THE AUTOMOTIVE LEAD KUZNETS CURVE: AN ANALYSIS OF THE THEORY AND EMPIRICS*

LA CURVA DE KUZNETS PARA EMISIONES DE PLOMO DE ORIGEN AUTOMOTOR: UN ANÁLISIS DE LA TEORÍA Y HALLAZGOS EMPÍRICOS

Danny García Callejas**

Recibido: agosto 18 de 2006
Aprobado: octubre 02 de 2006

ABSTRACT

This paper analyzes and criticizes Hilton and Levinson (1998), by showing that even though an interesting and well written paper, the theoretical background can be restrictive. For example, the composition effect does not allow for the existence of economies of scale of pollution and the scale effect theory does not permit a changing technology. Finally, we show that the empirical model could be giving spurious results due to the presence of unit roots or its result could be inconclusive because it lacks other regressors that the literature has shown that explain the level of emissions in an economy. Additionally, the authors do no verify their theory with their empirical model. Consequently, some suggestions and future research that could validate their findings are proposed.

* This paper is a critique to Environmental Kuznets Curve for automotive lead emissions, but focused on the paper by Hilton and Levinson (1998). Written in Montréal (Québec), Canada.

** Professor, Departamento de Economía, Facultad de Ciencias Económicas, Universidad de Antioquia. Member of the Environmental Economics Research Group (Grupo de Economía del Medio Ambiente, GEMA), Centro de Investigaciones Económicas, Universidad de Antioquia. Economist, Universidad de Antioquia. Master of Arts in Economics, McGill University. Ph.D. in Economics Student, McGill University. Email: danny.garcia@mail.mcgill.ca.

KEY WORDS: Environmental economics, environmental Kuznets curve, pollution, economic growth, spurious regression.

JEL CLASSIFICATION

Q500, Q530, O400.

RESUMEN

Este artículo analiza y critica a Hilton and Levinson (1998), al mostrar que aunque los autores hacen un estudio interesante, los fundamentos teóricos en los que se basa su análisis son restrictivos. Por ejemplo, el efecto de composición que proponen no permite la existencia de economías de escala contaminantes, y la teoría del efecto escala no consiente cambios en la tecnología. Finalmente, se muestra que el modelo empírico planteado puede estar arrojando resultados espúreos debido a la presencia de raíces unitarias. Sus resultados también podrían ser incorrectos debido a la falta de variables regresoras que la literatura académica ha mostrado explican el nivel de emisiones contaminantes en una economía. Adicionalmente, los autores no verifican su teoría con el modelo empírico presentado. En consecuencia, se proponen algunas sugerencias y futuros temas de investigación que podrían validar sus resultados y los de este tipo de estudios.

PALABRAS CLAVE: Economía ambiental, curva medio ambiental de Kuznets, contaminación, crecimiento económico, regresión espúrea.

1. INTRODUCTION

The Environmental Kuznets Curve (EKC) is an idea that proposes an inverted "U" type relation between pollution and economic growth, consequently proposing that as a country gets richer, there should be a point after which it will become to pollute less even though at first it had a high pollution. Hilton and Levinson (1998), try to establish if such a relation exists for the automotive lead emissions.

The paper written by Hilton and Levinson (1998) is an interesting theoretical and empirical analysis of the EKC for automotive lead emissions that presents an advantage over similar related papers since it innovates by determining the factor that can increase this pollutant, specifically, they will find that automotive lead pollution is a product of lead per gallon of gasoline and gasoline consumption. Additional findings will be that an EKC can be drawn for this pollutant and that the peak of the curve will be sensitive to the functional form and chosen time period.

However, this paper will show, that the Hilton and Levinson (1998), that is an overall interesting and good paper, can still be improved. Fundamentally, omitted variables like the number of cars or trade should have been included in order to justify their results. Additionally, the composition, scale and technique effects that they mention as a theoretical background should have been proven directly in their models. Finally, the possible presence of unit root in the data and not checking for it could be showing that their results are spurious and therefore their results inconclusive.

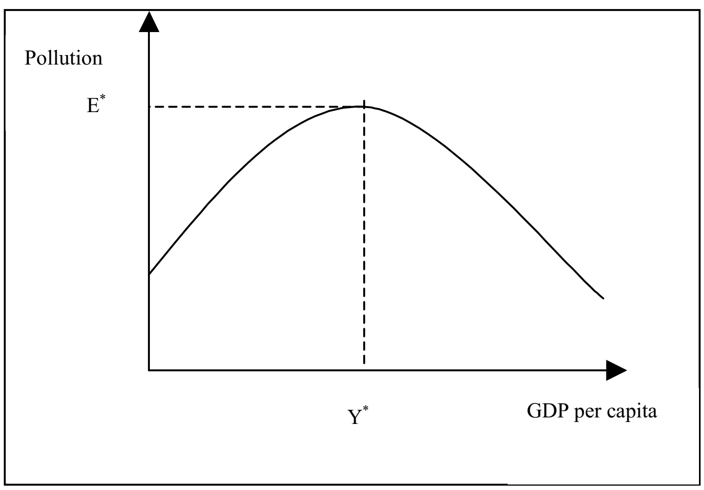
In order to facilitate the reading of this paper, it is divided in two sections: the first one, The Environmental Kuznets Curve (EKC): A Short Review, is a basic summary of the history of the idea of the Environmental Kuznets Curve; and, the second one, Factoring the EKC for Automotive Lead Emissions, that provides a summary of the paper by Hilton and Levinson (1998) that we are focusing on and later presents a critique to the basic theory and empirics that the authors propose and proposes some possible improvements and future research topics. Finally, the conclusions and references are presented.

2. THE ENVIRONMENTAL KUZNETS CURVE (EKC)

2.1. A short review

The Environmental Kuznets Curve (EKC) is, fundamentally, an empirical idea that tries to establish an inverted "U" shape relation between pollution and its different manifestations and income (Figure 1). The original idea was theorized by Kuznets (1955) and proposed that such a curve could be drawn between economic growth and income inequality, that is, low levels of GDP per capita are linked to similar levels of inequality but as the economy grows and with it GDP per capita, income inequality also increases until it peaks at a maximum and begins to diminish as the level of per capita GDP keeps on growing. Similarly, Grossman and Krueguer (1991) seem to be the first to apply this analogy with the variables plotted in Figure 1, by choosing as the peak level of pollution E^* and Y^* the per capita income level at which contamination would begin to fall.

Figure 1. The environmental Kuznets curve



Source: Kuznets (1955, p. 5) and Grossman and Krueger (1991).

The EKC is based on the idea of development economics that low levels of income are associated with economies where agriculture has an important weight on the total GDP and thus the levels of pollution is low, but as the economy grows, the industrial sector gains more importance relative to the GDP in contrast with agriculture that begins to loose it and therefore begins to generate more contamination. This stage is associated with a higher level of development but as the economy keeps on developing, its composition shifts towards the service sector that pollutes less than the manufacturing (industrial) one and would be related to a higher level of GDP and development. This development phenomenon would generate the pattern presented by the EKC.

However, it must be also noticed that the EKC's form is also attributable to the awareness that economic development generates in the government when the levels of pollution begin to rise and thus begin to produce a negative externality that society is not willing to tolerate and therefore gives rise to environmental regulation. The combination of this last effect with the one introduced previously or the transition from and agricultural based economy to a service based one, reaffirms the inverted "U" form of the curve.

Nevertheless, theoretical papers on the EKC show a number of possible causes that would generate an inverted U shape relationship. Among the assumptions that allow this form to arise is that pollution is generated by production (Selden and Song, 1995) or by consumption (John and Pecchenino, 1994; McConnell, 1997) or by permitting endogenous technical change (Stokey, 1998). Consequently, several economic aspects could configure the EKC, implying that empirical work would have to take in account all these factors.

2.2. Empirical Specification and Findings

Empirically, several papers have tried to establish the EKC hypothesis. As mentioned earlier one of the first is the Grossman and Krueguer (1991) that simply modeled quadratic or functions cubic functions of income to try to explain pollution (measured as emissions per capita) finding an inverted "U" form or an N-shaped curve. However, these models were usually estimated in levels or logs, following the form presented in equation (1).

$$\ln e_{it} = \beta_i + \beta_t + \beta_1 \ln y_{it} + \beta_2 (\ln y_{it})^2 + \varepsilon_{it} \qquad (1)$$

Where e is the level of per capita emissions, β_i takes into account the effects that might vary among countries or regions and β_t those that might change through time, y is the level of per capita income and ε_{it} is the error term. Nonetheless, other regressors have also been included in this model like trade, the structure of output or democracy as shown by Stern (1998), that turn out to be significant and capable of explaining part of the behavior of pollution in the analyzed countries in these type of studies.

Among the papers that have found this relation to be statistical significant are Shafik (1994), Panayotou (1997) and Hilton and Levinson (1998), among others. However, their results should be carefully analyzed since problems such as unit roots, omitted variables, endongeneity and heterosckedasticity might be present and therefore making their findings statistically flawed (Stern, 2004, pp. 1423).

3. FACTORING THE EKC FOR AUTOMOTIVE LEAD EMISSIONS

3.1. A summary

The paper presented by Hilton and Levinson (1998) tries to establish a relation between automotive lead emissions and real income per capita for a sample of 48 countries during a 20 year period. It presents three main findings: that lead emissions present an EKC pattern; that the peak for the curve depends on the chosen functional form and that there are two factors that influence automotive lead pollution: lead per gallon of gasoline and gasoline consumption.

In order to get to these conclusions, the authors assume the gasoline use is a measure of the level of the polluting activity in a country (Hilton and Levinson, 1998, pp. 131) and analyze a database obtained from Octel's Worldwide Gasoline Survey in which they focus on 48 countries with 1990 populations over 10 million for the period from 1972 to 1992, and complement this data with the one obtained for income and population from the Penn World Tables. They combine this data and estimate the following panel data equations:

$$\text{lead} = \alpha + \beta_1 G + \beta_2 G^2 + \beta_3 D_{83} + D_{83}[\beta_4 G + \beta_5 G^2] + \beta_6 (\text{population density}) + \beta_7 (\text{year}) + e_{it}$$

(2)

for which they present the result in Table II (Hilton and Levinson, 1998, p. 134) and,

$$\ln(\text{lead}) = \alpha + \beta_1 \ln G + \beta_2 \ln G^2 + \beta_3 D_{83} + D_{83}[\beta_4 \ln G + \beta_5 \ln G^2] + \beta_6 (\text{population density}) + \beta_7 (\text{year}) + e_{it}$$

(3)

for which they present the results in Table II (*ibid.*), and where α is the intercept, G is the GDP per capita, D_{83} is a dummy variable that takes the value of one for all the years after 1983 and e_{it} is the error term.

The results obtained in Table II by Hilton and Levinson (1998, pp. 137) are as follow. They use three different dependant variables for three regressions. Those variables are the total lead emissions (in millions of grams), lead per gallon (in grams) and gasoline use (in millions of gallons). These three variables constitute measures for pollution, pollution intensity and pollution activity. As independent variables, GDP per capita at different levels, population density, a time trend, a constant, a dummy for 1983 and interactions between this year and the diverse levels of income are included. The results tend to suggest an inverted "U" shape relation between income and pollution (in the three cases). However, the income level for the peak of the curve is not consistent in the three models.

In general, the estimation results seem to be significant for the key variables and thus implying a possible inverted U shape pattern. However, the location of the peak for the beginning of the decline in pollution emissions is not robust. This is due to the fact of structural change present in the data, that is, coefficients of the regressors or the impact of income on lead emissions is different after and before the year of 1983. Thus for the cubic regression in levels of income (results in column 2 of Table II), the peak is around $11,000 per capita but for the logarithmic regression the value is of $4,000, then generating imprecise results.

3.2. Revising the basic theory

The authors summarize two alternative theories that might explain the inverted "U" shape relationship between pollution and income. The first one is consistent with the idea of the "composition effect", that is that the natural pattern of economic development involves a transition from an agricultural based economy, that pollutes little, to a more polluting one or of manufacturing and finally to a service industry that pollutes much less. As a consequence, the best way to eliminate pollution is by growing. As a country gets wealthier, it will arrive to a point at which the pollution would be maximum but later will begin to decline. However, richer countries could be diverting their polluting activities to less developed countries and thus not leaving a possibility for these poorer nations to have in the future any other poorer countries to divert their not friendly environmental activities.

This theory leaves little room for the possibility of scale economies of pollution (Andreoni and Levinson, 2001), where it could be the case that the more a country produces the less it pollutes since the technology could be such that it performs more efficiently and becomes more environmentally friendly as the level of output rises. Thus, implying that economies with a big manufacturing sector with a high level of production could be polluting less than economies with a big service sector and a small manufacturing sector, thus contradicting this first theory.

Additionally, this theory does not take into account the possible benefits that developing countries could obtain from the technological advances or spillovers from developed countries. They could take into account "clean" technology that would allow them to produce in a more efficient and less polluting way. Also, the substitution of inputs specially those that pollute the most for more environmental friendly ones is also a possibility that could arise thanks to new technological discoveries, discovery of new, more and cheaper reserves of a product or the development of process that allow to incorporate them in the traditional production.

The second theory proposes that the EKC is based on two relationships: the "scale effect" and the "technique effect". The first one establishes the richer the country the more it pollutes, but the second one proposes that the citizens in those countries believe that environmental quality is a normal good and therefore demand for regulations such that reduce the amount of contamination. But, this generates a theoretically ambiguous shape.

However, the scale effect would imply that the structure of technology of the economy would have no change (Stern, 2004, pp. 1421) and thus there would be no space for improvements in production process, fact that has not been observed, no the contrary, technology evolves and allows for new more efficient production process to be used in the industry. Especially for automotive lead emissions, where the use of filters for car exhausts and gasoline diminish the impact of lead. Additionally, improvements in engines make them more efficient. Consequently, it could be the case that both scale and technique effects could move in the same direction and thus generate an EKC.

3.3. A Critique to the empirical work

The data used by Hilton and Levinson (1998) is for a pool of 48 countries during a period of 20 years, and like in any time series arrange and in this case panel analysis the possibility of the presence of unit root is plausible. However, no unit root tests were specified, generating a possibility of a spurious regression. If, the data was not integrated of order zero or I(0), the regression that was done could be actually not related and therefore driving to misleading results (Baltagi, 1999).

Additionally, Hilton and Levinson (1998, pp. 127) mention that other papers, like the ones referenced in their Table I,[1] "use other covariates such as time trends, population density and trade openness" but in their estimation they do not check for trade openness. In fact, an omitted variable problem could be arising not only from the lack of this variable but from others such as output structure that would be in accordance with their theoretical proposals and that have been included in other studies (Stern, 2004). In consequence, their results can be biased and inconsistent, giving an apparent relation that might not exist and even being the cause for finding a peak sensible to the functional form of the model that they estimated (Hilton and Levinson, 1998, pp. 135).

Another interesting fact is that the study is directed to the automotive lead emission; however, the econometric model has as a regressor the population density and not the number of cars or per capita cars, which would be more consistent with their model. As they say, one of the factors of automotive lead pollution is gasoline consumption and there is no doubt that this depends on the number of cars in the economy.

Also, they propose two theories, composition effect and the scale effect and technique effects but none of these are proven or rejected with the econometric models that they propose since they do not include variables related to GDP

1 Table I, in Hilton and Levinson (1998, pp.128), describes four papers that provide consistent results with the Kuznets curve hypotesis including the most relevant characteristics of the estimated econometric models in each paper. Also, they point out the independent variables used in these studies: population density, geography, investment, energy subsidies, trade openness, debt and civil and political liberties.

composition, in order to try to test the first theory for example.

Finally, even though studies have shown that simulteniety between per capita GDP and per capita emissions of pollution might not be significant (Stern, 2004, pp. 1429), a cautious analysis should be done and such a relation should be checked by performing a Durbin Wu Hausman test between these variables. In this case it would be hard to be found but, since automotive lead emissions depend on the number of cars in the economy, a higher number of these could generate such a level of pollution in important cities that could restrain growth. Nevertheless, this situation seems not plausible at the moment; even though cities like Mexico City present high levels of contamination that could hamper growth and economic activity in Mexico if we take in account that it has an important weight on the this Latin-American country.

3.4. Aspects for future research and improvement

Overall, the paper written by Hilton and Levinson (1998) is good, precise and well written; however, there are several aspects that can be improved and could be taken in account in future research about this topic.

The first one, is that we require to include more variables that have been shown are related to the level of pollution in the economy. Especially, the ones that can prove the ideas proposed in the paper as we discussed in the prior section.

Second, more diagnosis test should be done on the data in order to determine the validity of the conclusions that the model presents. Consequently, unit root test should be performed and the trends and behavior of the data for the countries in the sample should be carefully analyzed before the econometric model is estimated.

Third, the authors say that "polluting production in this case cannot be separated from consumption and exported to less developed countries", however developed countries do have the possibility of exporting cars with more efficient and "cleaner" engines that could indirectly contribute to a form of exporting a reduction of pollution, or if they send the least efficient and used cars in augmenting it. Therefore, some data or statistical evidence should be presented in this regard in order to sustain this idea.

Finally, the authors suggest in the conclusion that "government action such as taxes or bans on leaded gasoline appears to be behind much of the decline in automotive lead pollution", then why not include dummy variables or information on pollution taxes for each country such that we can control for these effects and therefore determine if this hypothesis is correct. Future research could focus on this aspect by also making an institutional analysis of the environmental policies that are related to lead emissions in the countries in the sample.

4. CONCLUSIONS

The paper written by Hilton and Levinson (1998) is an interesting theoretical and empirical analysis of the EKC for automotive lead emissions that presents progress over similar related papers since it determines the factor that can increase this pollutant. They find that automotive lead pollution is a product of lead per gallon of gasoline and gasoline consumption. They also find that and EKC can be drawn for this pollutant and that the peak of the curve will be sensitive to the functional form and chosen time period.

At a theoretical level, the composition effect that they propose leaves no room for the presence of economies of scale of pollution, that is, they more an industry produces the less it pollutes and therefore countries with big manufacturing sectors could have less pollution than ones with a small one. And the scale effect would imply that technology for more efficient and cleaner processes is constant, an assumption that seems to be not in accordance with the automotive sector were improvements have been held.

Finally, four empirical critiques can be done to the Hilton and Levinson (1998) paper: omitted variables such as trade openness, number of cars; lack of diagnosis test for the model; that they do not test their proposed theories and not including in their analysis and modeling the regulation on lead on the analyzed countries even though they explain that it is behind the decline in automotive lead emissions.

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