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A Test of the Environmental Kuznets Curve For Local and Global Pollutants

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I. Introduction

The early stages of economic development are generally associated with increases in the level of industrialization. Along with this industrialization comes increases in populations of cities and pollution causing transportation. For all these reasons, the development of a country is usually associated with increases in the amount of pollution. However, after a certain threshold level of income, the quality of the environment becomes important and people are willing to pay for a cleaner environment. After this point the level of pollution is likely to decrease. This hypothesized inverted-U relationship between the amount of pollution and the income of a country is known as the Environmental Kuznets Curve (EKC). It is an important idea because, if true, it would enable people to predict the levels of pollution for the coming years based on a countries expected GDP (Shafik).

One important aspect of the EKC hypothesis is the classification of the pollutants. In general, pollutants are classified by their zone of influence, or where their effects are felt most directly. A local pollutant would be one for which the effects are felt near the source of emission. The local residents bear all the costs of cleaning up the pollutant or living in a polluted environment. As incomes increase, there would be a desire to increase the environmental quality in the local surroundings. Examples of local pollutants are particulate matter, sulfur oxides, and nitrous oxides. On the other hand, global pollutants are responsible for the damage done in the upper atmosphere. The total costs of the pollution would not be felt directly by the local residents, but shared by all

the countries that are affected. Therefore, there would be little attempt to clean up or stop emissions. In this case, there would be either an inverted-U curve with a very high turning point or a curve that increases without a turning point. These pollutants are usually associated with problems like rising global temperatures or the greenhouse effect. Examples of global pollutants are CFC's, carbon dioxide and other greenhouse gases. (Tietenberg)

This paper tests the Environmental Kuznets Curve hypothesis for local and global pollutants. It determines whether there is the hypothesized inverted -U curve for the local pollutants particulate matter and sulfur dioxide and the global pollutant carbon dioxide. Two different models are used. Model 1 attempts to verify the findings of previous studies and Model 2 tests the effect that country specific variables have on the results. Since different policy responses are indicated in each situation, it is important to find out exactly what the relationship is between the three types of pollutants and economic development. In section two, literature is reviewed. Then, in section three, the theory behind the EKC is given. An empirical model is stated in section four. The results are presented and a conclusion with policy implications is given in sections five and six.

II. Literature Review

In the past few years there has been a lot of research on the topic of environmental quality and economic growth. Most studies agree that there is an EKC for some pollutants but they disagree on the exact values of the turning points. Nemat Shafik (1994), using data from a wide range of countries at different levels of development, finds an inverted-U relationship for the pollutants suspended particulate matter (SPM) and sulfur dioxide (SO_2), and for deforestation. For SPM he observes the

initial increase in emissions as income increases until the turning point of \$3,280. For SO_2 he observes the same pattern with a slightly higher turning point of \$3,670. Both of these pollutants exhibit the expected EKC for local pollutants. Shafik attributes the eventual downturns to improvements in cleaning technology and the switching to cleaner or more efficient fuels.

On the other hand, the results for carbon dioxide (CO_2) do not follow the inverted-U and, in fact, have an almost exponential increasing of emissions as income increases. The expected turning point occurs at an income level that is well outside the sample range of per capita income. Shafik attributes this to the fact that the costs are not felt locally, but are borne by the rest of the world.

Krueger and Grossman (1995), using cross sectional country data, also find the hypothesized inverted-U for urban air quality factors, with the exception of SPM. For smoke and SO_2, they find the relationship between emissions and income to have the initial increases of pollution but then the eventual down turn after income reaches a certain level. For SPM they find a monotonically decreasing relationship between heavy particles and GDP. This result shows that there is no initial increase but rather a continual decrease in the level of emissions. A unique variable in their study is a lagged GDP variable, which is supposed to capture the effect of past incomes on current pollution standards. This variable is inconclusive because it is highly correlated with the other variables of GDP.

A final article by Raynor and Bates (1997) studies a wide range of environmental pollutants and their relationship with per capita income. They also categorize the pollutants into those that would have direct local impact and those that would not. They

find all of the pollutants with direct local impact to follow the inverted-U shape and to have turning points of less than $8,000. The pollutants with no direct local impact do not have the inverted-U shape.

A lot of the research in the past has used the Environmental Kuznets Curve to describe the relationship between all kinds of pollutants and income. In general, for local pollutants, there is agreement in the literature that they follow an inverted-U curve. However, there is a disagreement on the specific turning point for any pollutant. This study attempts to show that an inverted-U does exist for particulate matter and sulfur dioxide and to reach a conclusion on the exact turning points. In the literature for global pollutants, there is also disagreement on the shape of the curve. Some of the literature suggests an inverted-U with a very high turning point and some suggests a constantly increasing curve is more accurate. This research also attempts to show the shape of the curve for the global pollutant carbon dioxide and to find a turning point if one exists. This study also uses more current data to try and capture some of the effects that have been happening recently.

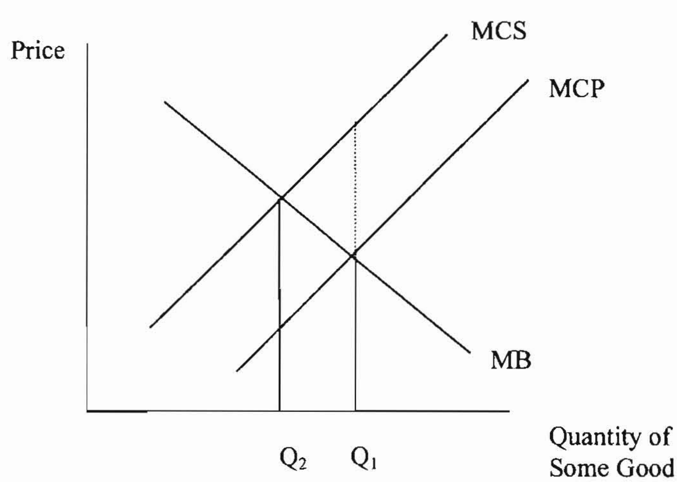
III. Theory

During the early stages of development, the income of a country is low and the quality of the environment is not a priority. The people are willing to trade off a clean environment to get the basic necessities they need to live. As the country continues to develop, the opportunity to pollute becomes greater and pollution increases. This is because the early stages of development usually involve more industrial production. Also along with this industrialization comes an increase in polluting transportation which

increases the amount of emissions. After a certain level of development, though, people will have more of all other goods and things like the quality of the environment become more important to them. A clean environment is a normal good. As incomes rise, people are willing to spend more to be in a cleaner environment. This leads to the general inverted-U shape of the Environmental Kuznets Curve.

Even though a cleaner environment is now desired, the market will not necessarily generate the desired level of cleanliness. Because the environment is a free good, producers will not consider pollution as a cost, which increases the amount of pollution. In general, there will be excess pollution because producers do not take the total costs of production into account. This can be seen in the figure below. In figure 1, the line MB represents the marginal benefit of some good to everyone in the society, MCS corresponds to its marginal cost to society, and MCP stands for its marginal cost to producers.

Figure 1



Because the cost of pollution on society is not considered, producers will produce where their marginal costs equal marginal benefits. They will produce at the level Q_1 which is not the efficient amount because it does not take into account the costs of the degradation of the environment. The efficient amount of production is at Q_2 where society's marginal costs equal marginal benefits. Because of this difference in production there is excess pollution (Tietenberg).

For local pollutants, though, there is reason to think the government will intervene. When the effects of the pollution are felt directly by society, producers will eventually have to take into account the costs of polluting the environment because the government will get involved. They will implement new policies that force producers to decrease their levels of production closer to the efficient amount. The more detrimental the local pollutant, the lower the level of development at which society and government will take action, and emissions will start to decrease.

On the other hand, the effects of global pollutants are not always felt directly by society or producers. Since the effects are more indirect, and all countries share them, there will be less incentive for producers to restrict production closer to the efficient amount. For this reason, government policies will also be slow to restrict levels of global pollutants. This means that there will be excess pollution even at higher levels of development.

IV. **Empirical Model**

The theory implies that environmental quality depends on the level of economic development. The most general measure of economic development is gross domestic product per capita (GDP/Cap). Environmental quality is measured in emissions per

square kilometer of the pollutant. The local pollutants are particulate matter and sulfur dioxide, both measured in metric tons. The global pollutant is carbon dioxide, measured in thousand metric tons.

The first model attempts to replicate the results found in previous studies. The model has GDP/Cap squared and cubed variables to take into account the theoretical shape of the EKC.

$$\textbf{(1)}\quad \textbf{Emission} = \beta_1 + \beta_2(\textbf{GDP/Cap}) + \beta_3(\textbf{GDP/Cap}^2) + \beta_4(\textbf{GDP/Cap}^3) + \hat{e}$$

In equation (1) Emission equals particulate matter, sulfur dioxide, and carbon dioxide emissions per square kilometer. The data used for sulfur dioxide and carbon dioxide are pooled data for twenty-four different countries from 1985 through 1996. The data used for particulate matter are pooled data for seventeen different countries using the same years. A complete list of the countries may be found in Appendix A. The data are obtained from World Development Indicators and OECD Environmental Data Compendium 1999.

Based on the theory and previous research, I expect to find a continuously decreasing line or an inverted-U with an extremely low turning point for particulate matter. I expect to find an inverted-U curve for sulfur dioxide with a relatively low turning point somewhere between the turning points for particulate matter and carbon dioxide. Finally, for carbon dioxide, I expect to find an inverted-U curve with the highest turning point or a constantly increasing curve.

A second model includes dummy variables to account for specific effects of the individual countries. These effects could be the population densities of the countries, which would increase congestion in cities and thus increase pollution. They could also take into account the cultural values of the country concerning the environment. If the country places high value on the environment, then they may be less likely to have high pollution in the first place. All pollutants are tested again using the same model below.

(2) $$\textbf{Emission} = \beta_1 + \beta_2(\textbf{GDP/Cap}) + \beta_3(\textbf{GDP/Cap}^2) + \beta_4(\textbf{GDP/Cap}^3) + \beta_5\textbf{Dum} + \hat{e}$$

In equation (2) Emission and GDP/Cap are as before. Dum is the set of dummy variables—twenty-three for sulfur dioxide and carbon dioxide, and sixteen for particulate matter. For the dummy variables a 1 is used for that country and 0 for all other countries. I expect that including the dummy variables will give more explanatory power to the model and the shapes will more closely resemble the inverted-U shape.

V. Results

The results are summarized below for the two models. Both models were originally estimated using the OLS regression procedure in SPSS, but the Durbin-Watson statistics revealed autocorrelation for both. Thus, the Prais-Winston procedure in SPSS is used instead. All of the R^2s are found using descriptive statistics.

A. Model 1

In the first model, the results of the regression for particulate matter do agree with the previous research. The curve is constantly decreasing with the emission levels

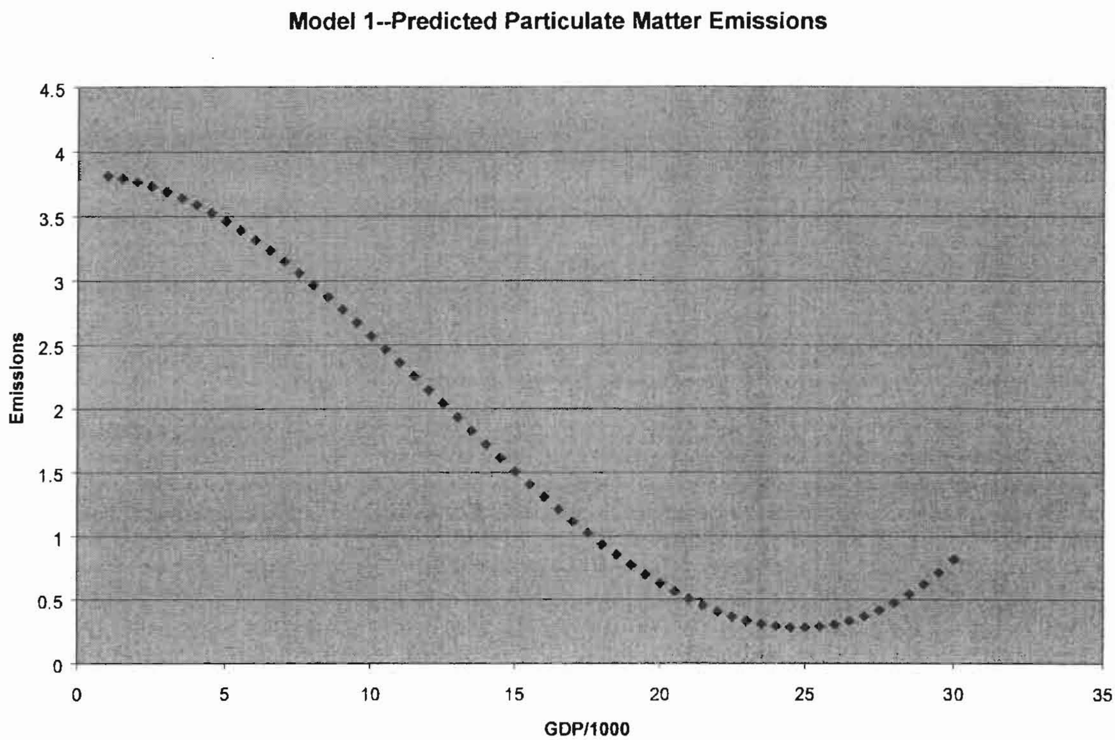
highest at the lowest amounts of GDP per capita. The results can be seen in Table 1. The GDP variables are significant as a group and the regression has a good R^2 of 0.87. A graph of the predicted emissions can be viewed in graph 1. At low levels of GDP the predicted emissions are the highest. Then as GDP increases, there is a steadily decreasing curve. For particulate matter, the model shows that GDP is a relatively good predictor of the level of emissions.

Table 1: Results of Model 1 for all Pollutants with Emissions as Dependent Variable

Variables	Particulate Matter	Sulfur Dioxide	Carbon Dioxide
Constant	3.83 (3.564)***	11.545 (2.768)***	-471.69 (-1.07)*
GDP	0.0029 (0.0114)	0.373 (0.4266)	361.939 (4.507)***
GDP^2	-0.0175 (-1.023)*	-0.0627 (-1.132)*	-22.128 (-3.675)***
GDP^3	0.0047 (1.32)*	0.0011 (1.066)*	0.3876 (2.967)***
R^2	0.87	0.77	0.85

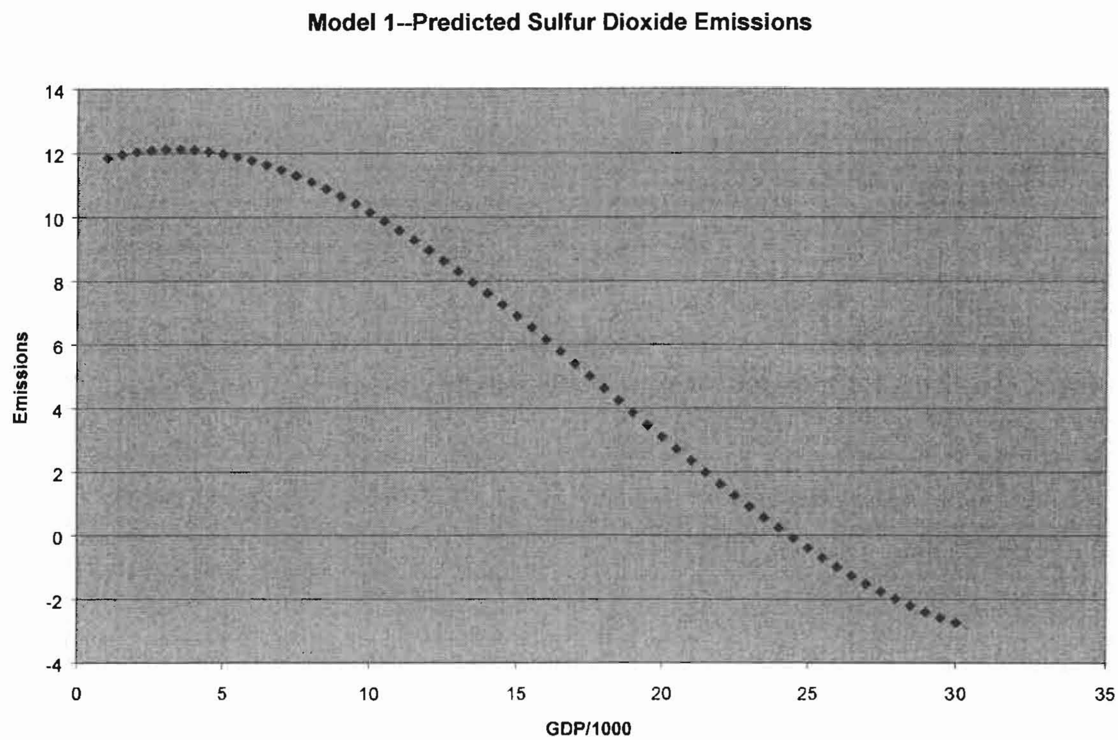
T-statistic in parenthesis
*0.10 Significance level
**0.05 Significance level
***0.01 Significance level

Graph 1



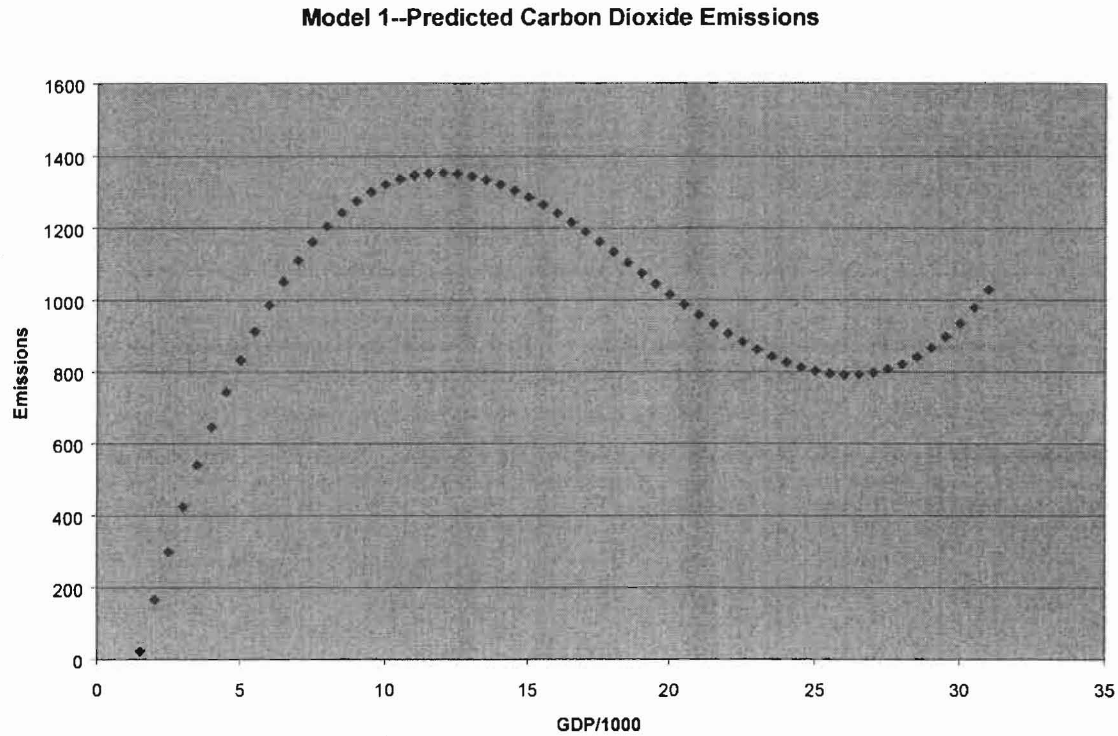
The results for sulfur dioxide also agree with the previous literature. The curve is constantly decreasing after a very low turning point around $5,000. The previous studies suggest that there should be an initial increase in emission levels and then a low turning point around $4,000, which is a bit smaller than what is observed. A possible explanation for not seeing the very low turning point is that no countries in this data set are represented in the low GDP range where the turning point is supposed to be. The results can be seen in Table 1. The GDP variables are significant as a group and the regression has a relatively good R^2 of 0.77. This result seems to suggest that GDP is a relatively good predictor of the amount of pollution for sulfur dioxide. A graph of the predicted emissions can be seen in graph 2.

Graph 2



For carbon dioxide, the results of the first model in general do agree with previous research. The emission levels exhibit the inverted-U shape, though with a lower than expected turning point of $13,000. The results can be seen in Table 1. The GDP variables are significant as a group and the regression has an R^2 of 0.85. This also seems to suggest that GDP is a good predictor of carbon dioxide emissions. A graph of the predicted emissions can be viewed in graph 3. At low levels of GDP, there are small amounts of emissions. As GDP increases the amount of emissions also increase with a low turning point.

Graph 3



For all pollutants, the results of the first model seem to be in agreement with the previous research. The outcomes, though not identical, are comparable to previous findings. The attempt to replicate the past studies with new data, for the most part, has produced acceptable results.

B. Model 2

For particulate matter, the results of the second model do not completely agree with the predictions. The curve does have the inverted-U shape but the turning point is around $10,000 which is much higher than expected. The results can be seen in Table 2. The GDP variables are significant as a group and the regression has an overall R^2 of 0.91. The dummy variables as a group are also significant. A graph of the predicted emissions

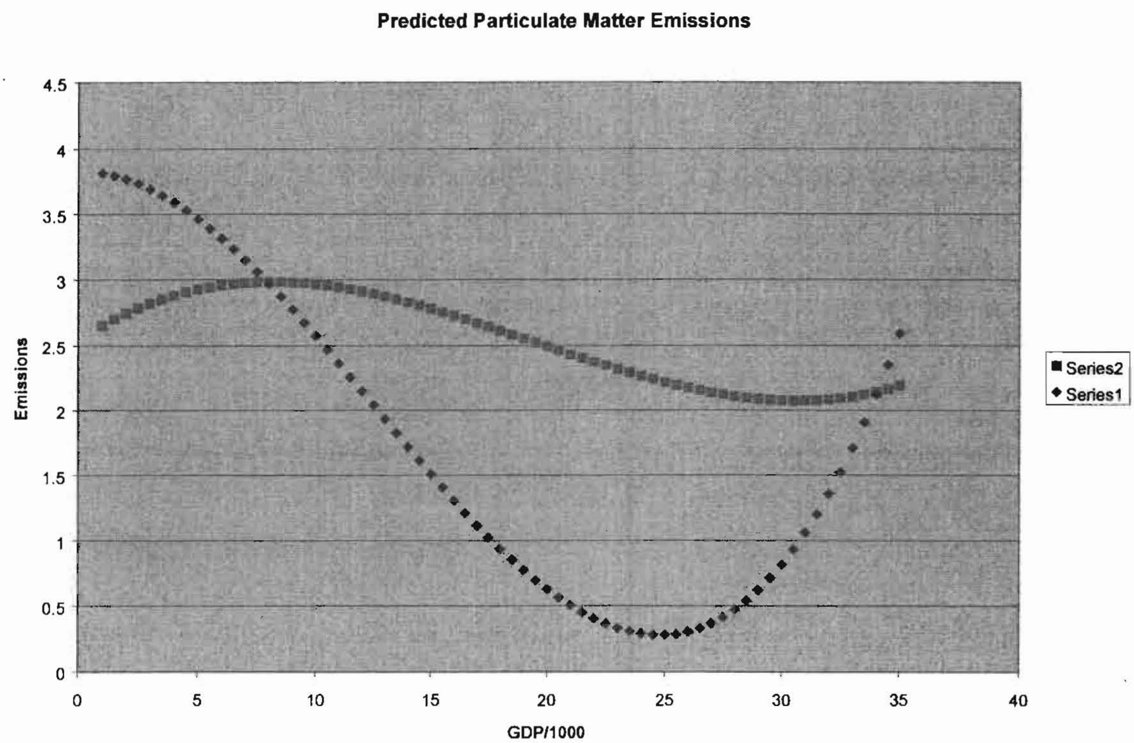
can be seen in Graph 4. The inverted-U is clearly visible but the turning point is much higher than expected.

Table 2: Results of Model 2 for all Pollutants with Emissions as Dependent Variable

Variables	Particulate Matter	Sulfur Dioxide	Carbon Dioxide
Constant	-4.466 (-2.009)**	-4.58 (-0.86)*	-2.495 (-0.0098)
GDP	0.1194 (0.515)	0.3227 (0.381)*	43.845 (0.989)*
GDP^2	-0.0093 (-0.639)	-0.497 (-0.98)*	-1.785 (-0.491)
GDP^3	0.0016 (0.542)	0.00084 (0.866)*	0.0172 (0.208)
R^2	0.91	0.92	0.98

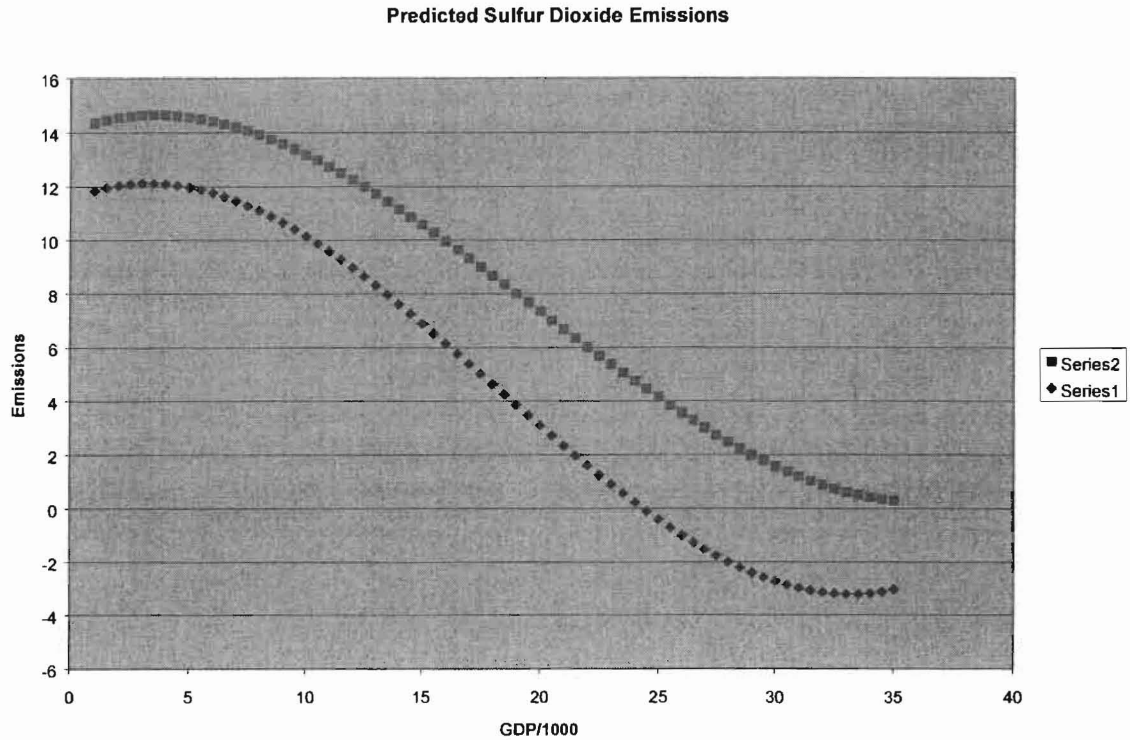
T-statistic in parenthesis
*0.10 Significance level
**0.05 Significance level
***0.01 Significance level

Graph 4



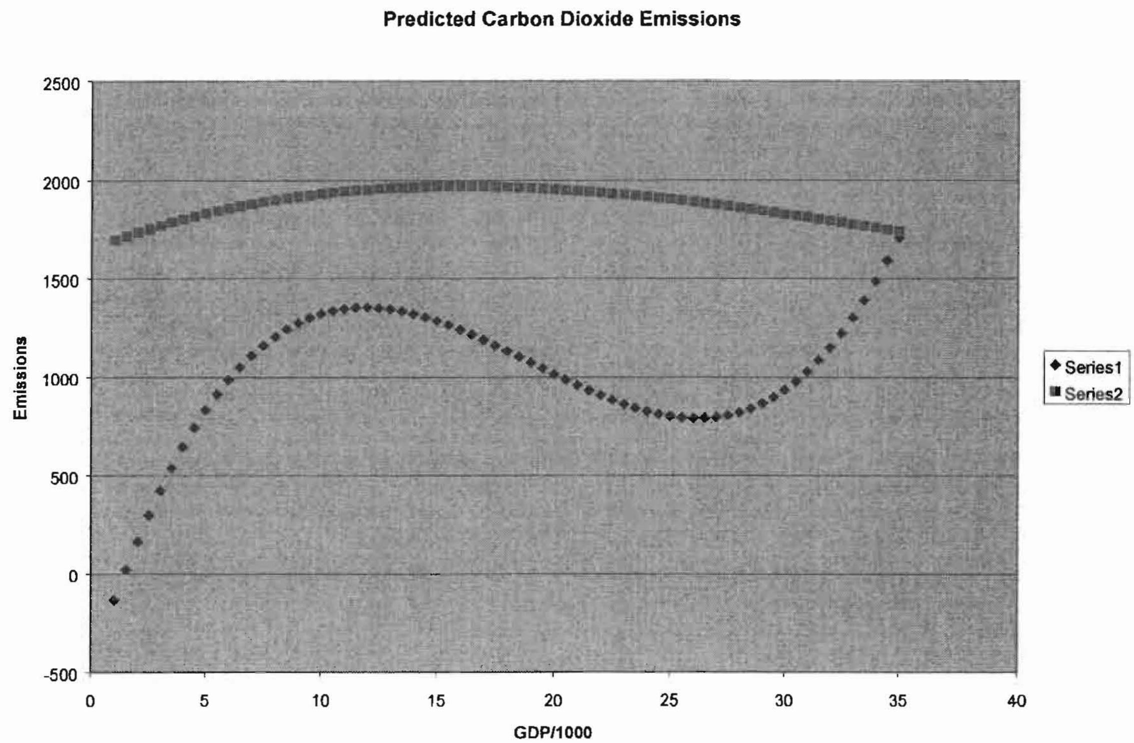
The results of the second model are very close to predictions for sulfur dioxide. The curve does show the inverted-U shape with a slightly higher than expected turning point of around $5,000. The results can be seen in Table 2. All GDP variables are significant with the correct signs. The dummy variables are also significant as a group. It also has an overall R^2 of 0.92, which is higher than the first model. A graph of predicted emissions can be viewed in Graph 5.

Graph 5



The results for carbon dioxide are also in agreement with predictions. The curve does have the inverted-U shape with a turning point around $17,000. The results can be seen in Table 2. All of the GDP variables are significant as a group with the correct signs. The dummy variables are also significant as a group. The regression has an R^2 of 0.98, which is higher than the first model. A graph of the predicted emissions can be seen in Graph 6. There are initial increases in emission levels with a small decrease after a lower than expected turning point.

Graph 6



In the second model there are some unexpected results for particulate matter. The curve has the wrong shape with a very high turning point. This result also contradicts the findings in the first model. The graph of the first model shows a curve that is constantly decreasing with a very low turning point that is not in range. This suggests the results are very fragile and not a lot can be concluded from either model. A potential problem with these regressions is the existence of severe multicollinearity. To explore this problem further a regression run using GDP as the dependent variable against all dummy variables gives an adjusted R^2 of 0.871. This suggests that the GDP variables and the dummy variables are competing to try and capture the same things. Also, there is not a very big improvement in R^2 from the first to the second models. In the second model, the dummy variables are not measuring much more than GDP. Adding the dummy variables to the

equation does not add much more explanatory power, and so the first model seems to be in better agreement with previous research for particulate matter.

The results for sulfur dioxide are in better agreement with the theory and previous research. The turning point is slightly higher than expected, but overall it did have the inverted-U shape. The turning points for both models are in the right range, though, and the results are very similar. Also in the second model the R^2 of sulfur dioxide increases from 0.77 to 0.92. This seems to suggest the dummy variables contribute a lot of explanatory power in the regression. These results support the idea of the Environmental Kuznets Curve, as well as the fact that other factors are also important in determining the level of emissions.

The results of the second model for carbon dioxide are generally in agreement with the theory and previous research. The curve has the inverted-U shape, but a lower than expected turning point. The turning point does increase from the first model, but still not as much as expected. The dummy variables do seem to add to the explanatory power of the second model because the R^2 increases from 0.85 to 0.98. However, the results on the shape of the curve are different in both models. The first model has the inverted-U being very noticeable with large increases and decreases. On the other hand, in the second model the inverted-U is visible but, the increases and decreases are very gradual. In the two models the results are fragile and therefore not a lot can be concluded from them.

VI. Conclusions

The results of this paper are in agreement with the theory and previous research and seem to show that an Environmental Kuznets Curve does exist for both local and global pollutants. The turning points of the local pollutants are lower than the global pollutant as expected. Also the inverted-U shapes of the graphs for the local pollutants are much more dramatic then the global pollutant. The inverted-U shape for carbon dioxide is very gradual, and it does not have the large increases and decreases. In Model 1, all of the findings are in close agreement with the previous literature. All pollutants have the correct shape and are comparable to the past studies. In Model 2, econometric tests for particulate matter reveal multicollinearity problems and therefore the model does not have the correct findings. The other two pollutants, sulfur dioxide and carbon dioxide, have the correct predicted shapes and turning points in the right range. Also, for these two pollutants, the country specific variables are important in adding to the explanatory power of the equation. This suggests that other things besides GDP are important in predicting emission levels.

While it is difficult to know exactly what the dummy variables are measuring for each country, it is important to speculate on what these things might represent. One major factor is the level of industrialization within the country. The greater the level of industrialization, the more pollution can be expected. Another factor that they might be representing is the population density within the country. The more dense and crowded the cities are, the more pollution would increase. Also, going along with this increase in city population, would be an increase in the pollution causing transportation. More people would demand more motor vehicles and other types of transportation, which

would also increase the pollution. A final factor that the dummy variables might be representing is the cultural values of a country. These are the tastes and preferences of the specific country that also influence the levels of pollution. Although many of these country specific factors are difficult to measure precisely, they would be an interesting area for future research. The more that is learned about the specific traits that contribute to the levels of pollution within countries, the better predictions can be about the future of the environment.

An important policy implication that comes from the results is that the promotion of growth within less developed countries will eventually help the environment. The idea of trying to hinder development to protect the environment in not the best approach. If less developed countries are given the chance to develop, then an increase in environmental quality will follow. Another policy implication that comes from this paper is that a joint agreement between countries needs to be reached to help decrease the overall amount of global pollutants that are emitted. Because the effects of these pollutants are not felt just by one country, an enforceable policy is needed to regulate the amounts emitted by everyone. Global warming is just one consequence of excess emissions and it appears to be a serious threat to the future. However, the inverted-U shape of the curve for carbon dioxide is promising for the future. It suggests that the amount of the pollutant will start to decrease, as countries continue to develop.

Appendix A

Countries included in the regressions

Particulate Matter	Sulfur Dioxide and Carbon Dioxide
Austria	Austria
Canada	Belgium
Finland	Canada
France	Denmark
Germany	Finland
Hungary	France
Ireland	Germany
Italy	Hungary
Korea	Iceland
Netherlands	Ireland
Norway	Italy
Poland	Korea
Slovak Republic	Luxembourg
Switzerland	Netherlands
United Kingdom	New Zealand
United States	Norway
	Poland
	Portugal
	Slovak Republic
	Spain
	Sweden
	Switzerland
	United Kingdom
	United States

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