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Meta-Analysis of Environmental Kuznets Curve Studies: Determining the Cause of the Curve's Presence

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Abstract

This investigation uses meta-analysis to explore the systematic variation across Environmental Kuznets Curve (EKC) studies to better understand the specific factors that affect the relationship between economic growth and environmental quality. Meta-analysis is the statistical synthesis of data from a set of comparable studies yielding a quantitative summary of pooled results. Following the findings of Li et al., (2007) a multinomial logit model is employed to analyze 929 observations from 120 different studies published between 1992 and 2012. Results indicate that seven variables (time, quality, emissions, development, fitness, anthropogenic-related gases, carbon dioxide, and sulfur dioxide) significantly affect the presence of the EKC. There is no statistically significant evidence indicating an increased or decreased probability of finding an EKC from the number of observations, panel data, global aspect, reverse publication date, GDP measures, chemically active gases, biologically related gases, nitrogen oxide, and air pollution.

Keywords: Environmental Kuznets Curve, Meta-Analysis
JEL Classification Codes: C59, O29, Q53

I. Introduction

Worldwide public concern over the quality of our environment has ignited large efforts toward finding the determinants of environmental degradation. The Environmental Kuznets Curve (EKC) hypothesis has become a hotly contested topic in recent years. This concept hypothesizes the relationship between per capita income and the level of environmental degradation in an economy. In early stages of economic growth, environmental degradation and pollution increase. After a certain level of per capita income, the trend reverses and environmental degradation decreases, leading to environmental improvement. This suggests that the relationship is an inverted U-shape. This relationship suggests that economic growth is necessary for environmental quality to be maintained or improved. Following the initial work of Grossman and Krueger (1991), who first described the EKC, a deeper understanding of the empirical relationship between income and environmental quality has been rapidly evolving through further studies of the EKC hypothesis.

The presence (i.e. Nasir, 2011; Lee, 2010; Poudel, 2009) and absence (i.e. He, 2012; Aslanidis, 2009; Brajer, 2008) of the EKC in a variety of empirical studies has spurred a debate over its relevance. The EKC literature includes many studies that employ different methods, evaluate different environmental indicators, and use different data, resulting in a broad spectrum of findings leading to conflicting interpretations. To date, there have been a limited number of attempts of systematically surveying the EKC literature using meta-analysis to discover the breadth of the curve's applicability.

Since 1991, the EKC has become a standard feature in environmental policy, though its application as an effective tool for policy implementation has been seriously questioned (Roberts and Thanos, 2003). Policy makers could be able to depend on the EKC as a core tool for

controlling environmental quality if economists could predict the types of data sets that would follow a true EKC. Uncertainty lies in the question of whether results from previous research can be used in the policy formation process. Intuitively, if developed economies pollute the environment less, then policies that stimulate economic growth should lead to less environmental degradation. However, this does not imply developed economies may never face environmental concerns in the future. Industrialized societies must consider the possibility they are not progressively improving all environmental degradation with the rise of income, but may be reducing only some easily measured pollutants when other threats exist (Dasgupta et al., 2002).

Cavlovic et al. (2000) conducted the first meta-analysis of the EKC hypothesis, using a compilation of EKC studies from the early 1990s. They analyzed 25 studies using 155 observations and considered 11 different environmental degradation measures. Their study found that methodological choices can significantly influence results [i.e. the magnitude of an income turning point (ITP).] A second meta-analysis has since been conducted by Li et al., (2007) adding 52 studies to the original Cavlovic et al. (2000) dataset, providing a total of 588 observations. This study looked at two broad categories of greenhouse gases: anthropogenic activity-related gases (i.e. CO_2, CH_4, N_2O, PFC, HFC and SF_6), and chemically-active gases (i.e. SO_2 or gases that can hinder the formation of other greenhouse gases through chemical interaction). Li et al. (2007) ultimately found no statistically significant evidence that supports the EKC for anthropogenic activity-related gases, but they did find that longer time periods, panel data, and global data all significantly increase the probability of finding a significant EKC pattern. For this study, I update the Li et al. (2007) dataset to include 120 papers providing a total of 929 observations. The focus of this paper is to determine if adding additional EKC studies will yield further insight into what factors can affect the presence of an EKC relationship.

The remainder of this paper is organized as follows: section II discusses published EKC studies, section III reviews the meta-analysis process, section IV explains the data being used, section V describes the model being used, section VI discusses empirical results, and section VII provides a detailed conclusion and possible policy implications.

II. Literature Review

The EKC hypothesis was made popular by the World Bank's *World Development Report 1992,* which argued that greater economic activity inevitably hurts the environment based on status assumptions of technology, tastes, and environmental investments (WRI, 1992). This report postulates that as a nation's income increases, the demand for improvements in a nation's environmental quality increases, as well as resources for available investment to improve the environment. Others have claimed that economic growth leads to environmental degradation in the earlier stages of growth, meaning the only way to attain a healthy environment is to become rich (Beckerman, 1992). Stern (2003) hypothesizes that at higher levels of development, structural change within the economy towards information-intensive industries, services, increased awareness of the environment, enforcement of regulations, and improved technology result in the decline of degradation. These findings suggest a number of causes for the EKC relationship, including environmentally friendly economies of scale in production, changes in product mix, changes in technology, changes in input mix, and underlying social considerations such as regulations, awareness, and education.

The economies of scale, concept, implies that as an economy grows, all activities will increase proportionally to the amount of growth, (i.e. pollution will increase proportionally with economic growth). In earlier phases of development, output mix changes causing a shift away from agriculture moving towards heavy industrial production leading to increased emission.

However, in later stages, an economy shifts to less resource intensive services and lighter manufacturing leasing to decreased emissions resulting in less environmental degradation (Stern, 2003). Input mix is the idea of substituting less environmentally damaging inputs for more environmentally damaging inputs and vice versa (Stern, 2003). Changes in technology increase levels of productivity, where being more productive should result in less pollutants being emitted per unit of output (Stern, 2003). Emissions process changes can result in less pollutants being emitted due to innovations directly related to lowering emissions. Policies developed after pollution occurs become an issue as they can lead to a fall in environmental degradation. Education and information accessibility may also help determine environmental quality (Dinda, 2004). All of these concepts support the inverse U-shape of the EKC as an economy develops.

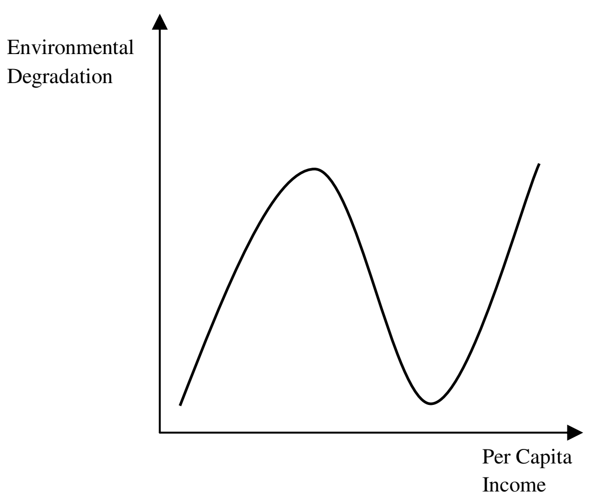

Fig. 1. N-Shaped Environmental Kuznets Curve

Many empirical studies in recent years have tested the EKC hypothesis through different environmental indicators, countries, regions, and econometric techniques (Ekins, 1997), finding conflicting results. Several studies focusing on the same pollution type have revealed contradicting results of an EKC's presence when comparing pollution and income (Aslandis and Iranzo, 2009; Poudel, 2009). One specific study by Aslandis and Iranzo (2009) examined CO_2 emissions of multiple countries from 1971 to 1997. Statistical evidence was not found supporting the presence of an EKC due to CO_2 emissions. On the contrary, Poudel (2009) found an N-shaped curve using 15 Latin American countries using CO_2 emissions. An N-shaped curve

is the same as the standard EKC shape except after environmental degradation falls, pollution begins to increase again and the curve begins an upward trend(see figure 1). These two studies demonstrate that conflicting results can be found in EKC literature. Contradictory results also lend support that a meta-analysis should be done to statistically summarize the literature in an effort to find out which factors can lead to the presence or absence of the curve.

In addition to the problem of contradictory results, many studies are conducted using large panel data sets where multiple countries are grouped together with different socio-demographic characteristics. As explained by Galeotti et al., (2009) this omission of relevant explanatory variables can skew the results. Past literature reflects the testing of the EKC over a variety of demographics. Many pieces of literature show that the country being studied truly affects the relationship between income and environmental degradation (i.e. Leitão, 2010; Lee et al., 2010; and Fodha and Zaghdoud, 2010). In Lee et al. (2010), water pollution was investigated finding that an inverted U-shaped curve existed for America and Europe but not for Asian and Oceania countries. In contrast Fodha and Zaghdoud (2010) do find evidence of an inverted U-shaped curve for SO_2 in their study except for the country Tunisia. Lastly, Leitão (2010) found evidence of an inverted U-shaped curve for SO_2 using data from 94 countries with a wide range of economic development. Once again, different findings using different country specific data demonstrates the wide variation in the EKC literature.

In order to look through the multitude of EKC studies and summarize the literature, Cavlovic et al. (2000) and Li et al. (2007) utilized a meta-analysis to investigate empirical EKC studies from 1992 to 2001 and updating to 2005 respectively. These two meta-analyses were the first attempt to fill that gap of reasoning behind the presence or absence of an EKC. Since this time, many new studies have been conducted to investigate the EKC hypothesis. This paper

updates the Li et al. (2007) meta-analysis further, investigating which variables can have an effect on the presence or absence of an EKC.

III. Meta-Regression Analysis

A meta-analysis is a statistical approach used to integrate the findings of a large collection of results among different empirical studies. The purpose of a meta-analysis is to reach meaningful conclusions relative to past literature on a particular subject and further explain the reasoning for a variation of results. Observations from each study are individually collected and transcribed based upon the results of the studies. Each explanatory variable is a characteristic of an individual observation (i.e. pollution type, GDP, developed country, etc.) which is then aggregated into a single database to be analyzed. The following five steps explain the process of conducting a meta-analysis:

Step 1: Variable Determination

The first step is to decide what specific variables will be collected and used from past studies in order to formulate a database. The list of variables must be relative to the theory and also be present in the studies being analyzed. Because this study furthers the exploration of determining factors influencing the presence or absence of an EKC, the variables used in Li et al., (2007) are replicated in addition to six other variables, QUALITY, REVPUBDATE, CO2, SO2, NOX, and AIRPOL. QUALITY and REVPUBDATE are added as a measure for quality control following the recommendation of Loomis (2011) with the remaining variables included to investigate pollutants in more detail. This study is conducted with the intent to find significant factors that affect the EKC by adding current findings to Li et al., (2007).

Step 2: Identify the Literature to be Analyzed

The next step is to identify what literature will be used in relation to the topic of the meta-analysis. A set of criteria is created to filter through the abundance of literature published about the subject matter. Because this study looks at all available findings about the EKC, all empirically based EKC studies are used. For the purpose of this paper, both peer reviewed and non-peer reviewed empirical studies from the year 2012 and prior are collected and used. Only empirical studies can be used because theoretical studies do not produce the variables needed for a meta-analysis. For example, theoretical papers do not provide any empirical evidence or resulting pattern that is needed for the curve shape variable of the meta-analysis. A total of 120 studies published between the years 1992 and 2012 were collected for this study.

Step 3: Identify Individual Observations in Each Study

Now that the list of variables and collection of literature are complete, individual observations from each of the studies must be identified. The unit of observation is "a study." Each of the studies produce values for the variables defined in step 1. One single study is not limited to any number of observations. That is, one study can easily produce 15 different observations. For an example of what multiple observations look like, refer to Table 1.

Table 1. Sample of Dataset

AUTHOR	RELATION	LNOBS	LNTIME	PANEL	GLOBE	EMISSION	GDP	DEVLPED
Song	1	1.099	2.996	1	0	1	1	1
Song	1	1.099	2.996	1	0	0	1	1
Song	1	1.099	2.996	1	0	0	1	1
Biagliani	3	1.792	0	1	1	1	1	0
Biagliani	3	1.792	0	1	1	1	1	0
Biagliani	3	1.792	0	1	1	1	1	0

Table 1 displays part of a meta-analysis dataset. Notice the study by Song, (2008) fills up three rows of data. The three rows of values show three different observations pulled from

their published study. In Song et al., 2008, three different types of pollution were tested: waste gas, waste water and solid wastes. These different pollutants qualify for separate observations within one study because they affect the value of the EMISSION variable. Only one pollutant can be considered at a single time, so the study must be broken down by pollution types.

Step 4: Transcribing the Data

After identifying every individual observation, the data collected from each study must be assigned a value and coded into the dataset. The majority of the variables in Table 2 are indicator variables, demonstrating the presence or absence of a variable. The other variables hold actual values, i.e. LNTIME and LNOBS where LNTIME is the natural log of the number of years a given study is based upon and LNOBS is the natural log of the total number of observations from a given study. For example, if a study has 12 years of data tested, then the value assigned to the YEARS variable is 12. The Song et al., (2008) study in Table 1 displays a 1 for EMISSION meaning that for this specific study and observation, the pollution being observed is a form of emissions; a zero would mean the pollutant is not an emission. This type of transcribing is done for each of the 120 studies used in this analysis.

Step 5: Statistical Estimation

The last step of a meta-analysis is to apply a statistical model to test the magnitude of each of the variables upon the dependent variable. The common technique utilized is a multinomial logit model (MNL). A MNL is a binary choice model used to predict probabilities of different possible outcomes of a categorically distributed dependent variable, given a set of independent variables.

IV. Data Description

The most recent EKC meta-analysis (Li et al., 2007) contained 77 studies and 588 observations. These studies included published papers (83%), book chapters (4%), and working manuscripts (13%). This study builds on Li et al., (2007) by adding 50 additional studies to compile 341 additional observations resulting in a total of 120 studies and 929 observations.

The dependent variable used for this study is a trichotomous categorical response variable titled RELATION as shown in Table 2. There are seven types of relationship variables that are identified: (1) monotonic increasing, (2) monotonic decreasing, (3) inverted U-shape (EKC), (4) U-shape, (5) N-Shaped, (6) insignificance (INSIG)[1], and (7) none[2]. The seven types of curves are grouped into three main categories used in the econometric estimation. Ultimately, the three categories representing the type of curve are used as the dependent variable. The first category is when environmental quality improves (IMPROVE) (i.e. categories 1 and 3), the second category is when results show evidence of an EKC curve but are insignificant (INSIG) (i.e. category 6), and the third category (ELSE), is every other relationship including no relationship at all (i.e. categories 2, 4, 5, and 7). To define each of the three relationships further, IMPROVE means the level of pollution decreases as an economy grows, meaning environmental quality is improving. Studies resulting in insignificant EKCs are a part of the INSIG category, and observations with no relationship or any other pattern not in the previous two categories fall in the ELSE category. These groups are summarized into the three RELATION groups which represent the dependent variable in the MNL.

The explanatory variables found in Table 2 are derived from the studies examined and transcribed into the database. The explanatory variables are grouped into four different

[1] Insignificance means that the estimated coefficients have consistent signs for an EKC relationship to be existent, but the results are not statistically significant in the observation used from empirical results.
[2] None refers to when no relationship exists.

Table 2. Descriptive Statistics for Model Variables

	Variable	Descriptions	Mean (Std. Dev.)
Dependent Variables	RELATION	Indicator variable of the environment-income relationship. If an inverted U-shape or a monotonically declining trend is found the n=1; if an insignificant inverted U-shape exists the =2; else=3.	1.726 (0.925)
Data-Related	LNOBS	Logarithm of the number of observations.	5.368 (1.856)
	LNTIME	Logarithm of the data coverage period.	2.661 (1.310)
	PANEL	Indicator variable of the data in the study; if panel data is used then PANEL=1, else=0.	0.780 (0.414)
	GLOBE	Indicator variable of using multi-country data; if yes GLOBE=1; else=0.	0.640 (0.480)
	QUALITY	Indicator variable of whether data comes from a published study or not; if yes, QUALITY=1; else=0.	0.870 (0.480)
	REVPUBDATE	Number of years since publication date.	0.640 (0.337)
Variable Controls	EMISSION	Indicator variable of using emission as the pollution measurement; if yes, EMISSION=1; else=0.	0.808 (0.397)
	GDP	Indicator variable of using GDP as the income measurement in a study; if yes, GDP=1; else=0.	0.582 (0.493)
	DEVLPED	Indicator variable of whether data comes from developed countries or not; if yes, DEVLPED=1; else=0.	0.365 (0.482)
Statistical Methods	FITNESS	Fitness of the regression in a study (percentage).	0.402 (0.352)
	TEST	Indicator variable of applying robustness test for regression results; if applied, TEST=1, else=0.	0.507 (0.364)
Environmental Quality Degradation Categories	ANTHPGR	Indicator variable of anthropogenic activity-related greenhouse gases; if yes, ANTHPGR=1, else=0.	0.627 (0.484)
	CHACTGR	Indicator variable of chemically-active greenhouse gases; if yes, CHACTGR=1, else=0.	0.252 (0.434)
	BIOREL	Indicator variable of biologically-related pollutants; if yes BIOREL=1, else=0.	0.067 (0.250)
	CO2	Indicator variable of whether pollution is from carbon dioxide or not; if yes, CO2=1; else=0.	0.365 (0.482)
	SO2	Indicator variable of whether pollution is from sulfur dioxide or not; if yes, SO2=1; else=0.	0.365 (0.482)
	NOX	Indicator variable of whether pollution is from nitrogen oxide or not; if yes, NOX=1; else=0.	0.365 (0.482)
	AIRPOL	Indicator variable of whether pollution is airborne or not; if yes, AIRPOL=1; else=0.	0.365 (0.482)

categories: data-related, variable controls, statistical methods, and pollutant categories. The six variables in the data-related group are: (1) LNTIME, (2) LNOBS, (3) PANEL, (4) GLOBE, (5) QUALITY, and (6) REVPUBDATE. Loomis (2010), emphasizes the importance of including a quality component to all meta-analyses to better explain for variations in results. QUALITY and REVPUBDATE are both added as quality components. Quality indicates whether or not a study is published, whereas reverse publication date is the number of years since the study was published.

The variable controls subgroup includes three variables that capture important distinctions between different studies: (1) whether the pollution is measured through emissions (EMISSION), (2) whether the study uses GDP or GDP per capita as a measurement of income (GDP) and (3) whether a study uses data from a developed country or an undeveloped country (DEVLPED).

The statistical subgroup specifies what type of modeling is done in order to clear up any criticisms of methodology used within a study: (1) goodness-of fit measure as in R^2 or adjusted R^2 (FITNESS) and (2) evidence of a robustness test for heteroscedasticity, fixed effects, cointegration, etc. (TEST). Variable means and standard deviations can be found in Table 2.

It is worth noting that some variables were omitted in the coding process due to incomplete information as several studies did not produce all of the necessary variables. This omission of variables is one of the weaknesses of meta-analysis as it relies upon the reported characteristics of each study.

V. Empirical Model

The response variable (or dependent variable) used is trichotomous, meaning there are three potential categorical responses. Because this model has a qualitative dependent variable,

the objective is to find the probability of observing an inverted U-shaped EKC, an insignificant EKC relationship, or no relationship at all. Thus, qualitative response regression models, known as probability models, are employed.

The categorical dependent variable for the environment-income relationships is RELATION. As described before, the RELATION variable is grouped into three categories: category 1 (IMPROVE); category 2 (INSIG); and category 3 (ELSE) as defined in the previous section. A weighted multinomial logit model of the probability of RELATION is given by equation (1):

$$P(Y_i = j \mid C) = \frac{\exp(\beta_j' x_i),}{\sum_{k \in C} \exp(\beta_k' x_i)} \tag{1}$$

Where $P(Y_i = j \mid C)$ is the probability that the relationship category falls in alternative j within set C, and C = {IMPROVE, INSIG, and ELSE} for study *i*. β_j and β_k are vectors of the explanatory variables' coefficients, and x is a vector of study-specific modeling choices. In order to find the effects of each specific attribute of choice k on the probability P_j, we calculate the elasticities of the probabilities (Greene, 2003). The third category, ELSE, is set as the base category, meaning the explanatory coefficients of one category produced explain the probability of the variables in that category showing an effect against the base RELATION, ELSE. The estimated beta demonstrates the impact of that variable in relation to the ELSE category.

VI. Empirical Results

The estimated results of the MNL are presented in Table 3.[3] The coefficients of the MNL are somewhat difficult to directly interpret. Table 3 shows three columns, IMPROVE, INSIG, and marginal effects of IMPROVE. The three categories of the dependent variable are

[3] Two additional logit models were run excluding TEST and FITNESS variables. The first model excluded only TEST to increase observations by 202 but this did not significantly change the findings. The second model excluded TEST and FITNESS increasing total observations by 312 from the presented model but again not statistically change the findings.

IMPROVE (1), INSIG (2), and ELSE (3). The third category, ELSE, is used as the reference category within the model in order to compare instances when an EKC is present against when an EKC is not present.

Table 3. Results

Variables	Column 1 IMPROVE	Column 2 INSIG	Marginal Effects IMPROVE
LNOBS	-0.068 (0.075)	-0.581 (0.147)***	-0.009
LNTIME	0.232 (0.114)**	0.354 (0.233)	0.047
PANEL	0.457 (0.397)	0.585 (0.823)	0.097
GLOBE	-0.004 (0.345)	-1.994 (0.586)***	0.040
QUALITY	1.128 (0.378)***	0.087 (0.732)	0.268
REVPUBDATE	0.030 (0.030)	0.381 (0.065)***	0.003
EMISSION	1.046 (0.351)***	1.567 (0.635)**	0.213
GDP	-0.096 (0.277)	-0.321 (0.555)	-0.017
DEVLPED	0.817 (0.318)***	0.817 (0.588)	0.154
FITNESS	0.807 (0.314)***	0.352 (0.612)	0.172
ANTHPGR	-1.534 (0.789)*	0.154 (1.102)	-0.320
CHACTGR	1.137 (0.838)	-2.506 (1.462)*	0.228
BIOREL	0.599 (0.371)	-13.801 (504.564)	0.143
CO2	2.080 (0.799)***	0.365 (1.086)	0.359
SO2	1.185 (0.596)**	2.158 (1.314)	0.174
NOX	0.495 (0.578)	0.623 (1.560)	0.092
AIRPOL	0.257 (0.336)	0.132 (0.642)	0.055
CONSTANT	-2.503 (0.744)***	-4.066 (1.556)***	
Number of Observations	617	617	617

Notes:

1. Standard errors are included in parenthesis
2. * denotes significance at the .10 level
3. ** denotes significance at the .05 level
4. *** denotes significance at the .10 level

5. Marginal effects are calculated as discrete changes in predicted probabilities. Changes in LNOBS are measured by increasing every 100 observations; while that of LNTIME are measured by increasing one more year of data. All the dummy variables are measured by changing from 0 to 1.

Since the dependent variable is trichotomous, the effects of the explanatory variables are shown through calculating elasticities of probability. Elasticities are calculated for continuous variables to represent a small increase in original mean values. The elasticities produced in Table 3's marginal effects column indicate how a one unit change in the independent variable (or equaling one in the case of a dummy variable) affects the probability of the occurrence of the "category." For example, the marginal effect of LNTIME shows the probably of finding an EKC relationship over any other relationship when the number of years of a study is increased by one. For the dummy variables, elasticities are calculated from 0-1.

Estimation results from the MNL presented in Table 3 indicate that all variables were found to be significant between the two categories except, PANEL, GDP, ANTHPGR, BIOREL, NOX, and AIRPOL. When looking at the effects of the data-related variables, results imply that using longer time periods (LNTIME) and published studies (QUALITY) will significantly increase the probability of finding the IMPROVE category for the environment-income relationship. For example, when a study is published, the probability of finding an IMPROVE relationship increases by 0.268, *ceteris paribus.* Neither LNTIME nor QUALITY is significant for INSIG (column 2). When comparing the effect of these two variables across categories (column 1 and column 2), the longer the study's time horizon, the greater the effect on the IMPROVE group than the INSIG group. The EKC hypothesis is a long run phenomenon assuming a given economy passes through different stages during its time of growth and development. Therefore, as time increases, the probability of an EKC being found also increases, confirming the EKC hypothesis. Over time, countries grow through different stages that could be reflected by increasing and decreasing levels of pollution.

The significant variable controls that do not have an effect on the IMPROVE group are EMISSION and DEVLPED. EMISSION is an indicator variable that represents whether a study looked at pollutants that are measured as emissions. Using an emission measurement increases the probability of finding the IMPROVE relationship by 0.213. DEVLPED is an indicator variable that represents if a country is either developed or undeveloped/developing. Using a developed over an undeveloped/developing country increases the probability of finding an EKC curve by 0.290. When comparing the effect of these two variables across both groups (column 1 and column 2), development and emissions have a significant effect on the IMPROVE group and only emissions is significant in the INSIG group. Although emissions has a significant effect on both groups, the level of significance is greater for IMPROVE. Both groups are in relation to the base category, that is, no curve found. This means the probability of finding the curve in relation to the base increases for the significant findings but not the insignificant findings.

The FITNESS variable was highly significant for only the IMPROVE group. The FITNESS variable is a measure of a study's R^2 value. Therefore, a 0.1 increase in a study's R^2 would result in an increase in finding an EKC relationship by 0.017.

Among the environmental degradation measures, ANTHPGR is found significant for the IMPROVE category while CHACTGR and BIOREL were not found significant for the IMPROVE category. These findings mean that a study using anthropogenic activity-related greenhouse gases decreases the probability of finding a significant EKC by 0.320.

Lastly, the estimation results for two of the environmental quality relationship variables are highly significant for the IMPROVE group and not significant for the INSIG group. CO2 and SO2 were significant where as NOX was not. Using CO2 as the pollution source increases the probability of finding the IMPROVE relationship by 0.359. Using SO2 as the pollution

source increases the probability of finding the IMPROVE relationship by 0.174. Nitrogen oxide did not produce any significant results within the model.

VI. Conclusion

The information presented in this paper demonstrates that there is evidence of eight significant explanatory variables that lead to the presence of the EKC, time, quality of the paper, emission, developed countries, goodness of fit tests, anthropogenic-related activity gases, and whether or not the pollution is from carbon dioxide or sulfur dioxide.

The two categories of the dependent variable, IMPROVE and INSIG, used in the MNL produced different results based on significance. The INSIG category had less significant variables than the IMPROV category, meaning there are more variables that can explain the probability of finding a significant EKC relationship as opposed to finding a statistically insignificant EKC pattern. Based off the results, specific variables should be noted by researchers in conducting an EKC analysis.

The time factor holds importance suggesting we need to allow for a passage of time in order to observe a "turning point" of a country's level of pollution. Stern (2004) points out that the various potential causes of an EKC relationship (i.e. scale, change in economic structure, change in technology, change in input and product mix, environmental regulations, changes in awareness and education) all have an effect through proximate variables. Considering time as a variable, all potential causes are things that take time to change and cause an effect. The structure of an economy and any significant advancement in technology and abatement are going to happen through the passing of time.

In addition to time, a countries level of development should be strongly considered when looking for an EKC relationship. Both intuitively and based on economic theory, a country

develops through time. As countries develop higher per capita income levels will be realized and environmental quality may improve demonstrating an EKC relationship. The major finding of these two variables is that countries pollute their way to growth. Development that occurs over a period of time eventually reaches a turning point where environmental degradation begins to fall. This lends support to the hypothesis that economies eventually grow themselves toward a cleaner environment. The idea of developed countries exhibiting this pattern over time is relevant in deciding if people should invest in countries from abroad to stop pollution from occurring. In addition, policies that stimulate growth are an option to be implemented if an economy is ultimately going to grow enough to sustain a cleaner environment. If the length of a study increases, the probability of finding an EKC present can lead to the idea that investment and policy should not be spent on economies that are developed. Knowing that it takes time to see a true EKC pattern, policy makers are going to have the ability to maximize improvements on environmental quality through policy directed at developing countries.

Emissions, CO_2 and SO_2 significantly affect the presence of the curve in a positive way. In addition to looking at the cause of pollution by breaking down environmental degradation measures into anthropogenic, chemically-active, and biologically-related pollutants (Li et al., 2007), pollution was also categorized with dummy variables based on the specific catalytic chemical; CO_2, SO_2, and NO_x. CO_2 and SO_2 significantly and positively affect the presence of the EKC curve. This demonstrates that this type of pollution has potential long term solutions to decreasing levels. Considering anthropogenic-related greenhouse gases hold a negative effect on the presence of the curve, this shows naturally generated pollution promotes the EKC pattern. Knowing the source of pollution that formulates the curve can assist in policy implications to target and lower these pollutants. Further research is necessary to explore the differences among

CO_2 studies and SO_2 studies. Two last further extensions of this meta-analysis could be to include cross variables and employ a censored tobit model to account for the missing data points.

Moving forward, further studies should pursue environmental-degradation measures in relation to the presence of an EKC. This meta-analysis provides insight that future researchers should make sure to include such variables as time, emissions, development, anthropogenic-related activities, and CO2 and SO_2 pollutants in order to investigate if an EKC is present in a given country. The insignificance of NOx and AIRPOL for both categories, IMPROVE and INSIG, provides evidence for further research to focus upon other types of pollution. With a stronger basis of variables to control for, policy implications to control pollution problems can and will be more effective in the long run.

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