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The Validity of the Environmental Kuznets Curve for the European Union

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ABSTRACT

This research empirically explores the validity of the environmental Kuznets curve (EKC) for the European Union. Data for CO_2 emission per capita, GDP per capita, population density, and fossil fuel consumption percentage was gathered for the 28 countries within the European Union for years 1990-2010 and regression analysis was conducted in order to see if the EKC relationship held true. However, under this analysis, that result is inconclusive. As GDP per capita increases, CO_2 increases to a certain point and then, instead of having a negative relationship, it continues to increase but at a lesser rate. The coefficients of the natural log of GDP and the natural log of GDP squared were both positive. In fact, the coefficient does not turn negative until the cubed root of the variable was taken. In order to explore this outcome, we separated the EU into two groups: first 13 members and newer members. We ran the same analysis for both groups and found that the EKC relationship was true for the first 13 members and was not true for the new members. This shows that the first 13 members are more developed and further along the left side of the Kuznets curve than the newer members, and the newer member countries have skewed the overall outcome for the EU causing them to sit further left upon the EKC.

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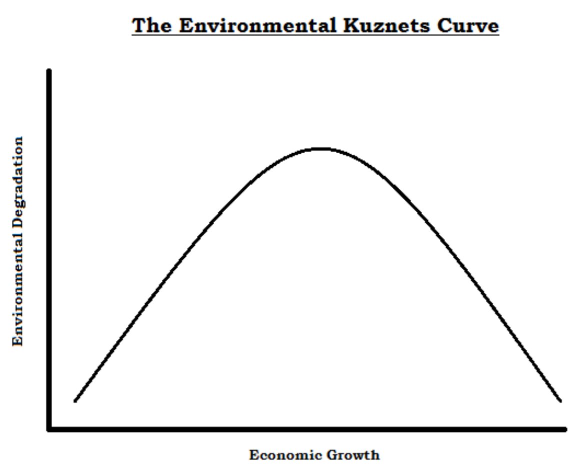
Introduction

The idea of the Kuznets curve was first proposed by Simon Kuznets in his presidential address to the American Economics Association in 1954 and in his paper, "Economic Growth and Income Inequality", which was published in 1955 in *The Journal of Economic Perspective.* Kuznets argued and showed evidence that there was a relationship between economic growth and inequality. This relationship was characterized by an increase and then a decrease in inequality as an economy develops, creating an inverted "U" shape.

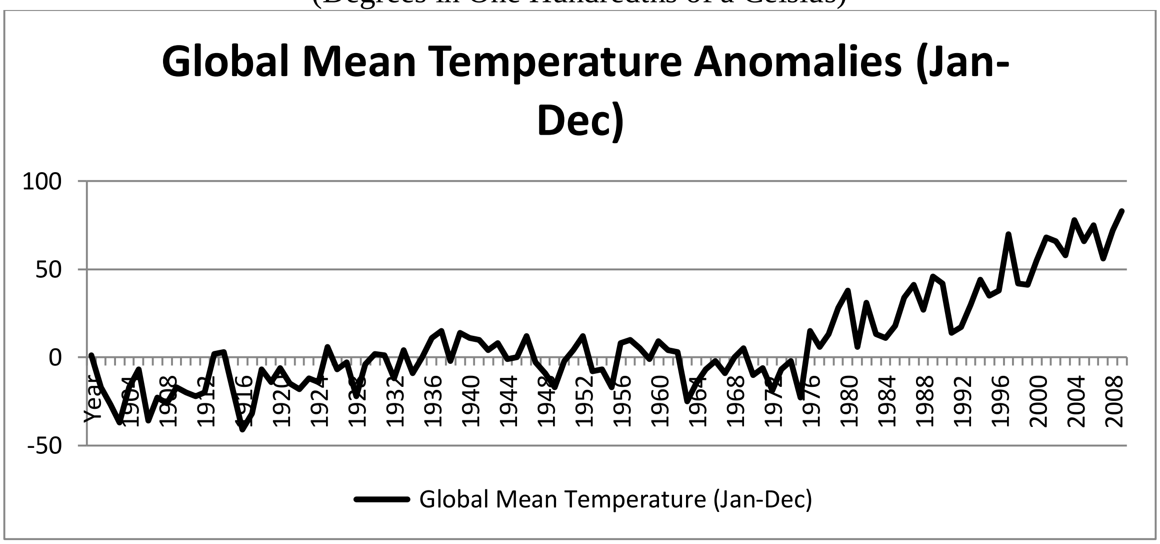
The Kuznets relationship was applied to environmental indicators such as greenhouse gas emissions and other pollutants. The relationship states that as an economy develops and grows, the level of environmental degradation factors increases to a certain point and then decreases. This indicates that a growing economy may eventually get to a threshold in which stricter environmental and economic regulations, a higher percentage of imported manufactured goods from developing countries, and increased investment in cleaner energy may help combat pollution. Figure One shows the typical EKC relationship.

Figure One: Typical Relationship of EKC



In recent years, there has been an increased concern for environmental sustainability and pollution reduction because of the phenomenon called global warming. Global warming is a gradual increase in the overall temperature of the earth's atmosphere generally caused by the increased greenhouse effect that is caused by higher levels of atmospheric pollutants. This is not just an abstract idea. Figure Two shows data gathered from the world development indicators at the World Bank and graphically shows the global increase in temperature that has occurred.

Figure Two: Annual Average Global Surface Temperature Anomalies 1901-2010
(Degrees in One Hundredths of a Celsius)



Source: World Development Indicators

According to the Union of Concerned Scientists, global warming is primarily a problem of too much CO_2 in the atmosphere, which acts as a blanket that traps heat and warms the planet. Of all the gases that contribute to the gradual temperature rise, CO_2 is considered the main culprit and draws the focus of many scientists, environmental preservation advocates, and policy makers. CO_2 will be focused upon in our research because of its primary role in environmental degradation and global warming. Carbon emissions prove to be a difficult factor to control because it is a product of many sectors in the economy and its pollution is widespread throughout all industries. Table One shows the breakdown of global warming emissions by economic sector and it can be seen that the burden and responsibility of sustainability lies on a variety of sectors.

Table One: Global Warming Emissions by Economic Sector

Sector	Emission Percentage
Waste and Wastewater	2.8%
Forestry	17.4%
Agriculture	13.5%
Industry	19.4%
Residential and Commercial Buildings	7.9%
Transport	13.1%
Energy Supply	25.9%

Source: Union of Concerned Scientists, Climate Hot Map

The European Union offers an interesting sample and is a prime candidate to analyze. It consists of 28 countries that have a range of economic development and size, but are all under high levels of regulations and environmental protection rules. They continuously review their impact and environmental footprint to establish further measures of reduction. For example, on November 24, 2010, the European Union adopted the Industrial Emissions Directive (IED) in order to regulate the pollutant emissions from industrial installations. This is just one of the many measures that the EU has taken to eliminate emissions of air pollutants, waste generation, and discharges of waste water [ec.europa.eu]

Literary Review

The EKC has been analyzed for many different circumstances and presented with both support and criticisms. According to Dasgupta, Laplante, Wang, and Wheeler

[2002], the environmental Kuznets curve model has elicited conflicting reactions from researchers and policymakers, but applied econometricians have generally accepted the basic tenets of the model and focused on measuring its parameters.

There has been evidence that there are particular conditions that limit the strength of the EKC model. In "The Rise and Fall of the Environmental Kuznets Curve" by David Stern [2004], the model is challenged. Stern argues that developing countries sometimes adopt developed countries environmental control standards and that these have a greater effect and performs better than in the wealthy countries. The EKC, in this case, has a very weak and flimsy statistical foundation and that a better model is needed to explain the relationship between development and environmental impact.

Other research suggests that an economic development variable only explains part of the story of the EKC. Mariano Torras and James Boyce [1998] argue that there is more than just income per capita that predicts the level of pollution. Empirical analysis of international variations in air and water quality shows that literary, political rights, and civil liberties also have a strong effect on the prediction of environmental quality in low-income countries. This shows there are limitations of the model and that there are many exogenous variables that can go into determining the validity of this relationship.

However, other research has loosely confirmed the idea of the EKC. The main goal of the EKC is to specifically find the turning point in order to find the theoretical level of development that would decrease environmental degradation. In "Economic Growth and Environmental Quality in the European Union Countries – Is There Evidence for the Environmental Kuznets Curve? [Mazur, Phutkaradze, Jaba. 2015]," the relationship between carbon dioxide emission and economic growth during the period

1992-2010 was examined using panel data on the European Union. And even though the typical inverted "U" relationship was not confirmed empirically for the 28 EU member states, there was a turning point found for carbon dioxide emissions as GDP per capita reaches the level of $23,000. Even though the curve was not empirically confirmed, there is enough data to show that the EKC does exist and is applicable in EU countries.

The following paper examines and tries to replicate the results that were found in previous EU research. The difference in research is found in the longer time period used (1990-2010 instead of 1992-2010), the elimination of four countries that lacked relevant data, and the separation of the EU into two groups to evaluate separately.

Data and Methodology

EKC relationship hypothesizes that as an economic development variable increases the level of pollution or environmental degradation will first increase to a certain point and then decrease. The importance of this relationship is that by taking the derivative of that curve, the point at which the slope is zero (turning point) can be found. This allows for an estimation of the economic development level that a particular economy or group of countries will need to reach before environmental degradation levels begin to decrease.

The goal of this paper is to validate previous literature that supports the EKC for the European Union and to see if that relationship does exist. The European Union consists of 28 member countries: Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. The wealth of these nations varies and the status of these countries range from developing to developed.

Data for GDP per capita, CO_2 per capita, population density, and fossil fuel consumption was gathered from the United Nations and World Bank data sets. After gathering and compiling all data, Malta, Luxembourg, Croatia, and Estonia were thrown out of the sample due to lack of essential data for this particular analysis. Table Two shows the summary statistics of the data.

Table Two:

Variable	Observation	Mean	Std. Deviation	Minimum	Maximum
GDP per Capita	473	26007.50	15350.46	3527.12	102397.70
CO2 per Capita	473	7.72	2.41	2.63	21.60
Population Density	473	128.53	92.30	14.75	406.80
Fossil Fuel Consumption	473	77.90	15.80	31.98	99.68

Variable Explanation

GDP per Capita is real gross domestic product per person adjusted for base year 2010. The mean of the data is around $26,000 per person. The min and maximum values for GDP per capita are greatly different. This shows that there is a wealth gap among member countries which confirms that some countries within the EU are developing while others are developed and very wealthy. Within our model, this represents our independent variable and our economic indicator that we will be using to determine the size and level of development for our sample.

CO_2 per Capita shows the amount of carbon dioxide emissions per person within member countries. CO_2 in this case is measured in metric tons. This variable in

our model will be used to show our level of environmental degradation and pollution.

Population Density shows how populated a particular country is based upon their size. This shows the number of people that live within a square kilometer. This variable is a constant and will be used to strengthen and eliminate error within our model.

Fossil Fuel Consumption shows the amount of fossil fuels that our sample uses per year. It is the percentage of fossil fuel consumption that is used out of the countries whole energy consumption. It is also a constant variable used to strengthen and eliminate error within our model.

Due to the unavailability of data for a few years within some of our countries, an unbalanced panel dataset was used. The natural logarithm was then taken for all data points in order to find the growth of the next data point. The natural log of GDP per capita was then squared in order to try to create the expected parabolic relationship of the EKC. GDP per capita was also cubed to examine a possible cubic relationship within the model. For testing the EKC, we developed the model as follows:

$$\ln(CO_2) = ai + yt + \beta1\ln(\mathrm{GDP})it + \beta2\ln(\mathrm{GDP})^2 it + \beta3\ln(\mathrm{GDP})^3 it + \beta4\ln(\mathrm{Pop}) + \beta5\ln(\mathrm{Fossil}) + eit$$

where CO_2 is our dependent variable and environmental indicator and GDP is GDP per capita and our independent developmental variable. Pop and Fossil are respectively population density and fossil fuel consumption and are used as constants within the model. The natural logarithms are denoted by ln, and *a* and *y* are parameters for the intercepts. Countries and years are denoted by *i* and *t*, respectively. β is the coefficient of the variables that shows the amount the dependent variable will change for a per unit change in the independent variable. Finally, *e* is the variable that catches and explains the error within the model. [Mazur, Phutkaradze, Jaba. 2015]

Regression analysis was performed in two ways: Random effect estimation and fixed effect estimation. Random effect model assumes the same intercept and slopes while testing the variance components for the countries, times, and errors. In random effect estimation the difference in the model among the countries or times are explained within the error term and not the intercepts. Fixed effect model allows for different intercepts for each country in the estimation. The *ai* and *yt* are used as regression parameters and least squares dummy variables are used within the estimation.

The Hausman test [1978] was used to see which one of the two estimations would be more appropriate for the model. The Hausman test shows that if a null hypothesis that individual effects are uncorrelated with other regressors in the model is not rejected, then the fixed effect estimation model is not an appropriate model. After conducting the test, the Hausman test holds true and shows that random effect estimation is a better model.

The EU was then split into two separate groups: the first 13 members and the rest of the EU that we will call "newer countries". The first 13 members group consists of : Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom, and Luxembourg and the newer countries group consists of Bulgaria, Cyprus, Czech Republic, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia. In this particular analysis, Greece, Ireland, and Estonia was excluded from our analysis. The same analysis was conducted for both groups to see if there is any difference between the older countries and newer countries. The summary statistics for the first 13 members is shown in Table Three and the summary statistics for the newer countries is shown in Table Four.

Table Three: First 13 Countries

Variable	Observation	Mean	Std. Deviation	Minimum	Maximum
GDP per Capita	272	41395.64	16306.15	16790.05	108098.30
CO2 per Capita	272	9.55	4.36	4.26	37.48
Population Density	272	162.86	109.41	14.75	406.80
Fossil Fuel Consumption	272	75.97	17.47	31.98	98.52

Table Four: Newer Countries

Variable	Observation	Mean	Std. Deviation	Minimum	Maximum
GDP per Capita	242	12833.17	6616.32	3527.12	31096.41
CO2 per Capita	242	6.74	2.16	2.63	13.42
Population Density	242	193.04	336.79	32.41	1344.11
Fossil Fuel Consumption	242	82.76	12.96	52.16	99.93

Result

Table Five shows the regression results for the random effect for the entire European Union and the two separated groups at a 95% confidence interval.

Table Five: Results of All EU Countries, First 13 Countries, and Newer Countries

	All EU Countries		*First 13 Countries*		*Newer Countries*	
lnCO2	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
lnGDP	0.2966***	0.0398	0.3678**	0.1656	0.1229**	0.0555
lnGDP2	0.0612***	0.0213	-0.2823***	0.0760	0.1774*	0.0935
lnGDP3	-0.0458**	0.0183	N/A	N/A	N/A	N/A
lnPop	-0.1384	0.0889	-0.4818*	0.2668	-0.0839	0.5206
lnFossilfuel	2.2836***	0.2355	2.7328***	0.3952	2.0779***	0.4003
Constant	.8271	0.3392	2.4340*	1.2282	.4750	2.3146
Observations	473		272		242	
R^2 (within)	.5051		.6163		.5007	
Number of Countries	24		13		12	

***denotes 1% significance level; **denotes a 5% significance level; *denotes a 10% significance level

The coefficients of the variables show the elasticities that the variables have upon CO_2. For example, GDP for *All EU Countries* has a coefficient of .2966. This means that a 1% increase in GDP will result in a .2966% increase for CO_2. Conversely, a 1% decrease in GDP will result in a .2966% decrease in CO_2. The asterisks denote the confidence level that the particular variable has. Again using GDP for *All EU Countries*, the three asterisks denotes a 99% confidence level (1% significance level) meaning that we can be 99% confident that the true value of the parameter is in our confidence interval. Likewise, two asterisks show a 95% confidence level, and one asterisk shows a 90% confidence level.

Within our results, we can see that all variables within the *All EU Countries* column, with the exception of population density, are significant at either a 1% or 5%

level. We can see that a 1% increase in GDP would cause a .2966% increase in CO_2. Likewise we are statistically confident that a 1% increase in GDP^2, GDP^3, and fossil fuel consumption would affect CO_2 emissions by the value found in the coefficients column. In the EKC model, it is expected that the coefficient for the natural log of GDP is positive and the coefficient for the natural log of GDP^2 is negative. This develops and supports the inverted "U" curve that the model is known for. However, in our model, it is seen that the coefficients for both GDP and GDP^2 are positive. This is showing that the curve continues to increase. It must be noted that the coefficient for GDP^2 is less than the coefficient of GDP, indicating that the curve is increasing to a certain point and then continuing to increase but at a lesser rate. In theory, the cube of the natural log of the economic indicator will be positive showing a curve that increase to a point, decreases, and then increases, giving the EKC an upward tail. Interestingly, this relationship did not hold true either. GDP^3 within our model is shown to be negative indicating a decreasing relationship. Our curve increases to a point, then continues to increase at a lesser rate, and finally decreases.

This interesting relationship led to further research for the European Union countries by separating them into two groups and evaluating them separately. Within the *First 13 Countries* column, all variables are significant and the hypothesized ECK relationship is actually confirmed. GDP2 and fossil fuel consumption are significant at a 99% confidence level, GDP is significant at a 95% confidence level, and population density is significant on a 90% confidence level. This means that every variable can explain the model with a confidence of at least 90%. We can see that a 1% increase in GDP, GDP^2, Population Density, and Fossil Fuel Consumption would cause CO_2 to increase by .3678%, decrease by .2823%, decrease by .4818%, and increase by 2.1328%, respectively. The GDP coefficient is positive, and the GDP^2 coefficient is negative which confirms the expected inverted "U" relationship that was illustrated in Figure One.

Conversely, within the *Newer Countries* column, the relationship obtained is opposite of the first 13 countries. It is seen that all variables are significant, with the exception of population density. At a 99% confidence level, a 1% increase in fossil fuel consumption will increase CO_2 emissions by 2.0779%. At a 95% and 90% confidence level we can predict that a 1% increase in GDP and GDP^2 will increase CO_2 by .1229% and .1774%, respectively, because the coefficients of GDP and GDP^2 are both positive and shows a linear relationship. This is because most countries' GDP is still on ascending side of the EKC curve which implies their income is lower than the threshold (turning point) as shown in our results- the significant and positive signs of the coefficients for both GDP and GDP-squared variables. This directly mimics the relationship of the original analysis of the entire EU. The typical Kuznets curve relationship is not confirmed in this case.

Conclusion

In seeking to replicate similar results as previous literature on the EKC for the European Union and validating the model within the group of countries, our research finds that the EKC does not hold true for the European Union for the 1990-2010 time series. Instead, an interesting relationship was created. One that increases to a point, then increases at a lesser rate, and finally decreases; creating a relationship that was contrary from our original EKC expectation.

However, when separated into two separate groups, one with the first 13 members and one with the newer members, the outcome is slightly different. Even though the outcome was relatively the same for the newer members, the outcome for the first 13 members confirms the EKC. This shows that the group of the first 13 members of the EU is more economically developed than the newer members group of the EU. When imagining the inverted “U” curve of the EKC, the newer members are further left on the curve than the first 13 member countries. When the natural log of GDP per capita is squared for the newer members, the countries still find themselves on the left side of the curve, showing that continuous increase in the coefficient of the GDP^2 variable. Conversely, the first 13 countries are further along the curve. Thus, when the natural log of GDP per capita is squared, the coefficient turns negative as the countries now find themselves on the right side of the curve with decreasing CO_2 emissions.

Interestingly, when all countries are put together, they find themselves further to the left of the curve where even the squared natural log of GDP per capita is still on the left side of the curve. The curve initially increases at a high rate and then continues to increase but at a lesser rate as it approaches the turning point. That is confirmed by our data, and when cubed, the result turns negative, showing that the countries are now on the right side of the curve. The newer countries have a negative effect on the total of the EU in this case, shifting them further left along the EKC and away from the turning point where CO_2 per capita emissions begin to decrease.

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