Searching for an Environmental Kuznets Curve (EKC)-pattern for CO_2 emissions

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Abstract: The Environmental Kuznets Curve (EKC) hypothesis has been tested for various types of environmental degradation in the relative literature. This paper focuses on the studies dealing with CO_2 emissions, because CO2 is the major greenhouse gas. CO_2 is directly connected with the use of energy, which is one of the most important parameters of the economic development of countries. The results indicate that the EKC concept may be inappropriate to describe the particular relationship between economic growth and carbon dioxide emissions.

Key-Words: Environmental Kuznets Curve, Carbon Dioxide emissions, economic growth

1 Introduction

According to the Environmental Kuznets Curve hypothesis (EKC for short), the environmental degradation is created in the early phase of the development process during the transition of the production of an economy from the agriculture sector to the industry sector. That environmental degradation is expected to decrease during the late stages of economic growth. The EKC concept was based on the original theory of the relationship between income inequality - economic growth which was presented by Simon Kuznets in 1955 [1]. Kuznets proposed that the distribution of income is moving towards equality when an economy reaches a certain level of economic development, after an initial phase of rising income inequality due to the transition of the rural population to the industry sector. Returning to environmental issues, many authors –mostly from the early 1990s- propose that the best and probably the only way for an economy to overcome environmental degradation is to concentrate on its economic growth.

From the early 1990s a global concern for the future of our planet started, due to scientific research which revealed that the over-accumulation of CO_2 emissions is expected to alter the earth's climate with unpredictable effects on nature and human beings. Carbon dioxide, the major greenhouse gas, does not directly affect human health, but affects the natural climatic system. The over-accumulation of such greenhouse gas during the last two centuries is the result of the intensive economic growth of the most –so-called today- developed economies: their development was based on industrialization and the use of relatively cheap energy, mainly from fossil-fuels.

Given the concern about climate changes, some researchers attempted to study the possible links between economic growth and CO_2 emissions under the EKC view. Research became more intense during the first decade of 2000s. In general, the results of these studies are rather mixed. It seems that CO_2 emissions are not expected to decline in the long-term following an EKC pattern, as an economy grows. Contrary, a positive monotonic relationship appears, implying that CO_2 emissions are rising as an economy is expanding.

This paper is organized as follows. Initially, a brief presentation of the EKC concept is given. Next, the issues regarding the measurement of CO_2 emissions data are discussed. Then a review of studies on the EKC concept dealing with CO_2 emissions follows. Next, some critical points regarding the EKC-CO_2 emissions studies are highlighted. Finally, some conclusions are drawn.

2 The EKC concept

The EKC states that further economic growth can improve the deterioration of environment which occurred in the early stages of economic growth of an economy. The relationship between environmental degradation and income per head takes the form of an inverted U. More specifically, in the early stages of the economic process, there is abundance of natural resource stock and a low production of wastes because of low economic activity. As industrialization takes off, resource

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depletion and waste production accelerate. At this phase of transition from agriculture to industry, industrialization of the production process creates a positive relationship between per capita income (or else economic growth) with environmental degradation, in a general sense. So, pollution is linked positively with economic growth. At higher levels of economic development, the production process of the economy becomes more information based and the service sector is boosted. This shift in the composition of production, combined with improvements in technology and increased demand for environmental quality, results in a leveling-off and a steady decline of environmental degradation [2]. So, after a certain level of income per head (or growth), pollution is negatively linked with the process of economic growth and further expansion improves the quality of environment.

In order to test empirically the EKC hypothesis, the following general reduced-form model is used [3]:

$$y_{it} = a_i + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 x_{it}^3 + \beta_4 z_{it} + e_{it}, \quad (1)$$

$i = 1,...., N$ countries, $t = 1,...., T$ years

In (1), y is the depended variable which expresses an environmental indicator of degradation on a per capita basis, x is the income per capita, z reflects other parameters that may influence y, α is the constant term, and β_k is the coefficient of the κ explanatory variables that have to be estimated. The e represents the error term. The cubic term of x is not always included in the models except of those studies that try to examine an N-shaped or a monotonic rising relationship between pollution and income. Many studies estimate the (1) in a logarithmic transformation by using *ln(x)* and *ln(y)* instead of x and y in order to avoid indicators to become zero or negative [4]. The empirical estimation of the (1) consists in testing the significance of the coefficients β_i. Only if $\beta_1>0$, $\beta_2<0$ and $\beta_3=0$, an inverted U relationship (EKC) exists.

The (1) is the solution of a structural grid of (unknown) equations that shape the final relationship between environmental degradation and income. With the use of such a reduced-form model, it is possible to measure directly the impact of income on environmental degradation but it is unknown which exactly are the underlying component functions of the economic system that create this final relation. The model (1) is usually estimated with time series-cross sectional data (TSCS) or panel data. Only a few studies have attempted to estimate the model with strictly time-series data due to the lack of available data over a long period of time.

3 Data on CO_2 emissions

The literature relative to EKC hypothesis examines air pollutants and more particularly sulphur dioxide (SO_2), suspended particulate matter (SPM), nitrogen oxides (NO_X), carbon monoxide, lead, volatile organic compounds (VOC) and carbon dioxide (CO_2) [5]. CO_2 data concerns emissions of this gas, while data of the other air pollutants are either ambient concentration or emissions data. The difference between those measurements is that emissions are directly related to current economic activity as they are calculated from estimates of fuel consumption and emissions coefficients for different fuel types, but they are independent of the area in which they are released and of the damage they cause. Reversely, concentration data measure the local impact on the environment but they are not always directly related to local-current economic activity [5].

Data availability on CO_2 emissions (and other various pollutants) started from the early 1990s through the Global Environmental Monitoring System (GEMS), the environmental data compendium of the OECD and the CO_2 emissions estimates from the Oak Ridge National Laboratory (ORNL) [3]. This data availability enforced researches to construct empirical models in order to examine the EKC relationship with respect to CO_2 emissions.

4 Studies of EKC with respect to CO_2 emissions

4.1 Studies which use panel data or time series cross sectional (TSCS) data

4.1.1. The first empirical study

The first empirical study about CO_2 emissions is the work by Shafic and Bondyopadhyay in 1992 for the World Bank [6]. The authors use ten indicators as environmental quality depended variables and they set panel regressions using data from 149 countries for the period 1960-1990. According to their result, income has a significant effect on all indicators of environmental quality. Most environmental indicators deteriorate initially with rising incomes but tend to improve as countries becoming richer. One of the exceptions to this pattern is carbon dioxide emissions which seem to rise monotonically as income rises.

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4.1.2. Studies dealing with energy issues

Some studies set the energy issues in the centre of consideration, as carbon dioxide is directly related to the use of energy for the needs of economic activity. Agras and Chapman [7] mention that the EKC concept omits a very important variable such as the energy prices. Energy is used everywhere and several pollutants are emitted by almost all forms of energy production, especially CO_2 emissions which are emitted from the consumption of fossil-fuels. The authors include in their study trade variables and energy prices and they propose a CO_2 model and an energy model. According to their results energy prices is an important indicator of energy demand and consequently of carbon emissions while in overall, no EKC pattern is found with the inclusion of energy prices. They also find that, due to oil-crises, there was a shift from carbon-intensive energy sources to less carbon-intensive sources (such as natural gas, nuclear or hydroelectric power) and this shift is reflected on the CO_2 model but not on the energy model. This point hints that an EKC pattern for CO_2 may arise because of the effect of oil-shocks during the 1970s decade. Moomaw and Unruch in 1997 [8] argue exactly this point by observing that the turning point of the inverted-U relationship occurred at widely different income level in 16 OECD countries in the 1970s. By this way, it is possible that the declining emissions of CO_2 are driven by the oil-price shocks. If the oil shocks shift the fuel mix of energy, the fuel mix could be an important determinant of an EKC relationship. Richmond and Kauffmann [9] examine this last case by estimating the relationship among income, energy mix and energy use and/or carbon emissions with a panel of international data for the period 1973-1997. Their results indicate that there is a positive relationship between income and energy use and/or CO_2 emissions for non OECD countries. A limited EKC pattern is found for OECD countries, but this could be an illusory effect of higher energy-prices in 1970s, which slowed energy use. The authors also mention that energy price should be taken in account as price is a significant determinant of energy use. In a similar way, Roberts and Grimes [10] estimate a curvilinear relationship between CO_2 emissions intensity and level of economic development, but only in the high-income countries just before the two oil crises of the 1970s. This was the result of a relatively small number of relatively wealthy countries becoming wealthier since 1970, while the average for the rest of the world gets poorest, as the authors support.

4.1.3. Studies which include structural changes and technology

Another factor that may affect the income-air pollution relationship is structural changes (transition from industry to services) and technology improvement. De Bruyn et al [11] use the emission-intensity as an index reflecting the changes in the composition of economic activities and technology. They try to test empirically such an influence on CO_2, NO_X, and SO_2 emissions in the Netherlands, Western Germany, UK and USA for various time intervals during 1960-1993. The authors estimate that emissions may have declined over time, probably due to technological and structural changes. However, the available data do not sufficiently support that in the above countries the improvements in environmental quality is due to income accumulation, probably because of the adoption of a reduced-form model, such as the EKC model. For the case of Canada, and with respect to CO_2 emissions, Lantz and Feng [12] find that while population size has a positive effect on carbon dioxide emissions, technological or structural changes have switched its influence from negative to positive, favoring CO_2 emissions intensity production for the sample period 1970-2000. For the case of Sweden, Kander [13] estimates a decline of CO_2 emissions after 1970 due to a stabilization of energy consumption which occurred as a result of the slow growth of the economy and a substantial decline in energy intensity within the industrial sector.

4.1.4. Other studies

Some studies attempt to include forecasts about future trends of CO_2 emissions. Galeotti and Lanza [14] use a panel data set of 110 countries for the period 1970-1996. Although the authors find an evidence of an EKC-pattern in the case of CO_2 emissions, they forecast that future global emissions will increase, due to the most rapid growth of per capita income in developing countries. According to the authors, income and population play a key-role in carbon dioxide emissions.

Other studies attempt to adopt a non-parametric functional model instead of the parametric reduced-form model of the EKC. Azomahou and Van Phu [15] use a non-parametric model and a sample panel data of 100 countries for the period 1960-1996 and they find a monotonous relationship which is different from the EKC shape. Similarly, in a revised paper, Azomahou et al [16] use a non-parametric model instead of a parametric model. The non-parametric model implies a monotonous relationship between income and CO_2 emissions,

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while the parametric model -which leads to an EKC pattern - is rejected in favour of the non-parametric model specification. The authors conclude that the economic development process always leads to an increase of CO_2 emissions.

Cole [17] tests the case of CO_2 emissions among other air and water pollutants and finds an income turning point for CO_2 outside the sample income range. Lee et al [18] find an evident inverted U-shape between income and CO_2 emissions in the case of the middle income American and European countries, but not in the case of the high or low income African, Asian and Oceania countries for the time period 1960-2000. Aslanidis and Iranzo [19] examine the case of non-OECD countries for the period 1971-1997 and they find no evidence of an EKC, while two regimes appear: a low income regime, where emissions increase with economic growth, and middle to high-income regime, which is associated with a decrease in environmental degradation. Narayan and Narayan [20] use the short-term elasticity versus the long-term elasticity in order to examine the EKC hypothesis in the case of developing countries. They find evidence of such a pattern for the 35% countries of the sample, while for a panel of countries in Middle, Eastern and South Asia there is evidence that CO_2 emissions decrease with an increase of income. For 29 OECD countries and for per capita CO_2 emissions during the period 1970-1998, Pauli [21] identifies a strong evidence of an EKC for 12 countries, an increasing or decreasing relationship for 9 countries, while for the rest 8 countries no clear trend can be concluded. Jaunky [22], following Narayan and Narayan's work [20], tests 36 high-income countries for the period 1980-2005 and finds that only for 5 individual countries the EKC is valid, while for the whole panel –even thought CO_2 are stabilizing- an EKC pattern is rejected. Iwata et al [23] use annual data of 17 OECD and 11 non-OECD countries and conclude that CO_2 emissions increase monotonically with income in all countries, while the increase rate of CO_2 emissions is decreasing in OECD countries and increasing in non-OECD countries. The authors find also a significant negative impact of nuclear power use on CO_2 emissions. Acaravci and Ozturk [24] examine 19 countries from Europe from 1960 to 2005. Their results support the validity of an EKC pattern only for two countries (Denmark and Italy), while energy consumption plays a key role in CO_2 emissions.

4.2 Studies using time-series data

Many authors diversify the data sample in their studies by focusing directly on one country for the most available time period. In fact, they use time-series data instead of panel data based, on the thought that countries are not homogenous in their characteristics. A limitation of such studies is that the available data do not cover a long and sufficient time period. Dijkgraaf and Vollenberg [25] conclude in a probably EKC-pattern with panel data, but their results are very different when they examine separately each country with time-series data. Egli [26] uses time series for a single country, Germany, for the years 1966-1998 for CO_2 emissions and seven other pollutants (SO_2, NO_X, CO, NH_3, CH_4, PM, NMVOC). Although the results remain ambiguous, the author finds an EKC-pattern only for nitrogen oxide and ammonia. The other six pollutants show no clear trends. Friedl and Getzner [27] examine the case of CO_2 emissions in Austria with time-series data (period 1960-1999). . The authors find an N-shaped relationship between CO_2 emissions and income, with 1974 to be a crucial year due to oil shock. An explanation of this pattern could be that the oncoming rise of emissions may be the result of a "recovery" effect because the initial shock of the oil crisis in the 1970s might have been reduced after one decade. Kunnas and Myllyntaous [28] use annual data for Finland for the period 1800-2003 on carbon dioxide and sulphur dioxide emissions, and find that till the 1970s the two pollutants had similar trends. Afterwards, CO_2 emissions continued to increase (but in a slower rate), while sulphur dioxide decreases at a significant rate as the economy is growing. So, an EKC pattern is valid in the case of sulfur dioxide but not in the case of CO_2 emissions. Halicioglu [29] uses time series data from 1960 to 2005 in order to estimate the EKC hypothesis in the case of Turkey. The results provide some evidence of an EKC pattern at first sight, but the graphical representation of per capita CO_2 emissions and per capita real income shows a positive monotonic relationship. During the period 1971-2005, the empirical study of Jalil and Mahmud [30] indicates a possible EKC-pattern in the case of China, despite the impressive growth of the industrial sector.

5 Critical points of EKC for CO_2 emissions

The rresults of most empirical studies of the EKC concept on various indicators of environmental degradation show that the EKC hypothesis is valid only for certain types of pollutants [3, 5]. But the EKC concept does not completely fit in the case of CO_2 emissions. The first empirical studies mention

that an action is taken at a local level by agents when there are generalized local costs and substantial private and social benefits. Reversely, when the cost of environmental degradation is created from other parts (outside the local level, for example by other countries) then there are few incentives to alter the damaging behavior and this holds for the case of CO_2 emissions [6]. Moreover, GHGs are specific pollutants because they create global and not only local degradation. That means that individual countries have often weak incentives to implement pollution control schemes, as other country also take benefit of the reduction of GHG emissions [31].

CO_2 emissions are directly related to the use of energy which in turn, is essential for the growth process. Therefore, higher CO_2 emissions occur from the economic growth due to the more intensive and higher use of energy [5]. As CO_2 emissions have long-term effects, they are associated with relative high abatement cost and that discourage agents to undertake restrictive actions [3, 32]. Also, the majority of the existing policies (governments) are short-lived, while GHG emissions have implications reaching the far future [31].

GHG emissions and CO_2 emissions cannot be treated like the other types of pollution which affect human health. However, CO_2 emissions affect nature, the quality of life and the wealth of nations, as climate changes will alter the possibilities for economic growth [33]. Therefore, accepting that the same process of economic growth may (sometime in the distant future) limit the over-accumulation of CO_2 emissions in the atmosphere may be proven to be a misleading policy and the damage on climatic system that will have been created by then, will be difficult to reverse.

6 Conclusions

In general, an EKC relationship is not sufficiently supported in the case of CO_2 emissions. The relationship is rather positive-monotonic which implies that economic growth is not expected to control CO_2 emissions. Any sign of an EKC-pattern for CO_2 is related only to the currently most developed countries, or the most developed regions. Even so, no clear-cut evidence arises for an EKC pattern in the case of CO_2 emissions. The studies including estimations for future projections of CO_2 emissions indicate an upward positive evolution of CO_2 emissions due to higher income growth. This is a consequence of the fact that economic growth leads to the increased use of energy which consequently leads to higher emission of greenhouse gases.

It is very possible that the peak of CO_2 emissions in the early developed and industrialized countries may occurred in the pre- Second World War period, while most of the aforementioned empirical studies examine the EKC hypothesis after 1970 or 1960 when the oil crises occurred. In any case, in order to test sufficiently the income-CO_2 relationship, it is necessary to use data for a much longer period of time. Additionally, such a relationship cannot be adjusted to a reduced and limited concept like the EKC concept. Various factors like energy mix, energy prices, structural changes, technology changes, institutions and population growth seem to affect the effect of economic growth on the environment and vice versa. Structural analysis is needed in order to reveal more accurately all these underlying links between economic growth and environmental degradation.

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