Critical evaluation of the determinants used in the Environmental Kuznets Curve (EKC) literature

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Abstract

The underlying model behind the Environmental Kuznets Curve (EKC) with policy interactions was first presented by Panayotou, which was an innovation to the original concept offered by Kuznets (Kuznets, 1955). This form of modelling used the traditional approach of atmospheric gasses (ambient effects) as the response variable in modelling output, demography and policy interactions (Panayotou, 1997). The reduced-form approach (Panayotou, 1997) on the income-environment relationship has been a useful first step towards answering the question of how economic growth affects the environment. However, without an explicit consideration of the underlying determinants of environmental quality, the scope for policy intervention is unduly constrained. Policy in this regard is considered to be any measure of reducing atmospheric gasses. The main purpose of this paper is to contribute to the EKC literature by evaluating the use of different variables (explainable as a function of inputs-production function) with particular interest to the path for policy implications regarding the energy efficiency of a country. The specific focus on the use of energy efficiency comes from the fact that its trend follows a similar pattern to atmospheric gasses, namely CO2 and SO2, which seems to suggest a better representation response variable in the EKC model (Gillingham, Newell, & Palmer, 2009). But does this hypothesis hold for all countries? Based on the current literature, we will establish if there are any significant differences for this hypothesis among the original case of 60 countries from 1970 to 2012.

1. Introduction

The concept of the Environmental Kuznets curve (EKC) is the empirical hypothesis which states a relationship between the state of the environment and income per capita. The original concept hypothesised that at the beginning of economic growth factors contributing to the degradation of the environment were present with increasing intensity; at a level of economic growth the intensity of environmental degradation decreases until (the turning point) economic growth results in decreasing environmental degradation (Panayotou, 2003). The concept of the EKC appeared in 1991 with Grossman and Krueger's study of the effect of NAFTA, further expanded by Shafik and Bandyopadhyay's study in 1992 for the World Development Report. The concept of the EKC has emerged from finding the relationship to identifying the variables responsible for capturing the theoretical EKC. Studies such as Dasgupta et al. (2002); Perman and Stern (2003) characterised the theoretical framework by introducing degradation variables. They challenged the notion of whether `getting rich' was a prelude to `environmental consciousness', for which the study raised irregularities namely that not all pollutants result in the inverted U shape of the characteristic EKC.

The Environmental Kuznets curve is a theoretical component of the effects of increases in income per capita. The study of increasing income per capita is regarded as a tool for understanding economic growth and development. The case for growth and economic activity is largely tested in economic literature, identifying the various stages and causes of economic activity on the natural and human environment. The Environmental Kuznets Curve is popular among economic theorists and policy makers, however, the vast literature suggests that there is no coherency among the findings.

The purpose of this study is to critically evaluate the existing literature taking into account issues such as the proximate factors as proposed by Panayotou (1993), various definitions of environmental performance, and policy variables. This paper also discusses the main criticisms

of the theoretical foundations of the concept of EKC and proposes structural components that need to be taken into account when modelling to investigate the existence of EKC.

2. Critical Evaluation of Literature

The study by Panayotou (1993) expanded the original concept by explaining the growth in the economy. Transforming the income per capita argument into a case for growth and development. In isolation, growth and development are negatively related in the original EKC model. Panayotou (1993) presented arguments in favour of structural influences that are negatively related to environmental degradation and positively related to growth. These factors also referred to as proximate factors serves as the modern theoretical model for the EKC. The 'Proximate Factors' are decomposed in Table 1.

Table 1 Proximate Factors

Term	Definition
Scale	Factor-intensities, Knowledge spillover
Output Mix	Pollution-intensities per industry
Input Mix	Substitution of pollution-intense inputs for "green" technologies
Technological Efficiency	Less polluting inputs are required to produce the same output
Technological Emissions	Less emissions per the same ratio of input to output

Lopez (1994) and Selden and Song (1995) made certain assumptions regarding the proximate factors, such as infinitely lived agents, exogenous technological change and the production in the economy was solely responsible for pollution. In contrast Pecchenino (1994), John et al. (1995), and McConnell (1997) made use of overlapping generation models. This contended that pollution is driven by consumption. This assumption allows for endogenous technological progress in the decomposition of economic growth and economic development further investigated by Stokey (1998) in the EKC framework. The underlying inconsistency of the EKC is detached from the proximate factors as expressed by Panayotou (1993). The inconsistency is in the variable for environmental degradation. Pollutants such as Sulphur have been vastly popular in EKC studies, however, the turning points are not unanimously determined for any country given the studies. The original EKC presented a theoretical

justification for the relationship, however, the nature of the relationship between the state of the environment and the level of income has little econometric clarification.

The earliest EKC models explored the income-environment relationship using quadratic functions of income per capita and a dependent variable E indicating some form of emission, as denoted in Equation 1.

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \delta_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2 \left(\ln\left(\frac{GDP}{P}\right)\right)^2_{it} + \varepsilon_{it} \dots Equation\ 1$$

Where P is the population parameter and all variables are in natural logarithm form. These studies focused on determining the Fixed Effects as seen by the terms $\{\ \alpha_i + \delta_t\}$ for the panel of countries.

Early studies using this techniques were first explored in literature by Hauseman (1978), Mundlak (1978) and Hsiao (1986). Based on the empirical and statistical finding of Hauseman (1978); Perman and Stern (2003) contributed to the argument by exploring unit root tests and cointegration tests to isolate the endogeneity or time properties of the estimation equation. They found across a panel of 60 countries that sulphur may be cointegrated with GDP per capita, further proved by Coondoo and Dinda (2002) with carbon dioxide as a dependent variable. The results from Perman and Stern (2003) and Coondoo and Dinda (2002) find that although the specific effects of the variables are not conclusive in the EKC, the dependent and GDP are required econometrically to be cointegrated. Failure of cointegration may result in spurious estimates.

The foundation for modern EKC studies is widely considered to be from the innovative stance of Panayotou in his paper entitled "Demystifying the EKC: Turning a black box into a policy tool", 1997. Panayotou (1997) explored the income-environment relationship in a reduced form approach with policy variables. He presented the model in an attempt to reason the theoretical identity of the inverted U shape.

$$X_{it} = a_0 + a_y Y_{it} + a_{yy} Y_{it}^2 + a_{yyy} Y_{it}^3 + a_d D_{it} + a_{dd} D_{it}^2 + a_{ddd} D_{it}^3 + a_g G_{it} + a_{gy} G_{it}^1 Y_{it} + a_p P_{it} + a_{py} Y_{it} P_{it} + a_t t + e_{it} \dots Equation\ 2$$

Equation 2 is the model presented by Panayotou (1997) with policy variable P, ambient SO_2 X, population density D, 100+g the annual growth rate G and the regression estimates a*. The explicit policy and growth rate interaction are included in the model both additively and multiplicatively with

income, this is done with the intent of testing the fixed effects nature and the contribution to the turning point and speed at which the turning point is reached. Panayotou (1997) found that in the absence of an explicit justification of the determinants of environmental quality, the range of policy intervention is constrained. A further contribution of Panayotou (1997) is the nature of the estimating equation, which is capable of determining the policy effects at low income levels and the subsequent effects at higher income levels.

Studies on the EKC, presented by Stern (2003), have made use of many dependent variables including waste, NO_x, SO_2, Suspended particles, CO, water consumption and deforestation. According to Stern (2003) the most coherent is SO_2 as the findings resemble the inverted U shape of the theoretical EKC. Studies which included CO_2 and suspended particles did not sufficiently produce the inverted U shape and therefore were considered to be estimators with weak EKC modelling character.

Grossman and Krueger (1991) estimated the EKC for SO_2 and Suspended particles. The data used was a panel of cities from various countries. Shafik and Bandyopadhyay's (1992) estimated the EKC using ten different indicators. They found with strong significance that lack of clean water and lack of urban sanitation declined as income per capita increased. Deforestation and river quality were not statistically substantial across the panel and air pollutants produced the desired U shape, however, at a very low level of significance. Selden and Song (1994) used SO_2, NO_x, Suspended Particles and CO, this study found that these variables are highly significant in recently industrialising countries and during early stages of economic development. Rising population and urbanisation provided a hinder to the reliance of the estimators at higher income levels. Dijkgraaf and Vollenbergh (1998) estimated the EKC for CO_2 across a panel of OECD countries, they found the inverted U shape with significant estimates. Stern and Common (2001) further investigated this relation and found that with high income countries the effect of CO_2 produces the well-defined EKC, however, lower income countries fail to produce the EKC's characteristic U shape. Studies such as Cole et al. (1997); Kaufmann et al. (1998); List and Gallet (1999); Panayotou (1993); Torras and Boyce (1996) and Panayotou (1997) explored the relationship between income and SO_2. In addition to the dummy variables of population, government, technological change and time effects; Torras and Boyce (1996) included literacy, civil rights and income inequality. These studies are not consistent in their findings. Suggestive of the nature of

environmental measurement proxy SO_2. Table 2 tabulates the findings of the baseline studies contending in the EKC argument, indicative of the inconsistency of results with particular focus on the turning point.

Table 2 Summary of Baseline Studies and Findings

Author(s)	Period	Degradation Variable	Turning point estimates in US dollars	Region of the study
Grossman and Krueger, 1994	1977-1988	SO_2, Suspended Particles	$4,000-$5,000	52 Cities across 32 Countries globally
Shafik and Bandyopadhyay, 1992	1960-1990	Clean water, urban sanitation, SO_x, deforestation, CO_x	$2,000 for ambient effects, $3,000-$4,000 for pollutants	149 Countries
Selden and Song, 1994	1973-1984	SO_2, NO_x, Suspended Particles, CO	SO_2 - $8,709 NO_x - $11,217 CO - $ 5,963 SPM - $10,289	22 High income, 6 Middle income, 2 Low income
Panayotou, 1993	1985-1991	SO_2, NO_x, Suspended Particles, deforestation	Deforestation-$823 SO_2 - $3,000 NO_x - $5,500 SPM - $4,500	68 Countries in the deforestation sample, 54 in the pollution sample
Kaufmann et al., 1998	1974-1989	SO_2	SO_2 - $14,730	13 Developed, 10 Developing countries
List and Gallet, 1999	1929-1994	SO_2	SO_2 - $22,675	55 Developed and Developing countries
Torras and Boyce, 1996	1977-1991	SO_2, Literacy, Urbanisation	SO_2 - $4,641	41 Countries

Analysis of the literature captured in Table 2 shows that the turning point for the estimates are not coherent. The latest studies such as List and Gallet (1999) have a turning point of $22,675 per capita in contrast Panayotou (1993) provides evidence of a turning point around $3,000 for the same variable SO_2. List and Gallet (1999) did not use PPP converted GDP where as Panayotou (1993) did; further the structural estimating equation used by Panayotou (1993) includes additional variables whereas List and Gallet (1999) estimated using equation 1 the original EKC model. The EKC theoretical model sets out a relationship between the state of the environment and income. The turning point is therefore an indicator of the level at which further economic growth results in a decline in environmental degradation (Panayotou, 2003). The outcome of the studies summarised in Table 2 shows the findings of the EKC

model in terms of the variable used to capture the state of the environment, given the region and the period. The majority of literature on the EKC provides an insight into some of the critiques associated with the study on the income-environment relationship. The most influential critique towards the EKC is the critique presented by Arrow et al. (1995) and Stern et al. (1996), the argument for trade and specialisation (presented as the Hecksher-Ohlin theory). Under free trade, countries will increase in specialisation of their production for which they have a comparative advantage. This reasons why developing countries would produce more goods which are intense in labour and natural resources. Whereas developed nations would trade services and specialise in capital intensive goods. This could have an effect on the distribution of factors causing the decline in the state of the environment. Earlier studies critiqued the use of atmospheric gases, the omission of population growth and the level at which the state of the environment would stop all economic production and by extension all economic activity (Stern, Common, & Barbier, 1996). Table 3 summarises the major critiques found in the literature.

Table 3 Environmental Kuznets Curve Critiques

Number	Author(s)	Critique
1	Arrow et al., 1995 Common, 1995	Simultaneity, State of the Environment affects labour and land, however, in some countries this has little effect on economic production. Quality of life is not necessarily captured in increasing levels of production (growth)
2	Herendeen, 1994	Import of raw materials may place the onus of the state of the environment within the exporting country and not the importing country.
3	Hettige, Lucas and Wheeler, 1992 Etkins, Folke and Costanza, 1994	Environmental regulations in developed countries provides an opportunity for developing countries to encourage pollution-intense activities. This is a form of transferring the polluting activity. Developing economies that take advantage of regulations in developed countries specialise in these activities resulting in higher polluting effects. The argument is whether the demand or the supply is in isolation and if so which is to bare the blame for pollution. Lack of measurement in principle.
4	Selden and Song, 1994 Stern et al., 1996 Munasinghe, 1998 Dinda, 2004	SO_2, NO_x, CO and other atmospheric gases migrate. Measurement techniques are to be consistent and relevant. Atmospheric gases do not display properties of divisibility and are not proportional to any particular process.

5	Dasgupta, Laplante, Wang and Wheeler, 2002 Stern, Common and Barbier, 1996	Developing countries that overcome the social cost of pollution pay for consuming the environment. Compensated labour and capital migrate leaving an unaccounted state of the environment. No economic activity does not mean no environmental degradation.

The literature suggests that modern EKC studies are gravitating towards addressing the critiques and determining, with some level of consistency, the turning point for any given region. Cole, Rayner and Bates (1997) contributed to the EKC literature by introducing energy as a determinant of the state of the environment. The model presented by Cole et al. (1997) serves as an econometric standpoint in addressing the weaknesses associated with traditional EKC modelling; which was outlined by Stern et al. (1996). This study created an avenue for the exploration of capturing both regional and global effects of the income-environment relationship. Cole et al. (1997) found that air pollution is consistent at low income levels but incoherent at higher levels, a trend throughout EKC studies. A further study by Dinda (2004) provided an assessment of the nature of industry and population suggestive of the value of energy in EKC modelling. Dinda (2004) showed that the EKC is only validated against some air pollutants such as SO_2. Dinda (2004) further explains that EKC models must be inclusive of the effects of technological progress and should capture this regionally, not aggregately. Table 4 summarises the components which are to be captured explicitly by modern EKC studies, in addressing the critiques. Table 4 expresses the structural components which have empirical and theoretical justification for the variables responsible in producing the EKC.

Table 4 Structural Components needing address in Environmental Kuznets Curve modelling

Number	Author(s)	Structural Component
1	De Bruyn, 1997 Rothman, 1998	Production-pollution accounting, proportion of pollutants in industries across industrialised versus industrialising countries, emission intensities, scale of operation over time.
2	Rothman, 1998 Gawande et al., 2000	Migration, population are unequal in the exposure to environmental degradation - internal migration of people away from degraded areas. This causes a skewness in the observed income-environment variables.
3	Kaufman et al., 1998 Friedl and Getzner, 2003 Dinda et al., 2000	Greater production is indicative of a greater manufacturing capacity which is associated with higher energy consumption. Ambient levels, atmospheric gases and other popular variables in EKC modelling have little power in capturing this effect.

4	Komen et al., 1997 Magnani, 2000 Dinda, 2003 Smulder and Bretschger, 2000	Efficient technology transitions into industrialising economies, however the effect of such technologies is not proportioned to the level of efficiency savings on the environment. Quantitatively how much effect does a particular innovation reduce damage on the environment?
5	Anderson and Cavandish, 2001 Pasche, 2002	Social and environmental gains of new technologies, and new processes. Country development is not devoid of economic growth; EKC modelling is not consistent in the approach or accounting of development concepts – particularly environmental gains from increases in income per capita.

The vast literature on the income-environment relationship shows inconsistency in the findings and measurements. Variables such as atmospheric gasses are subject to many critiques due to the physical nature of gasses. Identifying a variable with sufficient powers of capturing the state of the environment and economic activity serves as the basis for modern EKC studies. Variation in pollutants across industry, gas migration, services sector specialisation and social and technological factors are specific areas identified in the structural critique of the EKC. This is in favour of the argument that current environmental degradation (state of the environment) measures are not consistent in representing the income-environment relationship.

3. Conclusion

The literature suggests an inconsistency in the findings of the environmental Kuznets curve. This is particularly highlighted as an inconsistency in the method for capturing the effects of environmental degradation or more commonly the state of the environment. The concept of whether the changes in the income of a region is related to the state of the environment in that region is the central theme of the environmental Kuznets curve. The literature on the topic gives evidence of suitability across various indicators such as atmospheric gasses (ambient effects), waste, water quality, deforestation and urbanisation. The major critiques, as summarised in Table 3, suggest that no conclusive evidence exists for the consistency of the indicators used; due to either time constraints, lack of measurability of the state of the environment or theoretical support. The literature, however, makes mention of the merits of using a variable that is divisible, directly correlated to economic activity and has theoretical support. Identifying a variable which captures economic activity and the state of the environment serves as the

basis for modern EKC studies, this is particularly important in determining the turning point and policy objectives. Possible future studies centred on leading and lagging effects of growth, sector and region specific effects would better explain the turning point in EKC studies; reducing the unduly constraint EKC model as presented by Panayotou (1997).

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