The Existence of Environmental Kuznets Curve: Is it a Methodological Fact?

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Abstract
Environmental Kuznets curve is believed to exist for some environmental indicators but not for others. Carbon dioxide, as a global pollutant, is also believed to be one among those indicators for which the environmental Kuznets curve hypothesis cannot be verified. Quadratic and cubic parametric models have been commonly used in the environmental Kuznets curve estimation. The models tend to fix the relationship, while curve estimations need flexibilities that can only be met non-parametrically as it leaves room for data to speak for themselves. This paper applies the Epanechnikov kernel function for local polynomial smoothing of emission-income relationships. The overall (panel) emission-income relationship is an inverted U-shaped curve. Each country, except Norway, has reached its unique turning point. Developing countries must adopt stricter antipollution policies to slow down environmental damages.

Keywords: Environmental Kuznets curve, nonparametric estimations, local polynomial smoothing, Epanechnikov kernel.

1. Introduction
Environmental Kuznets curve (EKC) hypothesis suggests that environmental degradation follows an inverted U-shaped pattern in relation to economic growth (Heerink, Mulatu, & Bulte, 2001; Kander, 2005). The relationship is named after Kuznets, (1955) who hypothesised that income inequality rises and then falls with economic development. Studies concerning environmental Kuznets curve started early 1990s with Grossman & Krueger’s (1991) pathbreak study on the environmental effect of the North American Free Trade Agreement (NAFTA). Grossman & Krueger (1991) suggest three separate mechanisms through which a change in trade and foreign investment policy can affect the level of pollution and the rate of depletion of scarce environmental resources. These effects are also discussed from growth angle in Bousquet & Favard, (2005).

The scale effect in which pollution increases with trade and investment liberalization, if liberalization results into expansion of economic activities without changing the nature of those activities. The composition effect where, with trade liberalization, countries specialize in products of their competitive advantage. If competitive advantage is a result of differences in environmental regulations, then composition effect of trade liberalization will be damaging the environment. And as Dasgupta, Laplante, Wang, and Wheeler (2002) assert, with stricter environmental regulations, more developed nations will experience capital outflow due to high environmental standards that producers are required to meet. Enterprises will tend to invest in developing nations where environmental regulations are more loser. To prevent capital outflow, developed nations will have to reduce their strictness which will ultilimate increase pollution in both developed and developing nations (Dasgupta, Laplante, Wang, & Wheeler, 2002). Thus, protecting the capacity of ecological systems to sustain welfare is of as much importance to poor countries as it is to those that are rich (Arrow, et al., 1996). The technique effect is where environmental amenities improve with liberalization. In this case, competitive advantage is a result of advancement in technology.

Grossman & Krueger, (1995) argue that as output increases, new technologies that facilitate efficiency in production emerge, which in turn results into scarce resources conservation. Antle & Heidebrink, (1995) found a negative income-environmental amenities relationship at lower levels of income and a positive relationship at higher levels, implying more demand for quality environment at higher income levels. However, they also observed that for some environmental amenities, such as water quality, the relation is positive even at lower levels of income.

Developed economies moved from agriculture to heavy industrial production, and finally, to light manufacturing of services (Stern, 2004), suggesting a movement from low to high to low pollution levels. As Bousquet & Favard, (2005), point out that, the large share of services in Gross Domestic Product (GDP) in the post industrial phase of development could have a positive impact on the environment.

The hypothesised level of turning point indicates that most developing countries will continue to suffer low environmental quality for a long time. However, low-income countries may realize a turning point even at a low income level if stricter environmental regulations will be enforced. If governments are slowly responding to environmental pressures, communities, and non-governmental organizations may force polluters to produce to the optimal level of pollution. They may decide not to buy pollution-intencive products and thus force producers to improve the quality of the environment (Dasgupta, Laplante, Wang, & Wheeler, 2002).
Other studies, for example, Heerink, Mulatu, & Bulte, (2001) have focused on the relationship between income inequality and environmental quality. When income inequality decreases with average income, it is not possible to determine the sign of the variation for pollution, (Bousquet & Favard, 2005).

The curvature of pollution-income relationship is said to be determined by the scale of abatement cost. For pollution-income relationship to be inverse-U-shaped, pollution abatement cost must have increasing returns to scale (Andreoni & Levinson, 2001). Shafik (1994) found an inverse-U-shaped pollution-income relationship for annual deforestation, total deforestation, suspended particulate matter, ambient sulfur dioxide, and fecal coliform in rivers. The same result as in Mather, Needle, & Fairbairn’s (1999) study for deforestation and income. They, however, contend that the existence of EKC does not mean that economic growth is the sole determinant.

Some environmental issues do not portray the environmental Kuznets curve. Mozumder, Berrens, & Bohara, (2006) found a positive relationship between income per capita and loss of biodiversity. Seppälä, Haukioja, & Kaivo-oja, (2001) rejected the EKC hypothesis for direct material flow and income per capita in industrialized countries. Even though, they still believe that, with large samples, the hypothesis may not been rejected.

Giannias, Liargovas, & Alexandroovich, (2003) study, identified countries in a four quadrant model. A group of countries that have attained high economic growth and high environmental quality is found in the first quadrant. The second quadrant consists of countries with low income but high environmental quality. Quadrant three is inhabited by countries which have low economic growth and low environmental quality. While quadrant four harbors countries whose economic growth is very high but the quality of the environment is low. They suggest that development and environmental policies should go hand in hand. However, their findings may have been influenced by model specification as Milliment, List, & Stengos, (2003), rejected the null hypothesis of EKC for parametric models in favor of the semiparametric models.

2. Methodology
2.1. Data
This study utilizes secondary data from ten countries for a period of thirty one years (that is, from 1980 to 2010), thus making a panel data. The countries involved in the analysis are, Austria, Chile, Colombia, Cuba, Denmark, Finland, Greece, Ireland, Norway, and Portugal. At first, two years (2009 and 2010) were omitted because Cuba lacked data in these observations. This aimed at making the panel a balanced one. But after plotting their GDP trends, three countries (Chile, Colombia, and Cuba) were removed in the final analysis. This aimed at running away from the outlier problem. After removing the three countries, two years (2009 and 2010) were reintroduced for the final analysis because the remaining countries had all the observations. Carbon dioxide (CO2) emission is an environmental indicator which is used in this study. Both emission and income data have been extracted from the World Bank’s, (2013) World Development Indicators.

2.2. Empirical Models
Most of the literatures reviewed in this study, have analyzed the environmental Kuznets curve for different environmental indicators using the parametric approach. Some have analyzed using quadratic functions (see Stern, 2003; Heerink, Mulatu, & Bulte, 2001) and others cubic functions (e.g. Shafik, 1994) who analyzed and tested the significance of the three models (linear, quadratic and cubic). In curve estimation, pure parametric thinking often does not meet the need for flexibility in data analysis (De Brabanter, De Brabanter, De Moor, & Gijbels, 2013). Using panel data, Milliment, List, & Stengos, (2003), analyzed the environmental Kuznets curve for sulfur dioxide and nitrogen oxide emissions basing on semiparametric approach. This study follows a nonparametric approach in analyzing the environmental Kuznets curve (EKC) for carbondioxide emission. Adopting the local polynomial smoothing model illustrated by Gutierrez, Linhart, & Pitblado, (2003), the current study’s income and pollution variables have been considered as a set of scatter data \( \{x_1, y_1, \ldots, x_n, y_n\} \) from the model

\[
y_i = m(x_i) + \sigma(x_i) \epsilon_i \tag{1}
\]

for some unknown mean and variance functions \( m(\cdot) \) and \( \sigma^2(\cdot) \), and symmetric errors \( \epsilon_i \) with \( E(\epsilon_i) = 0 \) and \( \text{Var}(\epsilon_i) = 1 \). Without making any assumption about the functional form of \( m(\cdot) \), we wish to estimate \( m(x_0) = E(Y | X = x_0) \). For some \( x \) in the neighborhood of \( x_0 \), a Taylor expansion of \( m(\cdot) \) gives

\[
m(x) = \sum_{j=0}^{\infty} \frac{m^{(j)}(x_0)}{j!}(x - x_0)^j = \sum_{j=0}^{\infty} \beta_j (x - x_0)^j
\]

That is, \( m(x) \) can be approximated locally by a \( p \) order polynomial in \( x - x_0 \). Substituting the expression into equation (1), for \( x_i \)’s local to \( x_0 \), \( m(x_0) \) can be estimated as the constant term (intercept) of a regression of \( y_i \) on
the polynomial terms \((x_j - x_0), (x_j - x_0)^2, \ldots, (x_j - x_0)^p\).

To preserve the locality, we introduce a kernel function \(K(\cdot)\), which is a probability density function that is symmetric about zero and a bandwidth \(h\) to control the degree of locality. Defining \(\beta_j = m^{(j)}(x_0)/j!\) we can then estimate \(\beta_0 = m(x_0)\) by minimizing in \(\hat{\beta}_j\) the weighted least squares expression

\[
\sum_{i=1}^n \left\{ y_i - \sum_{j=0}^{p} \beta_j (x_i - x_0)^j \right\}^2 K_k(x_i - x_0)
\]

for \(K_k(a) = h^{-1}K(a/h)\).

Consider model (1) expressed in matrix notations

\[
y = m(x) + \varepsilon
\]

where \(Y\) and \(X\) are the \(n \times 1\) vectors of scatter plot values of pollution and income, \(\varepsilon\) is the \(n \times 1\) vector of errors with zero mean and covariance matrix \(\Sigma = \text{diag}(\sigma(x, t)I_n)\), and \(m(x)\) and \(\sigma(x)\) are some unknown functions as previously noted. We define \(m(x_0) = E[Y | X = x_0]\) and \(\sigma^2(x_0) = \text{Var}[Y | X = x_0]\) to be conditional mean and conditional variance of random variable \(Y\) (residual variance), respectively, for some realization \(x_0\) of random variable \(X\).

The method of local polynomial smoothing is based on the approximation of \(m(x)\) locally by a \(p^{th}\) order polynomial \(m(x)\) for some \(x\) in the neighborhood of \(x_0\). For the scatter plot data \(\{(x_i, y_i), \ldots, (x_s, y_s)\}\), the \(p^{th}\) order local polynomial smooth \(\hat{m}(x_0)\) is equal to \(\hat{\beta}\), an estimate of the intercept of the weighted linear regression,

\[
\hat{\beta} = (X^T W X)^{-1} X^T W y
\]

where \(\hat{\beta}_0 = (\beta_0, \beta_1, \ldots, \beta_p)^T\), is the vector of estimated regression coefficients (with \(\{\beta_j = (j^{th}) \hat{m}^{(j)}(x)|_{x=x_0}, j = 0, \ldots, p\}\) also representing estimated coefficients from a corresponding Taylor expansion); \(X = \{(x, x_0)^T\}_{i,j=0,1,\ldots}^{n,n}\) is a design matrix; and \(W = \text{diag}\{K_k(x_i-x_0)\}_{n,n}\) is a weighting matrix with weights \(K_k(\cdot)\) defined as \(K_k(x) = h^{-1}(x/h)\), with \(K_k(\cdot)\) being a kernel function and \(h\) defining a bandwidth. Assuming constant residual variance \(\sigma^2(x_0) = \sigma^2\) and odd degree \(p\):

\[
\hat{h} = C_{0,p}(K) \left[ \frac{\sigma^2 \int w_0(x) dx}{n \int \{m^{(p+1)}(x)\}^2 w_0(x) f(x) dx} \right]^{1/(2p+3)}
\]

where \(C_{0,p}(K)\), is a constant that depends on the kernel function \(K(\cdot)\) and the degree of a polynomial and \(w_0\) is chosen to be an indicator function on the interval \([\text{min}_x + 0.05 \text{range}_x, \text{max}_x - 0.05 \text{range}_x]\) with \(\text{min}_x, \text{max}_x, \text{range}_x\) being, respectively, the minimum, maximum, and range of \(X\). To obtain the estimates of a constant residual variance \(\sigma^2\) and \((p+1)^{th}\) order derivative of \(\hat{m}(x)\), denoted as \(m^{(p+1)}(x)\), a polynomial in \(X\) of order \((p+3)\) is fit globally to \(Y\), and \(\hat{\sigma}^2\), is estimated as a standardized residual sum of squares from this fit.

The expression for the asymptotically optimal constant bandwidth used in constructing the ROT bandwidth estimator is derived for the odd-order polynomial approximations. For even-order polynomial fits, the expression would depend not only on \(m^{(p+1)}(x)\) but also on \(m^{(p+2)}(x)\) and the design density and its derivative \(f(x)\) and \(f'(x)\). Therefore the ROT bandwidth estimator would require estimation of these additional quantities. Instead, for an even-degree \(P\) of the local polynomial, the command uses the value of the ROT estimator (3) computed using degree \(p + 1\). As such, for even degrees this is not a plug-in estimator of the asymptotically optimal constant bandwidth.

The estimates of the conditional variance of local polynomial estimators are obtained using
\[
\text{Var}\{\hat{m}(x_0)|X = x_0\} = \sigma^2 \left( x_0 \right) = \left( X^T WX \right)^{-1} \left( X^T W^2 X \right) \left( X^T WX \right)^{-1} \sigma^2 \left( x_0 \right)
\]

(4)

where \(\sigma^2 \left( x_0 \right)\) is estimated by the normalized weighted residual sum of squares from the \((p + 2)\)th order polynomial fit using pilot bandwidth \(h^*\).

When the bias is negligible the normal-approximation method yields a 
\((1 - \alpha) \times 100\%\) confidence interval for 
\(m \left( x_0 \right),\left\{ \hat{m}(x_0) - z_{(1-\alpha)/2} \sigma_m \left( x_0 \right), \hat{m}(x_0) + z_{(1-\alpha)/2} \sigma_m \left( x_0 \right) \right\}\)

where \(z_{(1-\alpha)/2}\) is the \((1 - \alpha / 2)\)th quintile of the standard Gaussian distribution, and \(\hat{m} \left( x_0 \right)\) and \(\hat{\sigma} \left( x_0 \right)\) are as defined in (2) and (4), respectively.

3. Empirical Findings
3.1. Variable Characteristics
Before undertaking the local polynomial smoothing, the study explores the trend of income for each country in the sample. Three countries, Chile, Colombia, and Cuba labeled as 2, 3 and 4, in Figure 1 are not included in the main analysis because their per capita GDP growth is very low compared to the rest of the countries in the sample. Including them, could have led into spurious results. The data have been transformed using logarithm to avoid ending up with abnormally larger bandwidths when undertaking the local polynomial smoothing. As it can be shown in Figure 2, using lowess smoother, which does not specify the kernel function, the shape of emission-income relationship of raw data is different from that of transformed data.

3.2. Estimation Results
Using the second-order Epanechnikov kernel, the local polynomial smoothing is performed. The panel estimation results are identified as overall while time series estimation results refer to each country separately. The nonparametric density curve estimations are as depicted in Figure 3. As it is shown in Figure 3, the first box represents the panel estimation and it is an inverted U-shaped curve. There exists an environmental Kuznets curve (EKC) for Carbon dioxide emission in the selected sample. The kernel curve estimations show that six out of seven countries investigated have attained the level of income where emissions have started decreasing. This level of income is what this study has referred to as the turning point in Table 1. Denmark has shown a remarkable emission reduction, which could mean stricter environmental regulations. Other countries have started reducing emissions, except Norway. But there is hope that Norway’s emission trend will start decreasing because other countries in the region demand quality air.

In Table 1, each country has a unique turning point, standard deviation, and a bandwidth. However, they both have the same constant used in bandwidth calculation. This is due to the fact that the study applied the same kernel function throughout and the same degree of a polynomial which this constant depends on.

4. Conclusions
The findings have shown that environmental Kuznets curve for carbon dioxide does exist. However, the result could have not materialized if careful sample selection was not carried out. The sample used for the final analysis involves European countries which have higher per capita income which means that using another sample could mean nonexistence of the EKC. For example, the inclusion of excluded three countries with low per capita income could have turned the curve into an inverted N curve. This is because though they have low per capita income, their carbon dioxide emission is very high.

The nonparametric, through Epanechnikov kernel, approach in this study might have something to do with the shape of the pollution-income relationship. So it follows that, careful sample selection and the estimation technique used might have determined the shape of the pollution-income relationship in this study. It is, therefore, important for developing countries to adopt strict antipollution policies because right now, even though their per capita income is very low, they are already suffering from severe environmental degradation resulting from carbon dioxide emissions. Natural realization of a turning point may take decades or may not materialize at all, making the adoption of stricter environmental regulations, in developing countries, an inevitable action.

References


Author's Biography

F. Dominick became a Tutorial Assistant, a position held for three consecutive years, at St. Augustine University of Tanzania since September, 2009. He was promoted to the position of Assistant Lecturer soon after his postgraduate studies in September, 2012. The author was born in Tarime District of Mara Region on 24th June, 1982.

The author pursued primary education from 1991 to 1997, at Kines A primary school in Rorya District. He undertook secondary education from 1999 to 2002 at Nyegina Secondary School in Musoma Rural District. He was then selected to join advanced secondary education from 2003 to 2005, at Tarime Secondary School in Tarime District. He joined St. Augustine University of Tanzania, in Mwanza city, for undergraduate studies, majoring in economics, from 2006 to 2009. The author joined the University of Dar es Salaam, in the City of Dar es Salaam, for postgraduate studies majoring in economics from 2010 to 2012.
Figure 3. Per capita Income Trend by Country from 1980 to 2008
Where, 1=Austria, 2=Chile, 3=Colombia, 4=Cuba, 5=Denmark, 6=Finland, 7=Greece, 8=Ireland, 9=Norway and 10=Portugal

Figure 4. Lowess smoother for Raw and Transformed Data
Figure 5. Non parametric Density curve Estimations (Environmental Kuznets Curves)
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Source: Author’s computation

Table 2. Data used for the analysis

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