	0.445944	0.505022	0.88	0.377	-0.54388	1.435768	
	renew	-2.65982	2.201936	-1.21	0.227	-6.97553	1.655897	
	t	0.066389	0.12281	0.54	0.589	-0.17431	0.307092	
	_cons	122.019	128.2905	0.95	0.342	-129.426	373.4638	
Argentina								
	lnGDP	-0.27144	3.575585	-0.08	0.939	-7.27946	6.736577	U-shaped
	lnGDP2	0.037616	0.194457	0.19	0.847	-0.34351	0.418745	$ 36.89
	lnpop	-1.50372	2.559537	-0.59	0.557	-6.52032	3.512883	
	renew	-0.01916	0.003618	-5.3	0	-0.02625	-0.01207	
	t	0.068914	0.043836	1.57	0.116	-0.017	0.154832	
	_cons	98.05859	47.55499	2.06	0.039	4.852516	191.2647	
Austria								
	lnGDP	0.015892	6.406737	0	0.998	-12.5411	12.57287	U-shaped
	lnGDP2	0.003565	0.323794	0.01	0.991	-0.63106	0.638189	$ 0.11
	lnpop	-0.25782	0.808975	-0.32	0.75	-1.84338	1.327745	
	renew	-0.01156	0.002654	-4.36	0	-0.01676	-0.00636	
	t	0.045663	0.02277	2.01	0.045	0.001036	0.090291	
	_cons	82.43968	34.24327	2.41	0.016	15.3241	149.5553	
Belgium								
	lnGDP	56.78325	14.7652	3.85	0	27.844	85.7225	EKC
	lnGDP2	-2.89505	0.776489	-3.73	0	-4.41694	-1.37316	$ 18,159.85
	lnpop	6.406315	3.200632	2	0.045	0.133192	12.67944	
	renew	-0.07421	0.039123	-1.9	0.058	-0.15089	0.002474	
	t	0.001088	0.031088	0.03	0.972	-0.05984	0.062019	
	_cons	-218.754	66.56345	-3.29	0.001	-349.216	-88.2921	
Bangladesh								
	lnGDP	2.177869	2.458223	0.89	0.376	-2.64016	6.995897	EKC
	lnGDP2	-0.38511	0.195611	-1.97	0.049	-0.7685	-0.00172	$ 16.90
	lnpop	-13.384	3.517749	-3.8	0	-20.2787	-6.48935	
	renew	-0.02625	0.011553	-2.27	0.023	-0.04889	-0.00361	
	t	0.474582	0.109063	4.35	0	0.260821	0.688342	
	_cons	277.2773	73.28299	3.78	0	133.6453	420.9093	
Bulgaria								
	lnGDP	-0.57494	8.647329	-0.07	0.947	-17.5234	16.37351	U-shaped
	lnGDP2	0.062265	0.475592	0.13	0.896	-0.86988	0.994408	$ 101.18
	lnpop	4.181445	2.127352	1.97	0.049	0.011911	8.350979	
	renew	-0.01954	0.016773	-1.17	0.244	-0.05242	0.013331	
	t	0.087965	0.076898	1.14	0.253	-0.06275	0.238683	
	_cons	104.9088	125.0914	0.84	0.402	-140.266	350.0835	
Brazil								
	lnGDP	-6.35433	4.766048	-1.33	0.182	-15.6956	2.98695	U-shaped
	lnGDP2	0.351706	0.263719	1.33	0.182	-0.16517	0.868585	$ 8,379.82
	lnpop	6.764949	3.132779	2.16	0.031	0.624816	12.90508	
	renew	-0.02077	0.006291	-3.3	0.001	-0.0331	-0.00844	
	t	-0.13746	0.062039	-2.22	0.027	-0.25905	-0.01587	
	_cons	-174.426	67.25604	-2.59	0.01	-306.246	-42.6069	
Canada								
	lnGDP	15.74815	5.560369	2.83	0.005	4.850033	26.64628	EKC
	lnGDP2	-0.78003	0.284936	-2.74	0.006	-1.3385	-0.22157	$ 24,210.14
	lnpop	-0.61749	1.895518	-0.33	0.745	-4.33264	3.097653	
	renew	-0.01058	0.006266	-1.69	0.091	-0.02286	0.001706	
	t	0.060999	0.028767	2.12	0.034	0.004617	0.117382	
	_cons	67.86388	32.1224	2.11	0.035	4.905138	130.8226	

<table>
<tr><td>Switzerland</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-9.8696</td><td>18.91365</td><td>-0.52</td><td>0.602</td><td>-46.9397</td><td>27.20047</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>0.507559</td><td>0.932634</td><td>0.54</td><td>0.586</td><td>-1.32037</td><td>2.335488</td><td>$</td><td>16,690.91</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>-0.9608</td><td>1.482525</td><td>-0.65</td><td>0.517</td><td>-3.8665</td><td>1.944895</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.00545</td><td>0.003951</td><td>-1.38</td><td>0.168</td><td>-0.01319</td><td>0.002293</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>0.02073</td><td>0.056389</td><td>0.37</td><td>0.713</td><td>-0.08979</td><td>0.13125</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>64.04878</td><td>111.121</td><td>0.58</td><td>0.564</td><td>-153.744</td><td>281.8419</td><td></td><td></td></tr>
<tr><td>Chile</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-4.84007</td><td>1.984094</td><td>-2.44</td><td>0.015</td><td>-8.72882</td><td>-0.95132</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>0.296801</td><td>0.113116</td><td>2.62</td><td>0.009</td><td>0.075097</td><td>0.518504</td><td>$</td><td>3,476.37</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>9.205328</td><td>2.742429</td><td>3.36</td><td>0.001</td><td>3.830266</td><td>14.58039</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.02327</td><td>0.002828</td><td>-8.23</td><td>0</td><td>-0.02881</td><td>-0.01773</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.10956</td><td>0.053087</td><td>-2.06</td><td>0.039</td><td>-0.21361</td><td>-0.00551</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-106.021</td><td>58.3901</td><td>-1.82</td><td>0.069</td><td>-220.464</td><td>8.421346</td><td></td><td></td></tr>
<tr><td>China</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-3.89681</td><td>1.30151</td><td>-2.99</td><td>0.003</td><td>-6.44772</td><td>-1.34589</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>0.269332</td><td>0.090451</td><td>2.98</td><td>0.003</td><td>0.092051</td><td>0.446612</td><td>$</td><td>1,386.06</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>-2.86962</td><td>3.571407</td><td>-0.8</td><td>0.422</td><td>-9.86945</td><td>4.13021</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.06335</td><td>0.019162</td><td>-3.31</td><td>0.001</td><td>-0.10091</td><td>-0.02579</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.00533</td><td>0.042602</td><td>-0.13</td><td>0.9</td><td>-0.08883</td><td>0.078171</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-2.04017</td><td>46.46515</td><td>-0.04</td><td>0.965</td><td>-93.1102</td><td>89.02985</td><td></td><td></td></tr>
<tr><td>Colombia</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>13.59609</td><td>8.118712</td><td>1.67</td><td>0.094</td><td>-2.3163</td><td>29.50847</td><td></td><td>EKC</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>-0.70054</td><td>0.455873</td><td>-1.54</td><td>0.124</td><td>-1.59403</td><td>0.192957</td><td>$</td><td>16,383.39</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>-1.4357</td><td>3.160584</td><td>-0.45</td><td>0.65</td><td>-7.63033</td><td>4.758932</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.01066</td><td>0.003552</td><td>-3</td><td>0.003</td><td>-0.01762</td><td>-0.0037</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.00196</td><td>0.06826</td><td>-0.03</td><td>0.977</td><td>-0.13575</td><td>0.131822</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-27.8191</td><td>55.65078</td><td>-0.5</td><td>0.617</td><td>-136.893</td><td>81.25441</td><td></td><td></td></tr>
<tr><td>Cyprus</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>9.95163</td><td>6.549356</td><td>1.52</td><td>0.129</td><td>-2.88487</td><td>22.78813</td><td></td><td>EKC</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>-0.4696</td><td>0.350623</td><td>-1.34</td><td>0.18</td><td>-1.1568</td><td>0.217613</td><td>$</td><td>39,973.10</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>1.832605</td><td>1.267242</td><td>1.45</td><td>0.148</td><td>-0.65114</td><td>4.316353</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.04877</td><td>0.060516</td><td>-0.81</td><td>0.42</td><td>-0.16738</td><td>0.069838</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.07673</td><td>0.05465</td><td>-1.4</td><td>0.16</td><td>-0.18385</td><td>0.030377</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-73.1261</td><td>63.75367</td><td>-1.15</td><td>0.251</td><td>-198.081</td><td>51.82881</td><td></td><td></td></tr>
<tr><td>Denmark</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-20.4371</td><td>25.96241</td><td>-0.79</td><td>0.431</td><td>-71.3225</td><td>30.44832</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>1.056099</td><td>1.303202</td><td>0.81</td><td>0.418</td><td>-1.49813</td><td>3.610329</td><td>$</td><td>15,926.44</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>4.033118</td><td>5.82784</td><td>0.69</td><td>0.489</td><td>-7.38924</td><td>15.45547</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.02599</td><td>0.017874</td><td>-1.45</td><td>0.146</td><td>-0.06102</td><td>0.009044</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.04937</td><td>0.09487</td><td>-0.52</td><td>0.603</td><td>-0.23531</td><td>0.136572</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-32.1654</td><td>145.2875</td><td>-0.22</td><td>0.825</td><td>-316.924</td><td>252.5927</td><td></td><td></td></tr>
<tr><td>Algeria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-3.31957</td><td>15.87587</td><td>-0.21</td><td>0.834</td><td>-34.4357</td><td>27.79657</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>0.291319</td><td>0.881004</td><td>0.33</td><td>0.741</td><td>-1.43542</td><td>2.018055</td><td>$</td><td>298.11</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>10.35157</td><td>3.257457</td><td>3.18</td><td>0.001</td><td>3.967071</td><td>16.73607</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.01688</td><td>0.167608</td><td>-0.1</td><td>0.92</td><td>-0.34539</td><td>0.311625</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>-0.29572</td><td>0.116832</td><td>-2.53</td><td>0.011</td><td>-0.5247</td><td>-0.06673</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>-223.959</td><td>135.522</td><td>-1.65</td><td>0.098</td><td>-489.577</td><td>41.65933</td><td></td><td></td></tr>
<tr><td>Ecuador</td><td>Group</td><td>1
6</td><td>Coef.</td><td>Std. Err.</td><td>z</td><td>P>|z|</td><td>[95% Conf.</td><td>Interval]</td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>10.83553</td><td>18.22929</td><td>0.59</td><td>0.552</td><td>-24.8932</td><td>46.56427</td><td></td><td>EKC
$</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>-0.6375</td><td>1.034352</td><td>-0.62</td><td>0.538</td><td>-2.66479</td><td>1.389794</td><td></td><td>4,907.31</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>-16.0954</td><td>8.060037</td><td>-2</td><td>0.046</td><td>-31.8928</td><td>-0.298</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>-0.0155</td><td>0.012436</td><td>-1.25</td><td>0.213</td><td>-0.03987</td><td>0.008873</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>0.402157</td><td>0.19203</td><td>2.09</td><td>0.036</td><td>0.025784</td><td>0.778529</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>267.9221</td><td>150.0503</td><td>1.79</td><td>0.074</td><td>-26.171</td><td>562.0152</td><td></td><td></td></tr>
<tr><td>Egypt, Arab Rep.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>12.08581</td><td>7.750423</td><td>1.56</td><td>0.119</td><td>-3.10474</td><td>27.27636</td><td></td><td>EKC</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>-0.67395</td><td>0.468271</td><td>-1.44</td><td>0.15</td><td>-1.59175</td><td>0.243841</td><td>$</td><td>7,835.02</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>-5.40325</td><td>2.851655</td><td>-1.89</td><td>0.058</td><td>-10.9924</td><td>0.185893</td><td></td><td></td></tr>
<tr><td></td><td>renew</td><td>|</td><td>0.004383</td><td>0.020228</td><td>0.22</td><td>0.828</td><td>-0.03526</td><td>0.044029</td><td></td><td></td></tr>
<tr><td></td><td>t</td><td>|</td><td>0.078132</td><td>0.065807</td><td>1.19</td><td>0.235</td><td>-0.05085</td><td>0.20711</td><td></td><td></td></tr>
<tr><td></td><td>_cons</td><td>|</td><td>31.22231</td><td>74.62171</td><td>0.42</td><td>0.676</td><td>-115.034</td><td>177.4782</td><td></td><td></td></tr>
<tr><td>Spain</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>lnGDP</td><td>|</td><td>-2.30995</td><td>4.373644</td><td>-0.53</td><td>0.597</td><td>-10.8821</td><td>6.262235</td><td></td><td>U-shaped</td></tr>
<tr><td></td><td>lnGDP2</td><td>|</td><td>0.159341</td><td>0.223936</td><td>0.71</td><td>0.477</td><td>-0.27957</td><td>0.598248</td><td>$</td><td>1,405.92</td></tr>
<tr><td></td><td>lnpop</td><td>|</td><td>0.408317</td><td>0.580391</td><td>0.7</td><td>0.482</td><td>-0.72923</td><td>1.545863</td><td></td><td></td></tr>
</table>

	renew	-0.01198	0.003796	-3.16	0.002	-0.01942	-0.00454		
	t	0.068175	0.029013	2.35	0.019	0.01131	0.12504		
	_cons	142.3545	24.39147	5.84	0	94.54808	190.1609		
Finland									
	lnGDP	14.94505	13.27097	1.13	0.26	-11.0656	40.95568		EKC
	lnGDP2	-0.76459	0.673657	-1.13	0.256	-2.08494	0.55575	$	17,556.81
	lnpop	-4.91141	11.80104	-0.42	0.677	-28.041	18.21821		
	renew	-0.02966	0.008627	-3.44	0.001	-0.04657	-0.01276		
	t	-0.05063	0.068835	-0.74	0.462	-0.18554	0.084284		
	_cons	-3.86008	157.3397	-0.02	0.98	-312.24	304.52		
United Kingdom									
	lnGDP	1.182158	7.426916	0.16	0.874	-13.3743	15.73865		EKC
	lnGDP2	-0.01838	0.38417	-0.05	0.962	-0.77134	0.734577	$	92,117,912,574,294.30
	lnpop	3.916349	2.238031	1.75	0.08	-0.47011	8.30281		
	renew	-0.03149	0.008536	-3.69	0	-0.04822	-0.01476		
	t	-0.02571	0.030265	-0.85	0.396	-0.08503	0.033606		
	_cons	-31.4982	35.98452	-0.88	0.381	-102.027	39.03015		
Greece									
	lnGDP	10.2557	3.059385	3.35	0.001	4.259417	16.25198		EKC
	lnGDP2	-0.48459	0.149937	-3.23	0.001	-0.77846	-0.19072	$	39,412.60
	lnpop	-0.42962	0.789175	-0.54	0.586	-1.97637	1.117139		
	renew	-0.02283	0.005056	-4.52	0	-0.03274	-0.01292		
	t	-0.00962	0.024081	-0.4	0.689	-0.05682	0.037574		
	_cons	-29.0627	30.2424	-0.96	0.337	-88.3368	30.21128		
Hong Kong SAR, China									
	lnGDP	17.94995	5.135078	3.5	0	7.885387	28.01452		EKC
	lnGDP2	-0.93238	0.261992	-3.56	0	-1.44587	-0.41888	$	15,152.16
	lnpop	-1.60145	1.103693	-1.45	0.147	-3.76464	0.561754		
	renew	0.11633	1.075387	0.11	0.914	-1.99139	2.224051		
	t	-0.01993	0.066764	-0.3	0.765	-0.15079	0.110921		
	_cons	-40.8895	72.04644	-0.57	0.57	-182.098	100.319		
Hungary									
	lnGDP	-5.92953	3.780254	-1.57	0.117	-13.3387	1.479631		U-shaped
	lnGDP2	0.344099	0.200585	1.72	0.086	-0.04904	0.737238	$	5,519.46
	lnpop	8.063976	2.08217	3.87	0	3.982998	12.14495		
	renew	-0.02425	0.025235	-0.96	0.337	-0.07371	0.025211		
	t	0.003583	0.032801	0.11	0.913	-0.06071	0.067873		
	_cons	-86.0145	49.14153	-1.75	0.08	-182.33	10.30111		
Indonesia									
	lnGDP	11.73959	6.605587	1.78	0.076	-1.20713	24.6863		EKC
	lnGDP2	-0.65404	0.392906	-1.66	0.096	-1.42412	0.116038	$	7,900.20
	lnpop	-14.0205	10.60385	-1.32	0.186	-34.8037	6.762661		
	renew	-0.04316	0.045251	-0.95	0.34	-0.13185	0.045527		
	t	0.190899	0.172416	1.11	0.268	-0.14703	0.528828		
	_cons	153.5455	184.212	0.83	0.405	-207.503	514.5943		
India									
	lnGDP	2.994389	3.640012	0.82	0.411	-4.1399	10.12868		EKC
	lnGDP2	-0.20787	0.24375	-0.85	0.394	-0.68561	0.269873	$	1,342.90
	lnpop	-5.74043	6.359223	-0.9	0.367	-18.2043	6.723423		
	renew	0.012054	0.009589	1.26	0.209	-0.00674	0.030849		
	t	0.040719	0.097227	0.42	0.675	-0.14984	0.231279		
	_cons	-53.9424	91.51979	-0.59	0.556	-233.318	125.4331		
Ireland									
	lnGDP	-1.24041	1.65936	-0.75	0.455	-4.49269	2.011882		U-shaped
	lnGDP2	0.089073	0.079317	1.12	0.261	-0.06639	0.244532	$	1,056.64
	lnpop	0.732322	0.470634	1.56	0.12	-0.1901	1.654747		
	renew	-0.04348	0.012097	-3.59	0	-0.06719	-0.01977		
	t	-0.07296	0.034903	-2.09	0.037	-0.14137	-0.00455		
	_cons	-91.6997	40.94092	-2.24	0.025	-171.942	-11.4569		
Iran, Islamic Rep.									
	lnGDP	2.55682	2.763993	0.93	0.355	-2.86051	7.974146		EKC
	lnGDP2	-0.12512	0.153644	-0.81	0.415	-0.42625	0.17602	$	27,383.61
	lnpop	0.882876	0.820967	1.08	0.282	-0.72619	2.491941		
	renew	-0.04643	0.020093	-2.31	0.021	-0.08581	-0.00705		
	t	0.055054	0.041851	1.32	0.188	-0.02697	0.137081		
	_cons	55.40826	53.61746	1.03	0.301	-49.68	160.4965		
Iceland									

	lnGDP	3.446487	6.237919	0.55	0.581	-8.77961	15.67258		EKC
	lnGDP2	-0.14798	0.312646	-0.47	0.636	-0.76075	0.464798	$	114,152.65
	lnpop	1.943294	1.651459	1.18	0.239	-1.29351	5.180094		
	renew	-0.01461	0.002844	-5.14	0	-0.02018	-0.00903		
	t	0.011785	0.031686	0.37	0.71	-0.05032	0.073888		
	_cons	1.485436	40.02199	0.04	0.97	-76.9562	79.9271		
Israel									
	lnGDP	12.39773	8.247784	1.5	0.133	-3.76763	28.56309		EKC
	lnGDP2	-0.59346	0.423237	-1.4	0.161	-1.42299	0.236065	$	34,379.70
	lnpop	2.639756	0.541541	4.87	0	1.578355	3.701157		
	renew	0.023149	0.069997	0.33	0.741	-0.11404	0.160342		
	t	-0.15833	0.044908	-3.53	0	-0.24635	-0.07032		
	_cons	-212.18	56.55241	-3.75	0	-323.021	-101.339		
Japan									
	lnGDP	-11.9307	6.432852	-1.85	0.064	-24.5388	0.67748		U-shaped
	lnGDP2	0.653438	0.321746	2.03	0.042	0.022827	1.284049	$	9,220.23
	lnpop	1.469367	4.137884	0.36	0.723	-6.64074	9.57947		
	renew	-0.0328	0.011526	-2.85	0.004	-0.05539	-0.01021		
	t	0.040385	0.023091	1.75	0.08	-0.00487	0.085643		
	_cons	85.47442	67.17299	1.27	0.203	-46.1822	217.1311		
Korea, Rep.									
	lnGDP	-4.16763	1.36002	-3.06	0.002	-6.83322	-1.50204		U-shaped
	lnGDP2	0.303988	0.079423	3.83	0	0.148322	0.459654	$	948.54
	lnpop	9.286033	2.17952	4.26	0	5.014252	13.55781		
	renew	0.0238	0.036625	0.65	0.516	-0.04798	0.095584		
	t	-0.13056	0.039424	-3.31	0.001	-0.20782	-0.05329		
	_cons	-163.119	50.12463	-3.25	0.001	-261.362	-64.8766		
Sri Lanka									
	lnGDP	9.377413	3.160614	2.97	0.003	3.182724	15.5721		EKC
	lnGDP2	-0.49691	0.189561	-2.62	0.009	-0.86844	-0.12538	$	12,527.63
	lnpop	5.544518	2.910597	1.9	0.057	-0.16015	11.24918		
	renew	-0.01786	0.003352	-5.33	0	-0.02443	-0.0113		
	t	0.120284	0.053155	2.26	0.024	0.016101	0.224467		
	_cons	118.7319	61.31897	1.94	0.053	-1.45111	238.9148		
Luxembourg									
	lnGDP	11.1135	5.676326	1.96	0.05	-0.0119	22.23889		EKC
	lnGDP2	-0.5135	0.272445	-1.88	0.059	-1.04749	0.020477	$	50,072.29
	lnpop	-5.77018	1.5549	-3.71	0	-8.81773	-2.72263		
	renew	-0.40892	0.057219	-7.15	0	-0.52107	-0.29677		
	t	0.127034	0.054817	2.32	0.02	0.019595	0.234473		
	_cons	300.34	61.6179	4.87	0	179.5711	421.1088		
Morocco									
	lnGDP	-2.48342	2.967201	-0.84	0.403	-8.29903	3.332184		U-shaped
	lnGDP2	0.169358	0.187911	0.9	0.367	-0.19894	0.537656	$	1,528.23
	lnpop	1.025157	1.780495	0.58	0.565	-2.46455	4.514864		
	renew	-0.00824	0.005035	-1.64	0.102	-0.01811	0.001627		
	t	-0.04742	0.029569	-1.6	0.109	-0.10538	0.010532		
	_cons	-42.179	29.1182	-1.45	0.147	-99.2496	14.89164		
Mexico		Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]		
	lnGDP	-0.69136	7.857247	-0.09	0.93	-16.0913	14.70856		U-shaped
	lnGDP2	0.047033	0.435895	0.11	0.914	-0.80731	0.901371	$	1,555.94
	lnpop	-0.59842	4.264598	-0.14	0.888	-8.95688	7.760038		
	renew	-0.00996	0.010985	-0.91	0.365	-0.03149	0.011573		
	t	-0.00068	0.056382	-0.01	0.99	-0.11118	0.109829		
	_cons	26.50968	53.67691	0.49	0.621	-78.6951	131.7145		
Malaysia									
	lnGDP	-0.51739	6.209592	-0.08	0.934	-12.688	11.65318		U-shaped
	lnGDP2	0.090301	0.337395	0.27	0.789	-0.57098	0.751582	$	17.55
	lnpop	-1.09288	2.998956	-0.36	0.716	-6.97073	4.784963		
	renew	-0.04091	0.015824	-2.59	0.01	-0.07192	-0.00989		
	t	0.029639	0.073982	0.4	0.689	-0.11536	0.174641		
	_cons	5.515645	53.3213	0.1	0.918	-98.9922	110.0235		
Norway									
	lnGDP	-25.2622	30.71663	-0.82	0.411	-85.4657	34.9413		U-shaped
	lnGDP2	1.24899	1.481072	0.84	0.399	-1.65386	4.151839	$	24,662.80
	lnpop	-0.46585	10.42127	-0.04	0.964	-20.8912	19.95946		
	renew	-0.01269	0.013001	-0.98	0.329	-0.03818	0.012788		
	t	-0.04557	0.119746	-0.38	0.704	-0.28026	0.189131		
	_cons	137.2815	193.8073	0.71	0.479	-242.574	517.1368		
Oman									

	lnGDP	23.15472	9.072116	2.55	0.011	5.373703	40.93574		EKC
	lnGDP2	-1.16503	0.453807	-2.57	0.01	-2.05447	-0.27558	$	20,690.60
	lnpop	-1.13674	0.688529	-1.65	0.099	-2.48623	0.212753		
	renew	-76.3716	49.41788	-1.55	0.122	-173.229	20.48571		
	t	0.020587	0.079611	0.26	0.796	-0.13545	0.176621		
	_cons	-120.253	127.7377	-0.94	0.346	-370.614	130.1084		
Pakistan									
	lnGDP	-0.30498	4.780522	-0.06	0.949	-9.67463	9.064676		U-shaped
	lnGDP2	0.060795	0.307879	0.2	0.843	-0.54264	0.664227	$	12.28
	lnpop	1.89031	1.5634	1.21	0.227	-1.1739	4.954517		
	renew	0.002086	0.002421	0.86	0.389	-0.00266	0.00683		
	t	-0.03441	0.041448	-0.83	0.406	-0.11565	0.046823		
	_cons	-23.7094	29.37885	-0.81	0.42	-81.2909	33.87213		
Peru									
	lnGDP	24.43452	7.532788	3.24	0.001	9.670524	39.19851		EKC
	lnGDP2	-1.44638	0.455158	-3.18	0.001	-2.33848	-0.55429	$	4,659.95
	lnpop	-6.8876	2.928214	-2.35	0.019	-12.6268	-1.14841		
	renew	-0.03163	0.009872	-3.2	0.001	-0.05098	-0.01228		
	t	0.016808	0.098613	0.17	0.865	-0.17647	0.210087		
	_cons	-192.308	101.7781	-1.89	0.059	-391.789	7.173942		
Philippines									
	lnGDP	-0.50754	4.451164	-0.11	0.909	-9.23167	8.216576		U-shaped
	lnGDP2	0.128236	0.290982	0.44	0.659	-0.44208	0.69855	$	7.24
	lnpop	15.06438	4.758674	3.17	0.002	5.737555	24.39121		
	renew	-0.01769	0.006848	-2.58	0.01	-0.03112	-0.00427		
	t	-0.24603	0.13893	-1.77	0.077	-0.51833	0.026263		
	_cons	-204.219	110.1485	-1.85	0.064	-420.106	11.66783		
Poland									
	lnGDP	-18.0564	3.013529	-5.99	0	-23.9628	-12.15		U-shaped
	lnGDP2	1.04878	0.16667	6.29	0	0.722113	1.375448	$	5,476.89
	lnpop	10.79248	2.171751	4.97	0	6.535925	15.04903		
	renew	-0.06769	0.026931	-2.51	0.012	-0.12047	-0.0149		
	t	0.039597	0.031322	1.26	0.206	-0.02179	0.100987		
	_cons	15.81085	32.78862	0.48	0.63	-48.4537	80.07537		
Portugal									
	lnGDP	-11.4754	3.856456	-2.98	0.003	-19.0339	-3.91687		U-shaped
	lnGDP2	0.671995	0.202819	3.31	0.001	0.274478	1.069512	$	5,106.68
	lnpop	-2.69175	0.863985	-3.12	0.002	-4.38513	-0.99837		
	renew	-0.00895	0.001656	-5.41	0	-0.01219	-0.0057		
	t	0.129511	0.020202	6.41	0	0.089915	0.169107		
	_cons	208.0129	31.21216	6.66	0	146.8381	269.1876		
Qatar									
	lnGDP	45.51547	19.36406	2.35	0.019	7.562617	83.46833		EKC
	lnGDP2	-2.07081	0.878067	-2.36	0.018	-3.79179	-0.34983	$	59,264.71
	lnpop	-0.56281	0.386658	-1.46	0.146	-1.32065	0.195025		
	renew	3.671811	1.934589	1.9	0.058	-0.11991	7.463536		
	t	-0.32834	0.13333	-2.46	0.014	-0.58966	-0.06701		
	_cons	-507.847	152.945	-3.32	0.001	-807.614	-208.081		
Romania									
	lnGDP	-2.59737	3.567242	-0.73	0.467	-9.58903	4.3943		U-shaped
	lnGDP2	0.201595	0.196929	1.02	0.306	-0.18438	0.58757	$	627.68
	lnpop	5.956307	1.234834	4.82	0	3.536077	8.376538		
	renew	-0.0234	0.007171	-3.26	0.001	-0.03745	-0.00934		
	t	0.017486	0.052454	0.33	0.739	-0.08532	0.120295		
	_cons	-40.1025	67.21433	-0.6	0.551	-171.84	91.6352		
Saudi Arabia									
	lnGDP	9.236393	15.14883	0.61	0.542	-20.4548	38.92755		EKC
	lnGDP2	-0.42167	0.73956	-0.57	0.569	-1.87118	1.027838	$	57,072.35
	lnpop	6.129698	1.688028	3.63	0	2.821225	9.438172		
	renew	-40.6773	16.7536	-2.43	0.015	-73.5137	-7.84085		
	t	0.09898	0.095604	1.04	0.301	-0.0884	0.286361		
	_cons	260.335	131.275	1.98	0.047	3.040714	517.6293		
Singapore									
	lnGDP	8.430411	9.105997	0.93	0.355	-9.41702	26.27784		EKC
	lnGDP2	-0.39325	0.43913	-0.9	0.371	-1.25393	0.467432	$	45,205.26
	lnpop	3.842384	1.191507	3.22	0.001	1.507072	6.177696		
	renew	0.029589	0.696524	0.04	0.966	-1.33557	1.394752		
	t	-0.22659	0.102582	-2.21	0.027	-0.42765	-0.02553		
	_cons	-386.953	125.7607	-3.08	0.002	-633.439	-140.466		
Sweden									

	lnGDP	-11.7044	13.60862	-0.86	0.39	-38.3768	14.96798	U-shaped
	lnGDP2	0.619128	0.674348	0.92	0.359	-0.70257	1.940826	$ 12,738.07
	lnpop	0.341398	2.638564	0.13	0.897	-4.83009	5.512888	
	renew	-0.00901	0.003513	-2.57	0.01	-0.0159	-0.00213	
	t	-0.01137	0.049699	-0.23	0.819	-0.10878	0.086034	
	_cons	5.135739	83.31407	0.06	0.951	-158.157	168.4283	
Thailand								
	lnGDP	0.798603	4.197801	0.19	0.849	-7.42894	9.026141	U-shaped
	lnGDP2	0.018068	0.248019	0.07	0.942	-0.46804	0.504177	$ 0.00
	lnpop	0.285292	3.898942	0.07	0.942	-7.3565	7.927079	
	renew	-0.02554	0.013415	-1.9	0.057	-0.05183	0.000753	
	t	0.080951	0.051639	1.57	0.117	-0.02026	0.182162	
	_cons	38.17933	70.16361	0.54	0.586	-99.3388	175.6975	
Trinidad and Tobago								
	lnGDP	-6.40304	2.760883	-2.32	0.02	-11.8143	-0.99181	U-shaped
	lnGDP2	0.394587	0.13716	2.88	0.004	0.125759	0.663415	$ 3,339.61
	lnpop	5.175173	5.606781	0.92	0.356	-5.81392	16.16426	
	renew	0.046655	0.667837	0.07	0.944	-1.26228	1.355592	
	t	0.065968	0.064487	1.02	0.306	-0.06042	0.192359	
	_cons	40.38257	101.6687	0.4	0.691	-158.884	239.6495	
Turkey								
	lnGDP	1.491335	2.782089	0.54	0.592	-3.96146	6.944129	EKC
	lnGDP2	-0.03813	0.147231	-0.26	0.796	-0.3267	0.250439	$ 311,449,488.11
	lnpop	3.04013	2.053391	1.48	0.139	-0.98444	7.064702	
	renew	-0.00656	0.003046	-2.15	0.031	-0.01253	-0.00059	
	t	-0.11571	0.059018	-1.96	0.05	-0.23138	-3.6E-05	
	_cons	-146.347	55.39211	-2.64	0.008	-254.914	-37.7809	
United States								
	lnGDP	0.028351	5.479135	0.01	0.996	-10.7106	10.76726	U-shaped
	lnGDP2	0.038145	0.276354	0.14	0.89	-0.5035	0.579788	$ 0.69
	lnpop	1.557588	0.854829	1.82	0.068	-0.11785	3.233022	
	renew	-0.01319	0.008073	-1.63	0.102	-0.02901	0.002633	
	t	-0.02665	0.023455	-1.14	0.256	-0.07262	0.019326	
	_cons	-7.36552	25.20083	-0.29	0.77	-56.7582	42.0272	
Venezuela, RB								
	lnGDP	0.053786	7.942839	0.01	0.995	-15.5139	15.62146	EKC
	lnGDP2	-0.01308	0.426013	-0.03	0.976	-0.84805	0.821893	$ 7.82
	lnpop	8.883281	3.05573	2.91	0.004	2.894161	14.8724	
	renew	-0.0362	0.013583	-2.67	0.008	-0.06283	-0.00958	
	t	-0.12462	0.13811	-0.9	0.367	-0.39531	0.146073	
	_cons	-117.626	130.2557	-0.9	0.367	-372.923	137.6702	
Vietnam								
	lnGDP	3.655039	3.242434	1.13	0.26	-2.70001	10.01009	EKC
	lnGDP2	-0.19121	0.222333	-0.86	0.39	-0.62697	0.244555	$ 14,152.57
	lnpop	-1.42736	2.819041	-0.51	0.613	-6.95258	4.097857	
	renew	-0.02252	0.004177	-5.39	0	-0.03071	-0.01433	
	t	0.093884	0.084054	1.12	0.264	-0.07086	0.258626	
	_cons	33.47828	77.28828	0.43	0.665	-118.004	184.9605	
South Africa								
	lnGDP	-6.86152	12.8507	-0.53	0.593	-32.0484	18.32539	U-shaped
	lnGDP2	0.438372	0.730365	0.6	0.548	-0.99312	1.869861	$ 2,505.26
	lnpop	-0.98251	3.533227	-0.28	0.781	-7.9075	5.942492	
	renew	0.02396	0.039204	0.61	0.541	-0.05288	0.100798	
	t	0.0664	0.067302	0.99	0.324	-0.06551	0.198309	
	_cons	83.55271	98.40469	0.85	0.396	-109.317	276.4224	

8.2: AMG Country Specific Results

The AMG estimator finds an EKC relationship in 29 of the 55 countries. These countries, and their turning points are indicated in the furthest column to the right. Additionally, the column indicates if the AMG-1 estimator finds a “U-shaped” pollution-income relationship for a country. The turning points displayed for these countries are local minimums.

Country		Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]	Shape and Turning Point
United Arab Emirates								
	lnGDP	11.79956	22.5153	0.52	0.6	-32.3296	55.92874	EKC
	lnGDP2	-0.53266	1.017031	-0.52	0.6	-2.526	1.460685	$ 64,609.50
	lnpop	0.384284	0.231242	1.66	0.097	-0.06894	0.837511	
	renew	0.355991	1.042355	0.34	0.733	-1.68699	2.39897	
	c	0.706925	0.677103	1.04	0.296	-0.62017	2.034022	
	t	0.036994	0.02209	1.67	0.094	-0.0063	0.080289	
	_cons	-53.2186	122.9848	-0.43	0.665	-294.264	187.8273	
Argentina								
	lnGDP	4.242345	2.814823	1.51	0.132	-1.27461	9.759297	EKC
	lnGDP2	-0.20673	0.151158	-1.37	0.171	-0.50299	0.089532	$ 28,581.90
	lnpop	-2.57896	1.650867	-1.56	0.118	-5.81459	0.656685	
	renew	-0.0187	0.003624	-5.16	0	-0.0258	-0.0116	
	c	0.342164	0.288045	1.19	0.235	-0.22239	0.906722	
	t	0.045226	0.018378	2.46	0.014	0.009206	0.081246	
	_cons	41.58448	16.5359	2.51	0.012	9.174715	73.99424	
Austria								
	lnGDP	0.136848	1.144074	0.12	0.905	-2.1055	2.379192	U-shaped
	lnGDP2	0.025487	0.063068	0.4	0.686	-0.09812	0.149099	$ 0.07
	lnpop	-0.31976	0.838898	-0.38	0.703	-1.96397	1.324451	
	renew	-0.01724	0.002766	-6.23	0	-0.02266	-0.01182	
	c	0.639443	0.252151	2.54	0.011	0.145236	1.133649	
	t	-0.00738	0.009506	-0.78	0.438	-0.02601	0.011255	
	_cons	19.83806	14.99166	1.32	0.186	-9.54505	49.22117	
Belgium								
	lnGDP	4.737839	2.553664	1.86	0.064	-0.26725	9.742927	EKC
	lnGDP2	-0.19674	0.134568	-1.46	0.144	-0.46049	0.067004	$ 169,508.02
	lnpop	2.928176	2.773939	1.06	0.291	-2.50864	8.364996	
	renew	-0.00071	0.033263	-0.02	0.983	-0.0659	0.064487	
	c	2.514262	0.518684	4.85	0	1.49766	3.530864	
	t	-0.00985	0.01821	-0.54	0.588	-0.04554	0.025838	
	_cons	-55.4533	53.63744	-1.03	0.301	-160.581	49.67411	
Bangladesh								
	lnGDP	3.648357	2.132626	1.71	0.087	-0.53151	7.828227	EKC
	lnGDP2	-0.34211	0.17302	-1.98	0.048	-0.68122	-0.003	$ 206.88
	lnpop	-6.40826	2.713252	-2.36	0.018	-11.7261	-1.09038	
	renew	-0.02931	0.011443	-2.56	0.01	-0.05174	-0.00688	
	c	-0.38729	0.503718	-0.77	0.442	-1.37456	0.599983	
	t	0.254096	0.078579	3.23	0.001	0.100085	0.408107	
	_cons	123.1258	44.74052	2.75	0.006	35.43595	210.8156	
Bulgaria								
	lnGDP	-0.42957	3.501336	-0.12	0.902	-7.29206	6.432925	U-shaped
	lnGDP2	0.056759	0.189393	0.3	0.764	-0.31444	0.427963	$ 44.00
	lnpop	1.731628	1.277903	1.36	0.175	-0.77302	4.236271	
	renew	-0.01024	0.0142	-0.72	0.471	-0.03807	0.01759	
	c	1.327387	0.811133	1.64	0.102	-0.26241	2.917179	
	t	-0.00675	0.018164	-0.37	0.71	-0.04235	0.028853	
	_cons	-9.92392	24.64534	-0.4	0.687	-58.2279	38.38006	
Brazil								
	lnGDP	-7.34613	5.049441	-1.45	0.146	-17.2429	2.550596	U-shaped
	lnGDP2	0.415641	0.274137	1.52	0.129	-0.12166	0.95294	$ 6,884.98
	lnpop	3.709723	1.582518	2.34	0.019	0.608046	6.811401	
	renew	-0.01675	0.004453	-3.76	0	-0.02548	-0.00802	
	c	0.793685	0.359173	2.21	0.027	0.089718	1.497651	
	t	-0.017	0.022632	-0.75	0.453	-0.06135	0.027362	
	_cons	-17.0792	10.34998	-1.65	0.099	-37.3648	3.206395	
Canada								
	lnGDP	-0.01585	2.142868	-0.01	0.994	-4.21579	4.184097	U-shaped
	lnGDP2	0.038399	0.116377	0.33	0.741	-0.1897	0.266494	$ 1.23

	lnpop	|	0.418493	1.855914	0.23	0.822	-3.21903	4.056017		
	renew	|	-0.01215	0.006731	-1.8	0.071	-0.02534	0.001044		
	c	|	1.097369	0.251353	4.37	0	0.604726	1.590011		
	t	|	-0.00894	0.026253	-0.34	0.733	-0.0604	0.042511		
	_cons	|	9.894453	23.17689	0.43	0.669	-35.5314	55.32032		
Switzerland	Group	9	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]		
	lnGDP	|	3.257375	1.566644	2.08	0.038	0.18681	6.32794		EKC
	lnGDP2	|	-0.13911	0.078316	-1.78	0.076	-0.29261	0.014385	$	121,525.25
	lnpop	|	-0.50896	0.941183	-0.54	0.589	-2.35364	1.335729		
	renew	|	-0.00535	0.003736	-1.43	0.152	-0.01267	0.00197		
	c	|	0.690581	0.378824	1.82	0.068	-0.0519	1.433063		
	t	|	0.000182	0.010458	0.02	0.986	-0.02032	0.020679		
	_cons	|	7.099819	19.65062	0.36	0.718	-31.4147	45.61433		
Chile										
	lnGDP	|	-4.21632	1.572967	-2.68	0.007	-7.29928	-1.13337		EKC
	lnGDP2	|	0.261604	0.086674	3.02	0.003	0.091727	0.431481	$	3,160.86
	lnpop	|	9.118088	2.197392	4.15	0	4.811278	13.4249		
	renew	|	-0.02187	0.002249	-9.73	0	-0.02628	-0.01747		
	c	|	0.478519	0.28378	1.69	0.092	-0.07768	1.034718		
	t	|	-0.10745	0.030149	-3.56	0	-0.16653	-0.04836		
	_cons	|	-113.701	28.85873	-3.94	0	-170.263	-57.1387		
China										
	lnGDP	|	-0.3236	0.750812	-0.43	0.666	-1.79516	1.147965		U-shaped
	lnGDP2	|	0.114485	0.051013	2.24	0.025	0.014502	0.214468	$	4.11
	lnpop	|	0.555228	2.619604	0.21	0.832	-4.5791	5.689559		
	renew	|	-0.05807	0.015696	-3.7	0	-0.08883	-0.02731		
	c	|	-0.94864	0.453269	-2.09	0.036	-1.83703	-0.06025		
	t	|	-0.11101	0.041066	-2.7	0.007	-0.1915	-0.03053		
	_cons	|	7.852099	51.89455	0.15	0.88	-93.8593	109.5635		
Colombia										
	lnGDP	|	13.7914	5.963525	2.31	0.021	2.103101	25.47969		EKC
	lnGDP2	|	-0.71759	0.339728	-2.11	0.035	-1.38344	-0.05173	$	14,906.65
	lnpop	|	-6.41398	3.092147	-2.07	0.038	-12.4745	-0.35348		
	renew	|	-0.01654	0.003361	-4.92	0	-0.02313	-0.00995		
	c	|	0.442366	0.444156	1	0.319	-0.42816	1.312895		
	t	|	0.082295	0.055532	1.48	0.138	-0.02655	0.191135		
	_cons	|	63.26436	27.63156	2.29	0.022	9.107496	117.4212		
Cyprus										
	lnGDP	|	1.965737	1.498109	1.31	0.189	-0.9705	4.901977		EKC
	lnGDP2	|	-0.0469	0.092777	-0.51	0.613	-0.22874	0.134936		(too large to include)
	lnpop	|	1.409859	0.99274	1.42	0.156	-0.53588	3.355594		
	renew	|	-0.00289	0.047262	-0.06	0.951	-0.09552	0.08974		
	c	|	1.950467	0.664924	2.93	0.003	0.647241	3.253693		
	t	|	-0.0206	0.027712	-0.74	0.457	-0.07491	0.033715		
	_cons	|	-17.224	16.06477	-1.07	0.284	-48.7104	14.26241		
Denmark										
	lnGDP	|	2.514356	3.945961	0.64	0.524	-5.21959	10.2483		EKC
	lnGDP2	|	-0.09782	0.195671	-0.5	0.617	-0.48133	0.285684	$	381,367.60
	lnpop	|	2.689313	4.239646	0.63	0.526	-5.62024	10.99887		
	renew	|	-0.03713	0.009277	-4	0	-0.05531	-0.01895		
	c	|	1.757881	0.559527	3.14	0.002	0.661228	2.854534		
	t	|	0.008424	0.024846	0.34	0.735	-0.04027	0.057122		
	_cons	|	-38.6179	79.72222	-0.48	0.628	-194.871	117.6348		
Algeria										
	lnGDP	|	-24.246	4.869674	-4.98	0	-33.7904	-14.7016		U-shaped
	lnGDP2	|	1.45398	0.280312	5.19	0	0.904578	2.003382	$	4,178.93
	lnpop	|	10.27911	1.71594	5.99	0	6.915932	13.64229		
	renew	|	-0.02696	0.165374	-0.16	0.87	-0.35109	0.297164		
	c	|	4.235683	1.211665	3.5	0	1.860864	6.610503		
	t	|	-0.17786	0.033903	-5.25	0	-0.24431	-0.11141		
	_cons	|	-53.3884	22.5315	-2.37	0.018	-97.5493	-9.22744		
Ecuador										
	lnGDP	|	20.85362	13.20707	1.58	0.114	-5.03177	46.739		EKC
	lnGDP2	|	-1.18739	0.748955	-1.59	0.113	-2.65532	0.280533	$	6,511.19
	lnpop	|	-10.9091	4.878034	-2.24	0.025	-20.4699	-1.34833		
	renew	|	-0.00994	0.009621	-1.03	0.302	-0.02879	0.008922		
	c	|	-1.19246	1.284228	-0.93	0.353	-3.7095	1.324585		
	t	|	0.22888	0.100298	2.28	0.022	0.0323	0.425459		
	_cons	|	98.92972	31.88184	3.1	0.002	36.44245	161.417		
Egypt, Arab Rep.										

	Variable	Coef.	Std. Err.	t	P	Lower	Upper		
	lnGDP	5.459207	1.573055	3.47	0.001	2.376077	8.542338		EKC
	lnGDP2	-0.27373	0.10116	-2.71	0.007	-0.472	-0.07546	$	21,415.30
	lnpop	-4.68484	1.729302	-2.71	0.007	-8.07421	-1.29547		
	renew	0.008114	0.017746	0.46	0.648	-0.02667	0.042896		
	c	0.323305	0.511733	0.63	0.528	-0.67967	1.326284		
	t	0.11586	0.043292	2.68	0.007	0.031008	0.200711		
	_cons	74.17268	25.52271	2.91	0.004	24.14909	124.1963		
Spain									
	lnGDP	-8.89275	1.608939	-5.53	0	-12.0462	-5.73929		U-shaped
	lnGDP2	0.525257	0.086473	6.07	0	0.355774	0.69474	$	4,746.44
	lnpop	-0.08148	0.463957	-0.18	0.861	-0.99082	0.827856		
	renew	-0.0144	0.00523	-2.75	0.006	-0.02465	-0.00415		
	c	1.02597	0.327537	3.13	0.002	0.384009	1.667931		
	t	-0.03014	0.009941	-3.03	0.002	-0.04962	-0.01066		
	_cons	58.27354	14.33987	4.06	0	30.1679	86.37918		
Finland									
	lnGDP	5.03407	2.716803	1.85	0.064	-0.29077	10.35891		EKC
	lnGDP2	-0.2227	0.147754	-1.51	0.132	-0.5123	0.06689	$	81,001.70
	lnpop	3.307247	9.121124	0.36	0.717	-14.5698	21.18432		
	renew	-0.02524	0.008209	-3.07	0.002	-0.04133	-0.00915		
	c	2.776644	0.695912	3.99	0	1.41268	4.140607		
	t	0.012333	0.042224	0.29	0.77	-0.07042	0.09509		
	_cons	-60.1464	131.365	-0.46	0.647	-317.617	197.3242		
United Kingdom									
	lnGDP	1.146991	1.044872	1.1	0.272	-0.90092	3.194902		EKC
	lnGDP2	-0.01604	0.051072	-0.31	0.754	-0.11614	0.084063		(too large to include)
	lnpop	3.582925	1.207417	2.97	0.003	1.216431	5.949419		
	renew	-0.02597	0.004933	-5.26	0	-0.03564	-0.0163		
	c	0.80311	0.235906	3.4	0.001	0.340743	1.265476		
	t	-0.0415	0.008269	-5.02	0	-0.05771	-0.02529		
	_cons	-52.8575	25.95319	-2.04	0.042	-103.725	-1.99021		
Greece									
	lnGDP	11.77265	1.322088	8.9	0	9.181404	14.36389		EKC
	lnGDP2	-0.5559	0.063839	-8.71	0	-0.68102	-0.43078	$	39,688.78
	lnpop	0.225188	0.635821	0.35	0.723	-1.021	1.471373		
	renew	-0.02405	0.00447	-5.38	0	-0.03281	-0.01529		
	c	0.86665	0.184394	4.7	0	0.505245	1.228056		
	t	-0.00535	0.004515	-1.18	0.236	-0.0142	0.0035		
	_cons	-46.8839	8.043113	-5.83	0	-62.6481	-31.1197		
Hong Kong SAR, China									
	lnGDP	7.382742	1.495576	4.94	0	4.451467	10.31402		EKC
	lnGDP2	-0.39047	0.082132	-4.75	0	-0.55145	-0.2295	$	12,754.53
	lnpop	-1.99982	0.918307	-2.18	0.029	-3.79967	-0.19997		
	renew	-0.99598	0.711009	-1.4	0.161	-2.38954	0.397568		
	c	0.20504	0.575575	0.36	0.722	-0.92306	1.333145		
	t	0.074747	0.020746	3.6	0	0.034086	0.115408		
	_cons	12.78548	10.51543	1.22	0.224	-7.82439	33.39535		
Hungary									
	lnGDP	-1.92899	1.486898	-1.3	0.195	-4.84326	0.985276		U-shaped
	lnGDP2	0.134441	0.077416	1.74	0.082	-0.01729	0.286173	$	1,305.23
	lnpop	7.195255	1.931077	3.73	0	3.410413	10.9801		
	renew	-0.0394	0.018194	-2.17	0.03	-0.07506	-0.00374		
	c	0.217857	0.269859	0.81	0.419	-0.31106	0.746771		
	t	-0.02043	0.006377	-3.2	0.001	-0.03293	-0.00793		
	_cons	-91.6001	29.24056	-3.13	0.002	-148.911	-34.2896		
Indonesia									
	lnGDP	8.650986	3.270565	2.65	0.008	2.240797	15.06118		EKC
	lnGDP2	-0.46651	0.190252	-2.45	0.014	-0.8394	-0.09363	$	10,635.27
	lnpop	-10.9522	5.915267	-1.85	0.064	-22.5459	0.641549		
	renew	-0.02157	0.032662	-0.66	0.509	-0.08559	0.042447		
	c	1.066682	0.709729	1.5	0.133	-0.32436	2.457725		
	t	0.182019	0.079428	2.29	0.022	0.026343	0.337694		
	_cons	186.4251	97.88246	1.9	0.057	-5.42097	378.2712		
India									
	lnGDP	-9.63349	3.798222	-2.54	0.011	-17.0779	-2.18911		U-shaped
	lnGDP2	0.655132	0.243317	2.69	0.007	0.17824	1.132025	$	1,559.82
	lnpop	17.50453	5.943196	2.95	0.003	5.856077	29.15298		
	renew	-0.00989	0.011625	-0.85	0.395	-0.03267	0.012895		
	c	-0.97873	0.513894	-1.9	0.057	-1.98595	0.028482		
	t	-0.2912	0.106276	-2.74	0.006	-0.49949	-0.0829		

	_cons	-302.108	107.2412	-2.82	0.005	-512.297	-91.9192	
Ireland								
	lnGDP	0.41904	1.293529	0.32	0.746	-2.11623	2.95431	EKC
	lnGDP2	-0.00099	0.060049	-0.02	0.987	-0.11869	0.1167	(too large to include)
	lnpop	0.366206	0.339551	1.08	0.281	-0.2993	1.031714	
	renew	-0.03942	0.010456	-3.77	0	-0.05991	-0.01892	
	c	0.383682	0.244783	1.57	0.117	-0.09608	0.863447	
	t	-0.00174	0.01084	-0.16	0.872	-0.02299	0.019506	
	_cons	7.994078	11.2581	0.71	0.478	-14.0714	30.05954	
Iran, Islamic Rep.								
	lnGDP	3.24867	2.172138	1.5	0.135	-1.00864	7.505982	EKC
	lnGDP2	-0.1569	0.120094	-1.31	0.191	-0.39228	0.078477	$ 31,333.59
	lnpop	0.790333	0.332493	2.38	0.017	0.138659	1.442006	
	renew	-0.03603	0.018982	-1.9	0.058	-0.07323	0.001177	
	c	0.662949	0.426374	1.55	0.12	-0.17273	1.498626	
	t	0.032537	0.008233	3.95	0	0.016401	0.048674	
	_cons	-11.4913	7.829512	-1.47	0.142	-26.8369	3.854232	
Iceland								
	lnGDP	2.827405	0.92598	3.05	0.002	1.012517	4.642292	EKC
	lnGDP2	-0.1144	0.046901	-2.44	0.015	-0.20632	-0.02247	$ 232,768.25
	lnpop	1.523615	0.855289	1.78	0.075	-0.15272	3.19995	
	renew	-0.01458	0.002005	-7.27	0	-0.01851	-0.01065	
	c	1.514214	0.249048	6.08	0	1.02609	2.002339	
	t	0.001501	0.007277	0.21	0.837	-0.01276	0.015764	
	_cons	-19.9795	11.86495	-1.68	0.092	-43.2344	3.275393	
Israel								
	lnGDP	7.715509	1.606524	4.8	0	4.566779	10.86424	EKC
	lnGDP2	-0.33314	0.089128	-3.74	0	-0.50783	-0.15845	$ 106,940.94
	lnpop	2.308129	0.543475	4.25	0	1.242938	3.37332	
	renew	0.002128	0.044252	0.05	0.962	-0.08461	0.08886	
	c	1.057409	0.528951	2	0.046	0.020685	2.094134	
	t	-0.05511	0.018998	-2.9	0.004	-0.09234	-0.01787	
	_cons	-60.4515	7.845052	-7.71	0	-75.8275	-45.0755	
Japan								
	lnGDP	-5.33133	3.065585	-1.74	0.082	-11.3398	0.677103	U-shaped
	lnGDP2	0.313755	0.155488	2.02	0.044	0.009004	0.618506	$ 4,895.19
	lnpop	0.974259	2.377187	0.41	0.682	-3.68494	5.63346	
	renew	-0.0228	0.011745	-1.94	0.052	-0.04582	0.000219	
	c	1.045474	0.382395	2.73	0.006	0.295994	1.794954	
	t	-0.01405	0.009732	-1.44	0.149	-0.03313	0.005025	
	_cons	25.24647	31.97523	0.79	0.43	-37.4238	87.91677	
Korea, Rep.								
	lnGDP	-1.5223	1.240457	-1.23	0.22	-3.95355	0.908951	U-shaped
	lnGDP2	0.127307	0.076483	1.66	0.096	-0.0226	0.277211	$ 394.98
	lnpop	7.225751	2.465383	2.93	0.003	2.393688	12.05781	
	renew	0.0526	0.051707	1.02	0.309	-0.04874	0.153943	
	c	0.963763	0.457723	2.11	0.035	0.066642	1.860885	
	t	-0.06563	0.033505	-1.96	0.05	-0.1313	3.32E-05	
	_cons	-103.326	38.79017	-2.66	0.008	-179.353	-27.2983	
Sri Lanka								
	lnGDP	0.561998	1.501513	0.37	0.708	-2.38091	3.50491	EKC
	lnGDP2	-0.00317	0.089671	-0.04	0.972	-0.17893	0.172578	(too large to include)
	lnpop	0.008946	3.261604	0	0.998	-6.38368	6.401571	
	renew	-0.02023	0.003631	-5.57	0	-0.02734	-0.01311	
	c	0.800355	0.74632	1.07	0.284	-0.66241	2.263115	
	t	0.022266	0.0384	0.58	0.562	-0.053	0.097527	
	_cons	11.68017	49.05547	0.24	0.812	-84.4668	107.8271	
Luxembourg								
	lnGDP	-9.67953	2.804028	-3.45	0.001	-15.1753	-4.18374	U-shaped
	lnGDP2	0.468536	0.133546	3.51	0	0.20679	0.730281	$ 30,624.56
	lnpop	0.286755	1.994083	0.14	0.886	-3.62158	4.195086	
	renew	-0.2622	0.084896	-3.09	0.002	-0.42859	-0.0958	
	c	-1.33044	0.835226	-1.59	0.111	-2.96745	0.306577	
	t	-0.02901	0.04346	-0.67	0.504	-0.11419	0.056169	
	_cons	62.40743	35.63073	1.75	0.08	-7.42753	132.2424	
Morocco								
	lnGDP	2.206207	1.364502	1.62	0.106	-0.46817	4.880582	EKC
	lnGDP2	-0.09915	0.086686	-1.14	0.253	-0.26905	0.070749	$ 67,874.24
	lnpop	-0.41098	1.112004	-0.37	0.712	-2.59047	1.768506	
	renew	-0.0095	0.005489	-1.73	0.084	-0.02026	0.00126	

	c	1.027861	0.410389	2.5	0.012	0.223513	1.832209		
	t	0.034511	0.01735	1.99	0.047	0.000506	0.068516		
	_cons	12.74443	14.03862	0.91	0.364	-14.7708	40.25962		
Mexico									
	lnGDP	3.674545	5.594618	0.66	0.511	-7.29071	14.63979		EKC
	lnGDP2	-0.17217	0.308734	-0.56	0.577	-0.77727	0.432941	$	43,108.71
	lnpop	-0.61292	1.849292	-0.33	0.74	-4.23747	3.011623		
	renew	-0.02139	0.011514	-1.86	0.063	-0.04395	0.00118		
	c	0.32741	0.344428	0.95	0.342	-0.34766	1.002476		
	t	0.017771	0.033514	0.53	0.596	-0.04792	0.083457		
	_cons	11.66352	11.56741	1.01	0.313	-11.0082	34.33524		
Malaysia									
	lnGDP	6.240137	3.128757	1.99	0.046	0.107887	12.37239		EKC
	lnGDP2	-0.26921	0.173764	-1.55	0.121	-0.60978	0.071362	$	107,982.48
	lnpop	-1.1894	2.153727	-0.55	0.581	-5.41063	3.031825		
	renew	-0.02404	0.010823	-2.22	0.026	-0.04525	-0.00282		
	c	2.021397	0.697105	2.9	0.004	0.655096	3.387699		
	t	0.047411	0.061379	0.77	0.44	-0.07289	0.167711		
	_cons	3.835673	21.8477	0.18	0.861	-38.985	46.65639		
Norway									
	lnGDP	-11.3874	5.250878	-2.17	0.03	-21.679	-1.09591		
	lnGDP2	0.599652	0.260598	2.3	0.021	0.08889	1.110415	$	13,293.59
	lnpop	3.355258	5.280464	0.64	0.525	-6.99426	13.70478		
	renew	-0.00923	0.01161	-0.8	0.427	-0.03199	0.013524		
	c	-0.59731	1.391752	-0.43	0.668	-3.3251	2.130469		
	t	-0.07574	0.07237	-1.05	0.295	-0.21758	0.066102		
	_cons	21.13719	95.21875	0.22	0.824	-165.488	207.7625		
Oman									
	lnGDP	-0.41698	5.903882	-0.07	0.944	-11.9884	11.15441		EKC
	lnGDP2	-0.00067	0.307104	0	0.998	-0.60258	0.601242	$	0.00
	lnpop	-0.39887	0.414376	-0.96	0.336	-1.21104	0.41329		
	renew	-41.7185	43.06434	-0.97	0.333	-126.123	42.68607		
	c	-1.2676	1.053014	-1.2	0.229	-3.33147	0.796265		
	t	0.08095	0.026729	3.03	0.002	0.028563	0.133337		
	_cons	25.05665	25.7642	0.97	0.331	-25.4402	75.55355		
Pakistan									
	lnGDP	-1.37546	1.862391	-0.74	0.46	-5.02568	2.274757		U-shaped
	lnGDP2	0.139562	0.118875	1.17	0.24	-0.09343	0.372552	$	138.07
	lnpop	3.274411	1.122644	2.92	0.004	1.07407	5.474752		
	renew	0.001201	0.002148	0.56	0.576	-0.00301	0.00541		
	c	0.395047	0.30742	1.29	0.199	-0.20749	0.997579		
	t	-0.06477	0.03179	-2.04	0.042	-0.12708	-0.00246		
	_cons	-39.3594	13.36367	-2.95	0.003	-65.5517	-13.1671		
Peru									
	lnGDP	7.153098	4.128243	1.73	0.083	-0.93811	15.24431		EKC
	lnGDP2	-0.40748	0.252331	-1.61	0.106	-0.90204	0.087084	$	6,485.44
	lnpop	-1.52462	2.012758	-0.76	0.449	-5.46956	2.420313		
	renew	-0.0333	0.009036	-3.69	0	-0.05101	-0.01559		
	c	0.716021	0.742113	0.96	0.335	-0.73849	2.170536		
	t	0.062241	0.038392	1.62	0.105	-0.01301	0.137488		
	_cons	11.90002	22.5858	0.53	0.598	-32.3673	56.16737		
Philippines									
	lnGDP	-5.09786	4.461719	-1.14	0.253	-13.8427	3.646948		U-shaped
	lnGDP2	0.36115	0.296053	1.22	0.223	-0.2191	0.941403	$	1,161.90
	lnpop	7.449268	3.771978	1.97	0.048	0.056327	14.84221		
	renew	-0.02927	0.00593	-4.94	0	-0.04089	-0.01764		
	c	1.35958	0.801743	1.7	0.09	-0.21181	2.930968		
	t	-0.1407	0.091732	-1.53	0.125	-0.32049	0.039096		
	_cons	-95.9756	52.83311	-1.82	0.069	-199.527	7.57541		
Poland									
	lnGDP	-10.7588	2.387322	-4.51	0	-15.4379	-6.07976		U-shaped
	lnGDP2	0.63908	0.130494	4.9	0	0.383316	0.894844	$	4,525.28
	lnpop	9.270277	1.546873	5.99	0	6.238463	12.30209		
	renew	-0.05659	0.021402	-2.64	0.008	-0.09854	-0.01464		
	c	1.023341	0.427066	2.4	0.017	0.186308	1.860374		
	t	-0.06189	0.009578	-6.46	0	-0.08066	-0.04312		
	_cons	-95.9166	19.22363	-4.99	0	-133.594	-58.239		
Portugal									
	lnGDP	1.416071	2.326332	0.61	0.543	-3.14346	5.975599		EKC
	lnGDP2	-0.0066	0.130415	-0.05	0.96	-0.26221	0.249012		##############

	lnpop	|	-0.32724	0.89773	-0.36	0.715	-2.08676	1.432276		
	renew	|	-0.01085	0.002846	-3.81	0	-0.01643	-0.00527		
	c	|	1.341567	0.478464	2.8	0.005	0.403794	2.279339		
	t	|	-0.01493	0.013481	-1.11	0.268	-0.04136	0.011487		
	_cons	|	10.75075	20.47407	0.53	0.6	-29.3777	50.8792		
Qatar										
	lnGDP	|	32.72627	19.39098	1.69	0.091	-5.27935	70.73189		EKC
	lnGDP2	|	-1.47552	0.871049	-1.69	0.09	-3.18274	0.231706	$	65,496.78
	lnpop	|	0.28337	0.297837	0.95	0.341	-0.30038	0.86712		
	renew	|	2.006192	1.853141	1.08	0.279	-1.6259	5.638282		
	c	|	3.60763	1.614307	2.23	0.025	0.443646	6.771614		
	t	|	0.116308	0.027202	4.28	0	0.062994	0.169622		
	_cons	|	-168.534	110.9145	-1.52	0.129	-385.922	48.85477		
Romania										
	lnGDP	|	-1.44783	1.904915	-0.76	0.447	-5.18139	2.285737		U-shaped
	lnGDP2	|	0.134925	0.10468	1.29	0.197	-0.07024	0.340095	$	213.85
	lnpop	|	4.478929	0.974873	4.59	0	2.568213	6.389645		
	renew	|	-0.01872	0.006163	-3.04	0.002	-0.0308	-0.00664		
	c	|	1.522491	0.507057	3	0.003	0.528678	2.516303		
	t	|	-0.02628	0.008763	-3	0.003	-0.04346	-0.00911		
	_cons	|	-53.9849	12.54362	-4.3	0	-78.5699	-29.3998		
Saudi Arabia										
	lnGDP	|	-23.5166	7.925724	-2.97	0.003	-39.0507	-7.98245		U-shaped
	lnGDP2	|	1.169115	0.385651	3.03	0.002	0.413253	1.924978	$	23,328.43
	lnpop	|	2.404645	0.804842	2.99	0.003	0.827184	3.982107		
	renew	|	-12.6778	11.94324	-1.06	0.288	-36.0862	10.7305		
	c	|	2.056689	1.228513	1.67	0.094	-0.35115	4.464531		
	t	|	-0.02321	0.021344	-1.09	0.277	-0.06505	0.018621		
	_cons	|	98.32931	37.08212	2.65	0.008	25.64969	171.0089		
Singapore										
	lnGDP	|	0.807559	4.1921	0.19	0.847	-7.40881	9.023924		EKC
	lnGDP2	|	-0.04992	0.230652	-0.22	0.829	-0.50199	0.402145	$	3,254.33
	lnpop	|	5.594057	1.858208	3.01	0.003	1.952037	9.236077		
	renew	|	1.018374	1.16286	0.88	0.381	-1.26079	3.297538		
	c	|	-2.02944	1.797656	-1.13	0.259	-5.55278	1.4939		
	t	|	-0.14523	0.079979	-1.82	0.069	-0.30198	0.01153		
	_cons	|	-68.4118	26.62122	-2.57	0.01	-120.588	-16.2352		
Sweden										
	lnGDP	|	-0.83614	1.76458	-0.47	0.636	-4.29465	2.622373		U-shaped
	lnGDP2	|	0.058207	0.075322	0.77	0.44	-0.08942	0.205836	$	1,316.09
	lnpop	|	0.231765	2.383479	0.1	0.923	-4.43977	4.903298		
	renew	|	-0.00901	0.002869	-3.14	0.002	-0.01464	-0.00339		
	c	|	1.624813	0.693133	2.34	0.019	0.266298	2.983327		
	t	|	0.000858	0.021956	0.04	0.969	-0.04217	0.043891		
	_cons	|	17.42647	46.78705	0.37	0.71	-74.2745	109.1274		
Thailand										
	lnGDP	|	4.658268	2.70467	1.72	0.085	-0.64279	9.959324		EKC
	lnGDP2	|	-0.21362	0.159849	-1.34	0.181	-0.52692	0.099675	$	54,337.54
	lnpop	|	-0.52605	2.517651	-0.21	0.834	-5.46055	4.408458		
	renew	|	-0.01456	0.011668	-1.25	0.212	-0.03743	0.008305		
	c	|	2.543265	0.56444	4.51	0	1.436983	3.649548		
	t	|	0.039797	0.033553	1.19	0.236	-0.02597	0.10556		
	_cons	|	4.104114	33.58778	0.12	0.903	-61.7267	69.93496		
Trinidad and Tobago										
	lnGDP	|	-4.64192	1.083991	-4.28	0	-6.7665	-2.51734		U-shaped
	lnGDP2	|	0.29358	0.05592	5.25	0	0.183978	0.403182	$	2,712.75
	lnpop	|	3.971295	1.965474	2.02	0.043	0.119037	7.823553		
	renew	|	-0.11098	0.626596	-0.18	0.859	-1.33908	1.117128		
	c	|	0.857517	0.732663	1.17	0.242	-0.57848	2.29351		
	t	|	-0.028	0.012954	-2.16	0.031	-0.05339	-0.00261		
	_cons	|	-20.4373	26.5167	-0.77	0.441	-72.409	31.5345		
Turkey										
	lnGDP	|	2.906103	0.897073	3.24	0.001	1.147872	4.664335		EKC
	lnGDP2	|	-0.11175	0.047153	-2.37	0.018	-0.20417	-0.01934	$	443,366.11
	lnpop	|	0.717283	1.264588	0.57	0.571	-1.76127	3.19583		
	renew	|	-0.00491	0.003016	-1.63	0.104	-0.01082	0.001007		
	c	|	0.390387	0.33005	1.18	0.237	-0.2565	1.037274		
	t	|	-0.00741	0.018305	-0.4	0.686	-0.04328	0.028472		
	_cons	|	-10.7334	18.65925	-0.58	0.565	-47.3049	25.83803		
United States										

	lnGDP	-0.32053	0.687582	-0.47	0.641	-1.66817	1.027106	U-shaped
	lnGDP2	0.049469	0.03773	1.31	0.19	-0.02448	0.123419	$ 25.53
	lnpop	1.627689	0.579691	2.81	0.005	0.491516	2.763862	
	renew	-0.0151	0.007465	-2.02	0.043	-0.02973	-0.00046	
	c	0.928897	0.20805	4.46	0	0.521127	1.336666	
	t	-0.02526	0.008447	-2.99	0.003	-0.04182	-0.00871	
	_cons	-10.3806	10.594	-0.98	0.327	-31.1444	10.38329	
Venezuela, RB								
	lnGDP	-3.04639	5.627619	-0.54	0.588	-14.0763	7.983543	U-shaped
	lnGDP2	0.152915	0.294824	0.52	0.604	-0.42493	0.73076	$ 21,185.45
	lnpop	6.460954	1.106753	5.84	0	4.291758	8.63015	
	renew	-0.03727	0.011542	-3.23	0.001	-0.05989	-0.01465	
	c	1.047187	0.431187	2.43	0.015	0.202077	1.892297	
	t	-0.07269	0.019796	-3.67	0	-0.11148	-0.03389	
	_cons	-73.1568	31.47561	-2.32	0.02	-134.848	-11.4658	
Vietnam								
	lnGDP	3.36509	1.872301	1.8	0.072	-0.30455	7.034733	EKC
	lnGDP2	-0.18368	0.140001	-1.31	0.19	-0.45808	0.090715	$ 9,509.98
	lnpop	-4.20459	2.77733	-1.51	0.13	-9.64805	1.238882	
	renew	-0.02008	0.003912	-5.13	0	-0.02774	-0.01241	
	c	2.433182	0.498275	4.88	0	1.456582	3.409782	
	t	0.139172	0.069434	2	0.045	0.003083	0.27526	
	_cons	77.77324	43.57392	1.78	0.074	-7.63007	163.1766	
South Africa								
	lnGDP	5.160377	5.266966	0.98	0.327	-5.16269	15.48344	EKC
	lnGDP2	-0.22023	0.300686	-0.73	0.464	-0.80957	0.369101	$ 122,484.22
	lnpop	1.78562	1.308749	1.36	0.172	-0.77948	4.350722	
	renew	0.001105	0.036498	0.03	0.976	-0.07043	0.07264	
	c	-0.00571	0.487188	-0.01	0.991	-0.96058	0.949164	
	t	-0.0494	0.028165	-1.75	0.079	-0.10461	0.0058	
	_cons	-39.2745	15.58888	-2.52	0.012	-69.8282	-8.72087	

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8.3: AMG-1 Country Specific Results

The AMG-1 estimator finds an EKC relationship in 31 of the 55 countries. These countries, and their turning points are indicated in the furthest column to the right. Additionally, the column indicates if the AMG-1 estimator finds a "U-shaped" pollution-income relationship for a country. The turning points displayed for these countries are local minimums.

Country		**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf.**	**Interval]**	**Shape and Turning Point**
United Arab Emirates								
	lnGDP	16.3848	19.60532	0.84	0.403	-22.0409	54.81052	EKC
	lnGDP2	-0.74068	0.884488	-0.84	0.402	-2.47424	0.992888	$ 63,621.59
	lnpop	0.336765	0.200834	1.68	0.094	-0.05686	0.730392	
	renew	0.26587	1.007871	0.26	0.792	-1.70952	2.241261	
	t	0.044431	0.013699	3.24	0.001	0.017582	0.07128	
	_cons	-77.7928	107.6562	-0.72	0.47	-288.795	133.2095	
Argentina								
	lnGDP	0.500178	2.439396	0.21	0.838	-4.28095	5.281306	EKC
	lnGDP2	-0.00645	0.131221	-0.05	0.961	-0.26364	0.250741	(too large to include)
	lnpop	-0.013	1.289164	-0.01	0.992	-2.53972	2.513713	
	renew	-0.01784	0.003841	-4.64	0	-0.02536	-0.01031	
	t	0.023488	0.016756	1.4	0.161	-0.00935	0.056328	
	_cons	15.04208	12.53707	1.2	0.23	-9.53012	39.61427	
Austria								
	lnGDP	0.658672	1.102435	0.6	0.55	-1.50206	2.819405	U-shaped
	lnGDP2	0.000551	0.061622	0.01	0.993	-0.12023	0.121329	$ 0.00
	lnpop	-0.43301	0.849108	-0.51	0.61	-2.09724	1.231207	
	renew	-0.01571	0.002593	-6.06	0	-0.02079	-0.01062	
	t	-0.00256	0.009039	-0.28	0.777	-0.02028	0.015151	
	_cons	18.91652	15.22811	1.24	0.214	-10.93	48.76306	
Belgium								
	lnGDP	2.911729	2.759992	1.05	0.291	-2.49776	8.321213	EKC
	lnGDP2	-0.15076	0.148979	-1.01	0.312	-0.44275	0.141236	$ 15,631.45
	lnpop	4.239035	3.051484	1.39	0.165	-1.74177	10.21983	
	renew	-0.06181	0.028817	-2.15	0.032	-0.11829	-0.00533	
	t	0.006661	0.019296	0.35	0.73	-0.03116	0.044479	
	_cons	-63.6368	59.71094	-1.07	0.287	-180.668	53.39446	
Bangladesh								

	lnGDP	1.730163	2.219472	0.78	0.436	-2.61992	6.080248	EKC	
	lnGDP2	-0.10201	0.16456	-0.62	0.535	-0.42454	0.220524	$	4,819.90
	lnpop	-1.02021	2.070039	-0.49	0.622	-5.07741	3.036995		
	renew	-0.02547	0.012506	-2.04	0.042	-0.04998	-0.00096		
	t	0.086549	0.054764	1.58	0.114	-0.02079	0.193883		
	_cons	27.72306	31.17802	0.89	0.374	-33.3847	88.83085		
Bulgaria									
	lnGDP	-0.75993	3.358035	-0.23	0.821	-7.34156	5.821693	U-shaped	
	lnGDP2	0.07373	0.182156	0.4	0.686	-0.28329	0.430749	$	173.04
	lnpop	1.400715	0.966899	1.45	0.147	-0.49437	3.295801		
	renew	-0.01033	0.014006	-0.74	0.461	-0.03778	0.017122		
	t	-0.01349	0.007054	-1.91	0.056	-0.02731	0.000338		
	_cons	-3.05649	17.58697	-0.17	0.862	-37.5263	31.41334		
Brazil									
	lnGDP	-7.41263	4.993253	-1.48	0.138	-17.1992	2.373963	U-shaped	
	lnGDP2	0.420484	0.271029	1.55	0.121	-0.11072	0.951692	$	6,730.52
	lnpop	3.751517	1.563663	2.4	0.016	0.686794	6.81624		
	renew	-0.01578	0.004075	-3.87	0	-0.02377	-0.00779		
	t	-0.01551	0.02224	-0.7	0.485	-0.0591	0.028077		
	_cons	-17.656	10.18918	-1.73	0.083	-37.6264	2.314413		
Canada									
	lnGDP	0.156493	2.067275	0.08	0.94	-3.89529	4.208278	U-shaped	
	lnGDP2	0.028145	0.111765	0.25	0.801	-0.19091	0.2472	$	0.06
	lnpop	0.173054	1.720383	0.1	0.92	-3.19884	3.544944		
	renew	-0.01373	0.00527	-2.61	0.009	-0.02406	-0.00341		
	t	-0.00647	0.025113	-0.26	0.797	-0.05569	0.042751		
	_cons	13.3938	21.05003	0.64	0.525	-27.8635	54.6511		
Switzerland									
	lnGDP	3.633761	1.489278	2.44	0.015	0.714829	6.552692	EKC	
	lnGDP2	-0.1502	0.076715	-1.96	0.05	-0.30056	0.000158	$	179,226.94
	lnpop	-0.10529	0.796676	-0.13	0.895	-1.66674	1.456169		
	renew	-0.00499	0.003689	-1.35	0.176	-0.01222	0.002241		
	t	-0.00322	0.009543	-0.34	0.736	-0.02192	0.015488		
	_cons	-1.83169	16.23928	-0.11	0.91	-33.6601	29.99672		
Chile									
	lnGDP	-3.11571	1.509205	-2.06	0.039	-6.0737	-0.15772	U-shaped	
	lnGDP2	0.196373	0.082046	2.39	0.017	0.035565	0.357181	$	2,788.17
	lnpop	8.047982	2.198553	3.66	0	3.738898	12.35707		
	renew	-0.02152	0.002325	-9.26	0	-0.02608	-0.01697		
	t	-0.08061	0.027368	-2.95	0.003	-0.13425	-0.02697		
	_cons	-100.92	29.06192	-3.47	0.001	-157.88	-43.9593		
China									
	lnGDP	1.17386	0.83179	1.41	0.158	-0.45642	2.804139	U-shaped	
	lnGDP2	0.03492	0.059449	0.59	0.557	-0.0816	0.151438	$	0.00
	lnpop	-2.27998	3.170501	-0.72	0.472	-8.49405	3.934087		
	renew	-0.02217	0.016621	-1.33	0.182	-0.05475	0.010404		
	t	-0.09006	0.050993	-1.77	0.077	-0.19	0.009884		
	_cons	60.55961	63.06095	0.96	0.337	-63.0376	184.1568		
Colombia									
	lnGDP	18.75143	4.508563	4.16	0	9.914806	27.58805	EKC	
	lnGDP2	-0.99512	0.260359	-3.82	0	-1.50542	-0.48483	$	12,353.21
	lnpop	-8.81433	2.452738	-3.59	0	-13.6216	-4.00705		
	renew	-0.01715	0.003357	-5.11	0	-0.02373	-0.01057		
	t	0.126371	0.043425	2.91	0.004	0.04126	0.211482		
	_cons	82.4522	23.23324	3.55	0	36.91588	127.9885		
Cyprus									
	lnGDP	2.096882	1.520255	1.38	0.168	-0.88276	5.076528	EKC	
	lnGDP2	-0.06509	0.093434	-0.7	0.486	-0.24822	0.118037	$	9,893,960.05
	lnpop	2.159194	0.857118	2.52	0.012	0.479272	3.839115		
	renew	-0.02273	0.045933	-0.49	0.621	-0.11276	0.067297		
	t	-0.0357	0.026047	-1.37	0.17	-0.08675	0.01535		
	_cons	-27.1474	14.72916	-1.84	0.065	-56.016	1.721249		
Denmark									
	lnGDP	0.700258	3.761344	0.19	0.852	-6.67184	8.072358	EKC	
	lnGDP2	-0.01164	0.18751	-0.06	0.951	-0.37915	0.355876	(too large to include)	
	lnpop	3.832718	4.210322	0.91	0.363	-4.41936	12.0848		
	renew	-0.04368	0.008023	-5.44	0	-0.05941	-0.02796		
	t	0.000453	0.024462	0.02	0.985	-0.04749	0.048398		
	_cons	-46.8925	80.55082	-0.58	0.56	-204.769	110.9842		
Algeria									

	lnGDP	-20.1315	5.055723	-3.98	0	-30.0405	-10.2224	U-shaped	
	lnGDP2	1.167039	0.283349	4.12	0	0.611686	1.722392	$	5,569.28
	lnpop	6.639048	1.140744	5.82	0	4.403231	8.874864		
	renew	0.083708	0.175216	0.48	0.633	-0.25971	0.427125		
	t	-0.11962	0.028409	-4.21	0	-0.1753	-0.06394		
	_cons	-6.80639	15.60829	-0.44	0.663	-37.3981	23.7853		
Ecuador									
	lnGDP	25.41263	13.32773	1.91	0.057	-0.70923	51.53449	EKC	
	lnGDP2	-1.40535	0.760443	-1.85	0.065	-2.89579	0.085093	$	8,445.66
	lnpop	-11.1462	5.024381	-2.22	0.027	-20.9938	-1.29855		
	renew	-9.2E-05	0.007937	-0.01	0.991	-0.01565	0.015463		
	t	0.237983	0.103202	2.31	0.021	0.03571	0.440256		
	_cons	80.12279	30.82821	2.6	0.009	19.7006	140.545		
Egypt, Arab Rep.									
	lnGDP	4.782526	1.505351	3.18	0.001	1.832092	7.732961	EKC	
	lnGDP2	-0.22811	0.096237	-2.37	0.018	-0.41673	-0.03949	$	35,702.13
	lnpop	-3.69837	1.578846	-2.34	0.019	-6.79285	-0.60388		
	renew	0.000435	0.016971	0.03	0.98	-0.03283	0.033697		
	t	0.098488	0.041746	2.36	0.018	0.016667	0.180308		
	_cons	59.46693	23.24822	2.56	0.011	13.90126	105.0326		
Spain									
	lnGDP	-8.97328	1.227566	-7.31	0	-11.3793	-6.5673	U-shaped	
	lnGDP2	0.529466	0.067146	7.89	0	0.397862	0.66107	$	4,788.14
	lnpop	-0.0934	0.431821	-0.22	0.829	-0.93976	0.752949		
	renew	-0.01441	0.005142	-2.8	0.005	-0.02449	-0.00434		
	t	-0.03052	0.00858	-3.56	0	-0.04733	-0.0137		
	_cons	58.86375	12.0579	4.88	0	35.2307	82.4968		
Finland									
	lnGDP	5.258016	2.947148	1.78	0.074	-0.51829	11.03432	EKC	
	lnGDP2	-0.25607	0.159736	-1.6	0.109	-0.56915	0.057009	$	28,761.57
	lnpop	-7.74868	8.712661	-0.89	0.374	-24.8252	9.327826		
	renew	-0.03275	0.008317	-3.94	0	-0.04905	-0.01645		
	t	0.048483	0.043174	1.12	0.261	-0.03614	0.133102		
	_cons	110.6364	122.7058	0.9	0.367	-129.863	351.1355		
United Kingdom									
	lnGDP	1.768897	0.728902	2.43	0.015	0.340276	3.197519	EKC	
	lnGDP2	-0.04401	0.038352	-1.15	0.251	-0.11917	0.031163	$	535,434,941.31
	lnpop	4.144348	0.997763	4.15	0	2.188769	6.099928		
	renew	-0.02508	0.004794	-5.23	0	-0.03448	-0.01569		
	t	-0.04391	0.00771	-5.69	0	-0.05902	-0.0288		
	_cons	-66.2108	20.33489	-3.26	0.001	-106.066	-26.3551		
Greece									
	lnGDP	12.28152	1.11066	11.06	0	10.10467	14.45837	EKC	
	lnGDP2	-0.58096	0.053205	-10.92	0	-0.68524	-0.47668	$	38,951.66
	lnpop	-0.00993	0.54219	-0.02	0.985	-1.07261	1.052739		
	renew	-0.02472	0.004341	-5.69	0	-0.03322	-0.01621		
	t	-0.0031	0.003247	-0.95	0.34	-0.00946	0.003264		
	_cons	-45.6466	7.798302	-5.85	0	-60.931	-30.3622		
Hong Kong SAR, China									
	lnGDP	8.1651	1.404272	5.81	0	5.412777	10.91742	EKC	
	lnGDP2	-0.42643	0.079028	-5.4	0	-0.58132	-0.27154	$	14,382.10
	lnpop	-2.29558	0.905969	-2.53	0.011	-4.07124	-0.51991		
	renew	-0.71643	0.691496	-1.04	0.3	-2.07174	0.638877		
	t	0.085259	0.01958	4.35	0	0.046883	0.123635		
	_cons	13.29647	10.66164	1.25	0.212	-7.59997	34.1929		
Hungary									
	lnGDP	0.922924	1.240683	0.74	0.457	-1.50877	3.354618	EKC	
	lnGDP2	-0.01201	0.06528	-0.18	0.854	-0.13995	0.11594	(too large to include)	
	lnpop	4.998721	1.976814	2.53	0.011	1.124237	8.873206		
	renew	-0.01172	0.017236	-0.68	0.497	-0.0455	0.022063		
	t	-0.01922	0.007083	-2.71	0.007	-0.0331	-0.00534		
	_cons	-69.75	31.44386	-2.22	0.027	-131.379	-8.12112		
Indonesia									
	lnGDP	8.767336	2.978216	2.94	0.003	2.930141	14.60453	EKC	
	lnGDP2	-0.47354	0.172133	-2.75	0.006	-0.81091	-0.13616	$	10,480.62
	lnpop	-11.1806	5.305614	-2.11	0.035	-21.5794	-0.78176		
	renew	-0.02174	0.032087	-0.68	0.498	-0.08463	0.041153		
	t	0.1846	0.073321	2.52	0.012	0.040893	0.328308		
	_cons	190.2441	87.60779	2.17	0.03	18.53597	361.9522		
India									

	lnGDP	-1.8115	3.859202	-0.47	0.639	-9.3754	5.752396	U-shaped	
	lnGDP2	0.205622	0.256712	0.8	0.423	-0.29752	0.708767	$	81.85
	lnpop	8.174104	6.525672	1.25	0.21	-4.61598	20.96419		
	renew	-0.02225	0.013436	-1.66	0.098	-0.04858	0.004087		
	t	-0.16592	0.12166	-1.36	0.173	-0.40437	0.072534		
	_cons	-143.363	119.0471	-1.2	0.228	-376.691	89.96545		
Ireland									
	lnGDP	1.925224	1.241734	1.55	0.121	-0.50853	4.358978	EKC	
	lnGDP2	-0.07291	0.057188	-1.28	0.202	-0.185	0.039172	$	541,398.12
	lnpop	0.524357	0.361286	1.45	0.147	-0.18375	1.232464		
	renew	-0.02871	0.010343	-2.78	0.006	-0.04898	-0.00844		
	t	-0.00061	0.011726	-0.05	0.959	-0.02359	0.022374		
	_cons	-2.07893	11.3935	-0.18	0.855	-24.4098	20.25193		
Iran, Islamic Rep.									
	lnGDP	2.59492	1.996358	1.3	0.194	-1.31787	6.50771	EKC	
	lnGDP2	-0.12045	0.110214	-1.09	0.274	-0.33646	0.095567	$	47,666.22
	lnpop	0.948989	0.263475	3.6	0	0.432588	1.46539		
	renew	-0.03711	0.018817	-1.97	0.049	-0.074	-0.00023		
	t	0.033649	0.008063	4.17	0	0.017847	0.049452		
	_cons	-11.3061	7.778507	-1.45	0.146	-26.5517	3.939473		
Iceland									
	lnGDP	1.939641	0.862186	2.25	0.024	0.249788	3.629493	EKC	
	lnGDP2	-0.07143	0.044189	-1.62	0.106	-0.15804	0.015176	$	787,640.70
	lnpop	1.250709	0.888376	1.41	0.159	-0.49048	2.991895		
	renew	-0.01501	0.002096	-7.16	0	-0.01912	-0.0109		
	t	-0.0019	0.007452	-0.26	0.799	-0.01651	0.012704		
	_cons	-12.0834	11.80811	-1.02	0.306	-35.2269	11.06003		
Israel									
	lnGDP	7.623783	1.344264	5.67	0	4.989074	10.25849	EKC	
	lnGDP2	-0.32914	0.079848	-4.12	0	-0.48564	-0.17264	$	107,087.31
	lnpop	2.345945	0.410388	5.72	0	1.541598	3.150291		
	renew	0.000253	0.040086	0.01	0.995	-0.07831	0.078819		
	t	-0.05618	0.015946	-3.52	0	-0.08744	-0.02493		
	_cons	-60.5284	7.687469	-7.87	0	-75.5956	-45.4613		
Japan									
	lnGDP	-5.56626	2.306402	-2.41	0.016	-10.0867	-1.04579	U-shaped	
	lnGDP2	0.32522	0.120027	2.71	0.007	0.089972	0.560468	$	5,206.63
	lnpop	1.156653	1.787069	0.65	0.517	-2.34594	4.659243		
	renew	-0.02272	0.011537	-1.97	0.049	-0.04533	-0.00011		
	t	-0.01487	0.006727	-2.21	0.027	-0.02806	-0.00169		
	_cons	23.04472	25.65222	0.9	0.369	-27.2327	73.32216		
Korea, Rep.									
	lnGDP	-1.46673	1.00636	-1.46	0.145	-3.43916	0.505695	U-shaped	
	lnGDP2	0.124193	0.064534	1.92	0.054	-0.00229	0.250676	$	366.90
	lnpop	7.143335	2.19875	3.25	0.001	2.833864	11.45281		
	renew	0.053278	0.050168	1.06	0.288	-0.04505	0.151606		
	t	-0.06427	0.02824	-2.28	0.023	-0.11962	-0.00892		
	_cons	-102.129	35.14694	-2.91	0.004	-171.016	-33.2422		
Sri Lanka									
	lnGDP	0.485091	1.451502	0.33	0.738	-2.3598	3.329983	U-shaped	
	lnGDP2	0.00404	0.084229	0.05	0.962	-0.16105	0.169127	$	0.00
	lnpop	0.400385	2.870971	0.14	0.889	-5.22661	6.027384		
	renew	-0.02025	0.003576	-5.66	0	-0.02725	-0.01324		
	t	0.018873	0.035697	0.53	0.597	-0.05109	0.088838		
	_cons	5.409627	42.44265	0.13	0.899	-77.7764	88.59569		
Luxembourg									
	lnGDP	-5.97599	2.726907	-2.19	0.028	-11.3206	-0.63135	U-shaped	
	lnGDP2	0.290133	0.129441	2.24	0.025	0.036433	0.543833	$	29,694.49
	lnpop	-0.41882	2.183747	-0.19	0.848	-4.69888	3.861248		
	renew	-0.16331	0.08517	-1.92	0.055	-0.33024	0.003616		
	t	0.016408	0.044488	0.37	0.712	-0.07079	0.103602		
	_cons	52.37062	39.13629	1.34	0.181	-24.3351	129.0763		
Morocco									
	lnGDP	2.255023	1.140801	1.98	0.048	0.019094	4.490952	EKC	
	lnGDP2	-0.10263	0.068743	-1.49	0.135	-0.23737	0.032099	$	59,026.37
	lnpop	-0.46419	0.776065	-0.6	0.55	-1.98525	1.056872		
	renew	-0.00931	0.004635	-2.01	0.045	-0.01839	-0.00022		
	t	0.035279	0.012945	2.73	0.006	0.009907	0.060651		
	_cons	13.46551	9.03069	1.49	0.136	-4.23431	31.16534		
Mexico									

	lnGDP	0.696995	5.621771	0.12	0.901	-10.3215	11.71546	EKC	
	lnGDP2	-0.00867	0.310356	-0.03	0.978	-0.61696	0.599616		(too large to include)
	lnpop	0.801495	1.777075	0.45	0.652	-2.68151	4.284497		
	renew	-0.01633	0.011717	-1.39	0.163	-0.03929	0.006635		
	t	0.002507	0.034036	0.07	0.941	-0.0642	0.069216		
	_cons	-0.28614	10.25198	-0.03	0.978	-20.3797	19.80738		
Malaysia									
	lnGDP	2.638475	1.971103	1.34	0.181	-1.22482	6.501765	EKC	
	lnGDP2	-0.07294	0.112708	-0.65	0.518	-0.29384	0.147964	$	71,627,113.48
	lnpop	1.218756	1.417342	0.86	0.39	-1.55918	3.996696		
	renew	-0.02263	0.010978	-2.06	0.039	-0.04414	-0.00111		
	t	-0.02423	0.037784	-0.64	0.521	-0.09828	0.049825		
	_cons	-19.471	15.25092	-1.28	0.202	-49.3622	10.42028		
Norway									
	lnGDP	-7.59983	4.105048	-1.85	0.064	-15.6456	0.445913	U-shaped	
	lnGDP2	0.431453	0.216584	1.99	0.046	0.006955	0.85595	$	6,682.60
	lnpop	5.799098	4.856771	1.19	0.232	-3.72	15.3182		
	renew	-0.00153	0.009523	-0.16	0.872	-0.02019	0.017134		
	t	-0.07951	0.072665	-1.09	0.274	-0.22193	0.062913		
	_cons	-37.3663	80.83576	-0.46	0.644	-195.802	121.0688		
Oman									
	lnGDP	5.015281	5.642282	0.89	0.374	-6.04339	16.07395	EKC	
	lnGDP2	-0.27076	0.296315	-0.91	0.361	-0.85152	0.31001	$	10,526.08
	lnpop	-0.23364	0.430437	-0.54	0.587	-1.07728	0.610005		
	renew	-38.4756	45.49284	-0.85	0.398	-127.64	50.6887		
	t	0.109906	0.024418	4.5	0	0.062049	0.157764		
	_cons	-4.30297	23.10815	-0.19	0.852	-49.5941	40.98817		
Pakistan									
	lnGDP	1.369832	1.289704	1.06	0.288	-1.15794	3.897605	EKC	
	lnGDP2	-0.02921	0.086045	-0.34	0.734	-0.19785	0.139436	$	15,278,052,122.62
	lnpop	1.624358	0.780306	2.08	0.037	0.094986	3.15373		
	renew	0.00094	0.00224	0.42	0.675	-0.00345	0.005331		
	t	-0.01794	0.022034	-0.81	0.416	-0.06112	0.025246		
	_cons	-20.2356	9.588714	-2.11	0.035	-39.0291	-1.44202		
Peru									
	lnGDP	6.077918	2.982609	2.04	0.042	0.232112	11.92372	EKC	
	lnGDP2	-0.34157	0.18186	-1.88	0.06	-0.69801	0.014867	$	7,309.92
	lnpop	-1.02966	1.520756	-0.68	0.498	-4.01029	1.950963		
	renew	-0.03194	0.008185	-3.9	0	-0.04798	-0.01589		
	t	0.05563	0.033809	1.65	0.1	-0.01064	0.121895		
	_cons	8.021852	19.90453	0.4	0.687	-30.9903	47.03401		
Philippines									
	lnGDP	-3.72408	3.202047	-1.16	0.245	-9.99997	2.551822	U-shaped	
	lnGDP2	0.265639	0.202992	1.31	0.191	-0.13222	0.663495	$	1,107.28
	lnpop	6.07186	2.161552	2.81	0.005	1.835295	10.30843		
	renew	-0.03108	0.004286	-7.25	0	-0.03948	-0.02268		
	t	-0.10886	0.057344	-1.9	0.058	-0.22125	0.003535		
	_cons	-76.5525	29.871	-2.56	0.01	-135.099	-18.0064		
Poland									
	lnGDP	-10.6734	1.775763	-6.01	0	-14.1539	-7.19301	U-shaped	
	lnGDP2	0.63442	0.097176	6.53	0	0.443958	0.824882	$	4,500.62
	lnpop	9.205273	0.972974	9.46	0	7.298279	11.11227		
	renew	-0.05607	0.018857	-2.97	0.003	-0.09303	-0.01911		
	t	-0.06215	0.008184	-7.59	0	-0.07819	-0.04611		
	_cons	-95.1765	13.42391	-7.09	0	-121.487	-68.8661		
Portugal									
	lnGDP	0.347858	1.767065	0.2	0.844	-3.11553	3.811241	U-shaped	
	lnGDP2	0.051975	0.100567	0.52	0.605	-0.14513	0.249082	$	0.04
	lnpop	-0.36036	0.889411	-0.41	0.685	-2.10357	1.382851		
	renew	-0.01089	0.002823	-3.86	0	-0.01643	-0.00536		
	t	-0.02217	0.008817	-2.51	0.012	-0.03945	-0.00489		
	_cons	16.1271	18.88741	0.85	0.393	-20.8916	53.14574		
Qatar									
	lnGDP	29.14648	19.75761	1.48	0.14	-9.57773	67.8707	EKC	
	lnGDP2	-1.30288	0.886621	-1.47	0.142	-3.04062	0.434869	$	72,073.30
	lnpop	0.159811	0.295224	0.54	0.588	-0.41882	0.738439		
	renew	2.055935	1.900371	1.08	0.279	-1.66872	5.780593		
	t	0.077857	0.013502	5.77	0	0.051394	0.104319		
	_cons	-148.746	113.061	-1.32	0.188	-370.342	72.8491		
Romania									

	lnGDP	-0.78359	1.794317	-0.44	0.662	-4.30038	2.733208	U-shaped	
	lnGDP2	0.095094	0.097379	0.98	0.329	-0.09576	0.285952	$	61.56
	lnpop	3.744388	0.665669	5.63	0	2.439701	5.049076		
	renew	-0.01793	0.006121	-2.93	0.003	-0.02992	-0.00593		
	t	-0.03435	0.003946	-8.71	0	-0.04208	-0.02662		
	_cons	-44.3619	8.382762	-5.29	0	-60.7918	-27.932		
Saudi Arabia									
	lnGDP	-21.8471	7.652077	-2.86	0.004	-36.8449	-6.84931	U-shaped	
	lnGDP2	1.088656	0.372562	2.92	0.003	0.358449	1.818864	$	22,787.73
	lnpop	1.933331	0.587029	3.29	0.001	0.782775	3.083888		
	renew	-14.0795	11.78179	-1.2	0.232	-37.1714	9.012361		
	t	-0.02355	0.021251	-1.11	0.268	-0.0652	0.018103		
	_cons	97.19992	36.90305	2.63	0.008	24.87127	169.5286		
Singapore									
	lnGDP	2.841486	4.132028	0.69	0.492	-5.25714	10.94011	U-shaped	
	lnGDP2	-0.13673	0.231403	-0.59	0.555	-0.59027	0.31681	$	32,558.35
	lnpop	4.915707	1.867146	2.63	0.008	1.256168	8.575246		
	renew	0.559086	1.163537	0.48	0.631	-1.72141	2.839576		
	t	-0.0974	0.076961	-1.27	0.206	-0.24824	0.053443		
	_cons	-69.5416	27.39118	-2.54	0.011	-123.227	-15.8558		
Sweden									
	lnGDP	-2.10745	1.057318	-1.99	0.046	-4.17976	-0.03515	EKC	
	lnGDP2	0.104092	0.055352	1.88	0.06	-0.0044	0.212579	$	24,910.51
	lnpop	-1.51653	1.381252	-1.1	0.272	-4.22374	1.190671		
	renew	-0.00967	0.002766	-3.5	0	-0.01509	-0.00425		
	t	0.014252	0.016116	0.88	0.377	-0.01733	0.045838		
	_cons	53.12106	24.84563	2.14	0.033	4.424524	101.8176		
Thailand									
	lnGDP	0.706396	2.513524	0.28	0.779	-4.22002	5.632813	U-shaped	
	lnGDP2	0.012929	0.150297	0.09	0.931	-0.28165	0.307505	$	0.00
	lnpop	2.395649	2.506431	0.96	0.339	-2.51687	7.308164		
	renew	-0.03682	0.009193	-4	0	-0.05483	-0.0188		
	t	-0.01147	0.030594	-0.37	0.708	-0.07143	0.048497		
	_cons	-30.6768	34.1785	-0.9	0.369	-97.6654	36.31183		
Trinidad and Tobago									
	lnGDP	-4.7349	0.957641	-4.94	0	-6.61184	-2.85796	U-shaped	
	lnGDP2	0.298626	0.048761	6.12	0	0.203056	0.394197	$	2,773.34
	lnpop	4.25139	1.316489	3.23	0.001	1.67112	6.83166		
	renew	-0.16207	0.559972	-0.29	0.772	-1.25959	0.93546		
	t	-0.02789	0.01274	-2.19	0.029	-0.05286	-0.00292		
	_cons	-23.8901	19.38695	-1.23	0.218	-61.8878	14.10763		
Turkey									
	lnGDP	2.739524	0.926597	2.96	0.003	0.923427	4.555621	EKC	
	lnGDP2	-0.09453	0.047986	-1.97	0.049	-0.18858	-0.00048	$	1,964,155.90
	lnpop	1.592628	1.217179	1.31	0.191	-0.793	3.978255		
	renew	-0.00695	0.002914	-2.38	0.017	-0.01266	-0.00124		
	t	-0.02012	0.017608	-1.14	0.253	-0.05464	0.014388		
	_cons	-25.8719	17.40264	-1.49	0.137	-59.9805	8.236603		
United States									
	lnGDP	-0.25213	0.648387	-0.39	0.697	-1.52295	1.018681	U-shaped	
	lnGDP2	0.047588	0.036792	1.29	0.196	-0.02452	0.119699	$	14.14
	lnpop	1.52311	0.485292	3.14	0.002	0.571956	2.474264		
	renew	-0.0136	0.00597	-2.28	0.023	-0.0253	-0.0019		
	t	-0.02447	0.008006	-3.06	0.002	-0.04016	-0.00878		
	_cons	-8.85001	9.463091	-0.94	0.35	-27.3973	9.697309		
Venezuela, RB									
	lnGDP	-3.18511	5.394817	-0.59	0.555	-13.7588	7.388539	U-shaped	
	lnGDP2	0.160111	0.282776	0.57	0.571	-0.39412	0.714342	$	20,880.96
	lnpop	6.462749	1.088851	5.94	0	4.32864	8.596859		
	renew	-0.03728	0.011356	-3.28	0.001	-0.05954	-0.01502		
	t	-0.07331	0.018648	-3.93	0	-0.10986	-0.03676		
	_cons	-72.5257	30.44535	-2.38	0.017	-132.198	-12.8539		
Vietnam									
	lnGDP	3.835106	2.072432	1.85	0.064	-0.22679	7.896998	EKC	
	lnGDP2	-0.22829	0.154602	-1.48	0.14	-0.53131	0.07472	$	4,444.88
	lnpop	-5.39258	3.05166	-1.77	0.077	-11.3737	0.588566		
	renew	-0.02076	0.004339	-4.79	0	-0.02927	-0.01226		
	t	0.15243	0.07698	1.98	0.048	0.001551	0.303308		
	_cons	97.61429	47.80577	2.04	0.041	3.916713	191.3119		

South Africa

lnGDP	|	1.677205	5.245283	0.32	0.749	-8.60336	11.95777	EKC
lnGDP2	|	-0.00246	0.296015	-0.01	0.993	-0.58264	0.577715	(too large to include)
lnpop	|	3.52107	1.054469	3.34	0.001	1.454348	5.587792	
renew	|	0.023386	0.036654	0.64	0.523	-0.04845	0.095226	
t	|	-0.0794	0.025364	-3.13	0.002	-0.12911	-0.02969	
_cons	|	-55.1374	14.25897	-3.87	0	-83.0845	-27.1904	

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8.4: Robustness Tests:

Analyzing the robustness of the preferred EKC models, I tested whether changing the functional form of other variables in the model changes the results. Specifically, I tested if including a quadratic, rather than linear, time trend changed the results. Additionally, I checked if the including a quadratic, rather than linear population control variable changed the EKC results. My findings are in Table 49 and Table 50. They suggest that the results are largely unchanged. The signs of the coefficients are unchanged in all models except for the one using the AMG-1 estimator for Developed countries and when including the nonlinear time trend. The income variables remain jointly significant in all cases. The nonlinear time trend coefficients are not jointly significant except for when considering developed countries. The nonlinear population coefficients are not jointly significant in any of the cases.

Table 47: Robustness Analysis Testing for a Quadratic Time Trend

VARIABLES	**Full Panel** CCEMG 1	**Developed** CCEMG 2	**Developing** CCEMG 3	**Full Panel** AMG 1	**Developed** AMG 2	**Developing** AMG 3	**Full Panel** AMG-1 1	**Developed** AMG-1 2	**Developing** AMG-1 3
lnGDP	2.235	-2.470	2.082	2.828*	-0.235	3.986**	2.392*	0.570	3.958**
	(1.818)	(2.601)	(2.139)	(1.458)	(1.397)	(1.950)	(1.302)	(1.132)	(1.895)
lnGDP2	-0.0929	0.167	-0.0772	-0.111	0.0414	-0.175*	-0.0858	2.97e-06	-0.169*
	(0.0978)	(0.128)	(0.124)	(0.0747)	(0.0724)	(0.104)	(0.0682)	(0.0586)	(0.101)
lnpop	-1.751	-0.427	-2.455	-0.245	1.009	-0.540	0.0227	0.314	-0.153
	(1.546)	(1.385)	(1.732)	(0.895)	(1.158)	(1.414)	(0.874)	(1.206)	(1.330)
renew	-2.404	-0.0300**	-3.287	-2.091	-0.0314**	-3.338	-2.125	-0.0298**	-3.294
	(1.763)	(0.0127)	(2.266)	(1.689)	(0.0140)	(2.676)	(1.742)	(0.0139)	(2.658)
t	0.0657	0.0150	0.0656	-0.0104	-0.0306**	0.00740	-0.0159	-0.0305**	-0.00404
	(0.0526)	(0.0184)	(0.0569)	(0.0243)	(0.0123)	(0.0402)	(0.0207)	(0.0123)	(0.0344)
t2	-0.000318	0.000348	-0.000330	0.000381	0.000344	0.000315	0.000315	0.000360	0.000288
	(0.000470)	(0.000356)	(0.000535)	(0.000289)	(0.000290)	(0.000401)	(0.000227)	(0.000281)	(0.000317)
f				1.045***	0.957***	1.097***			
				(0.168)	(0.136)	(0.289)			
t				0	0	0	0	0	0
				(0)	(0)	(0)	(0)	(0)	(0)
Constant	36.26	43.65	45.38	7.721	1.086	8.286	4.979	8.371	1.751
	(39.23)	(43.46)	(39.23)	(17.04)	(21.94)	(25.31)	(15.83)	(21.75)	(23.30)
Observations	2,035	814	1,221	2,035	814	1,221	2,035	814	1,221
Number of ID_1	55	22	33	55	22	33	55	22	33
Test for joint significance t, t2, (Prob>chi2)=	0.2489	0.0185	0.3959	0.2188	0.0007	0.3293	0.3226	0.0020	0.3929
Test for joint significance lnGDP, lnGDP2, (Prob>chi2)=	0.0256	0.0000	0.0171	0.0001	0.0000	0.0039	0.0000	0.0000	0.0000
Turning Point (Local min. for Developed Countries)	$168,577.08	$1,620.88	$718,665.78	$341,384.48	$17.13	$89,323.22	$113,5019.8	$0	$124,269.46

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 48: Robustness Analysis Testing for a Quadratic Population

VARIABLES	**Full Panel** CCEMG 1	**Developed** CCEMG 2	**Developing** CCEMG 3	**Full Panel** AMG 1	**Developed** AMG 2	**Developing** AMG 3	**Full Panel** AMG-1 1	**Developed** AMG-1 2	**Developing** AMG-1 3
lnGDP	2.869**	-1.532	1.366	1.371	-0.898	2.941*	1.380	-0.143	3.152*
	(1.315)	(1.692)	(1.758)	(1.258)	(1.329)	(1.638)	(1.253)	(1.272)	(1.779)
lnGDP2	-0.125*	0.118	-0.0374	-0.0389	0.0717	-0.125	-0.0381	0.0348	-0.132
	(0.0706)	(0.0863)	(0.0921)	(0.0658)	(0.0686)	(0.0895)	(0.0657)	(0.0656)	(0.0956)
lnpop	-53.49	-273.8	58.70	86.69	207.4	-24.68	99.68	203.5	-21.19
	(114.3)	(310.8)	(101.8)	(116.1)	(281.6)	(56.57)	(113.8)	(298.9)	(58.19)
lnpop2	1.739	8.451	-1.602	-2.675	-6.554	0.821	-3.131	-6.679	0.738
	(3.375)	(9.186)	(2.857)	(3.454)	(8.300)	(1.616)	(3.412)	(8.923)	(1.643)
renew	-0.589	-0.0379**	-0.270	-2.238	-0.0350*	-3.765	-2.535	-0.0315*	-4.017
	(0.543)	(0.0175)	(0.276)	(1.859)	(0.0185)	(3.126)	(2.137)	(0.0184)	(3.364)
t	0.0390	0.00952	0.0756**	0.00153	-0.0228***	0.0245	0.00125	-0.0239***	0.0187
	(0.0390)	(0.0142)	(0.0381)	(0.0146)	(0.00784)	(0.0259)	(0.0144)	(0.00792)	(0.0251)
c				0.991***	0.952***	0.921***			
				(0.133)	(0.144)	(0.211)			
t				0	0	0	0	0	0
				(0)	(0)	(0)	(0)	(0)	(0)
Constant	295.4	2,094	-636.7	-697.8	-1,605	173.6	-789.6	-1,510	135.9
	(1,029)	(2,746)	(967.3)	(984.0)	(2,408)	(501.5)	(957.4)	(2,525)	(522.6)
Observations	2,035	814	1,221	2,035	814	1,221	2,035	814	1,221
Number of ID_1	55	22	33	55	22	33	55	22	33
Test for joint significance lnpop, lnpop2, (Prob>chi2)=	0.7430	0.5668	0.8424	0.6908	0.5373	0.6447	0.5675	0.4766	0.5933
Test for joint significance lnGDP, lnGDP2, (Prob>chi2)=	0.0028	0.0000	0.0347	0.0002	0.0000	0.0067	0.0000	0.0000	0.0005
Turning Point (Local min. for Developed Countries)	$94,653.13	$657.34	$83,767,678	$44,158,898	$522.70	$134,539.93	$72,855,300	$7.80	$155,035.94

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

8.5: D-H Granger Non-causality test results

Panel 1 (Full Panel)

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.7913
Z-bar = 4.1498 (p-value = 0.0000)
Z-bar tilde = 3.3859 (p-value = 0.0007)

H0: d_lnGDP does not Granger-cause d_ln$CO2$.
H1: d_lnGDP does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.2391
Z-bar = 1.2540 (p-value = 0.2098)
Z-bar tilde = 0.8058 (p-value = 0.4204)

H0: d_ln$CO2$ does not Granger-cause d_lnGDP.
H1: d_ln$CO2$ does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.4059
Z-bar = 2.1285 (p-value = 0.0333)
Z-bar tilde = 1.5849 (p-value = 0.1130)

H0: d_lnpop does not Granger-cause d_ln$CO2$.
H1: d_lnpop does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.2608
Z-bar = 1.3677 (p-value = 0.1714)
Z-bar tilde = 0.9071 (p-value = 0.3643)

H0: d_ln$CO2$ does not Granger-cause d_lnpop.
H1: d_ln$CO2$ does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.2504
Z-bar = 6.5572 (p-value = 0.0000)
Z-bar tilde = 5.5308 (p-value = 0.0000)

H0: d_renew does not Granger-cause d_ln$CO2$.
H1: d_renew does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.6904
Z-bar = 3.6203 (p-value = 0.0003)
Z-bar tilde = 2.9142 (p-value = 0.0036)

H0: d_ln$CO2$ does not Granger-cause d_renew.
H1: d_ln$CO2$ does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.8821
Z-bar = 9.8698 (p-value = 0.0000)
Z-bar tilde = 8.4824 (p-value = 0.0000)

H0: d_lnpop does not Granger-cause d_lnGDP.
H1: d_lnpop does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.6226
Z-bar = 8.5089 (p-value = 0.0000)
Z-bar tilde = 7.2698 (p-value = 0.0000)

H0: d_lnGDP does not Granger-cause d_lnpop.
H1: d_lnGDP does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.2606
Z-bar = 1.3667 (p-value = 0.1717)
Z-bar tilde = 0.9062 (p-value = 0.3648)

H0: d_renew does not Granger-cause d_lnGDP.
H1: d_renew does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.5574
Z-bar = 2.9228 (p-value = 0.0035)
Z-bar tilde = 2.2927 (p-value = 0.0219)

H0: d_lnGDP does not Granger-cause d_renew.
H1: d_lnGDP does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.2326
Z-bar = 1.2197 (p-value = 0.2226)
Z-bar tilde = 0.7753 (p-value = 0.4382)

H0: d_renew does not Granger-cause d_lnpop.
H1: d_renew does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.7749
Z-bar = 4.0638 (p-value = 0.0000)
Z-bar tilde = 3.3092 (p-value = 0.0009)

H0: d_lnpop does not Granger-cause d_renew.
H1: d_lnpop does Granger-cause d_renew for at least one panelvar (ID_1).

Panel 2:

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.3202
Z-bar = 1.3006 (p-value = 0.1934)
Z-bar tilde = 0.9175 (p-value = 0.3589)

H0: d_lnGDP does not Granger-cause d_ln$CO2$.
H1: d_lnGDP does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 0.9838
Z-bar = -0.0657 (p-value = 0.9476)
Z-bar tilde = -0.2999 (p-value = 0.7643)

H0: d_ln$CO2$ does not Granger-cause d_lnGDP.
H1: d_ln$CO2$ does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.4535
Z-bar = 1.8422 (p-value = 0.0654)
Z-bar tilde = 1.4001 (p-value = 0.1615)

H0: d_lnpop does not Granger-cause d_ln$CO2$.
H1: d_lnpop does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 0.6886
Z-bar = -1.2650 (p-value = 0.2059)
Z-bar tilde = -1.3684 (p-value = 0.1712)

H0: d_ln$CO2$ does not Granger-cause d_lnpop.
H1: d_ln$CO2$ does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.8026
Z-bar = 3.2602 (p-value = 0.0011)
Z-bar tilde = 2.6635 (p-value = 0.0077)

H0: d_renew does not Granger-cause d_ln$CO2$.
H1: d_renew does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.4667
Z-bar = 1.8959 (p-value = 0.0580)
Z-bar tilde = 1.4480 (p-value = 0.1476)

H0: d_ln$CO2$ does not Granger-cause d_renew.
H1: d_ln$CO2$ does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.2637
Z-bar = 5.1333 (p-value = 0.0000)
Z-bar tilde = 4.3324 (p-value = 0.0000)

H0: d_lnpop does not Granger-cause d_lnGDP.
H1: d_lnpop does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.9677
Z-bar = 3.9308 (p-value = 0.0001)
Z-bar tilde = 3.2610 (p-value = 0.0011)

H0: d_lnGDP does not Granger-cause d_lnpop.
H1: d_lnGDP does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.0367
Z-bar = 0.1490 (p-value = 0.8816)
Z-bar tilde = -0.1085 (p-value = 0.9136)

H0: d_renew does not Granger-cause d_lnGDP.
H1: d_renew does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.1199
Z-bar = 0.4872 (p-value = 0.6261)
Z-bar tilde = 0.1928 (p-value = 0.8471)

H0: d_lnGDP does not Granger-cause d_renew.
H1: d_lnGDP does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.1247
Z-bar = 0.5067 (p-value = 0.6124)
Z-bar tilde = 0.2102 (p-value = 0.8335)

H0: d_renew does not Granger-cause d_lnpop.
H1: d_renew does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.6323
Z-bar = 2.5683 (p-value = 0.0102)
Z-bar tilde = 2.0471 (p-value = 0.0407)

H0: d_lnpop does not Granger-cause d_renew.
H1: d_lnpop does Granger-cause d_renew for at least one panelvar (ID_1).

Panel 3

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.4981
Z-bar = 4.9686 (p-value = 0.0000)
Z-bar tilde = 4.2299 (p-value = 0.0000)

H0: d_lnGDP does not Granger-cause d_ln$CO2$.
H1: d_lnGDP does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.6221
Z-bar = 2.0633 (p-value = 0.0391)
Z-bar tilde = 1.6413 (p-value = 0.1007)

H0: d_ln$CO2$ does not Granger-cause d_lnGDP.
H1: d_ln$CO2$ does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.3344
Z-bar = 1.1092 (p-value = 0.2673)
Z-bar tilde = 0.7913 (p-value = 0.4288)

H0: d_lnpop does not Granger-cause d_ln$CO2$.
H1: d_lnpop does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.1192
Z-bar = 3.7119 (p-value = 0.0002)
Z-bar tilde = 3.1103 (p-value = 0.0019)

H0: d_ln$CO2$ does not Granger-cause d_lnpop.
H1: d_ln$CO2$ does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.9221
Z-bar = 6.3749 (p-value = 0.0000)
Z-bar tilde = 5.4829 (p-value = 0.0000)

H0: d_renew does not Granger-cause d_ln$CO2$.
H1: d_renew does Granger-cause d_ln$CO2$ for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.0258
Z-bar = 3.4022 (p-value = 0.0007)
Z-bar tilde = 2.8343 (p-value = 0.0046)

H0: d_ln$CO2$ does not Granger-cause d_renew.
H1: d_ln$CO2$ does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 3.8097
Z-bar = 9.3186 (p-value = 0.0000)
Z-bar tilde = 8.1057 (p-value = 0.0000)

H0: d_lnpop does not Granger-cause d_lnGDP.
H1: d_lnpop does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 3.6049
Z-bar = 8.6395 (p-value = 0.0000)
Z-bar tilde = 7.5006 (p-value = 0.0000)

H0: d_lnGDP does not Granger-cause d_lnpop.
H1: d_lnGDP does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.5965
Z-bar = 1.9785 (p-value = 0.0479)
Z-bar tilde = 1.5658 (p-value = 0.1174)

H0: d_renew does not Granger-cause d_lnGDP.
H1: d_renew does Granger-cause d_lnGDP for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 2.2135
Z-bar = 4.0246 (p-value = 0.0001)
Z-bar tilde = 3.3889 (p-value = 0.0007)

H0: d_lnGDP does not Granger-cause d_renew.
H1: d_lnGDP does Granger-cause d_renew for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.3944
Z-bar = 1.3080 (p-value = 0.1909)
Z-bar tilde = 0.9684 (p-value = 0.3329)

H0: d_renew does not Granger-cause d_lnpop.
H1: d_renew does Granger-cause d_lnpop for at least one panelvar (ID_1).

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = 1.9889
Z-bar = 3.2798 (p-value = 0.0010)
Z-bar tilde = 2.7253 (p-value = 0.0064)

H0: d_lnpop does not Granger-cause d_renew.
H1: d_lnpop does Granger-cause d_renew for at least one panelvar (ID_1).