International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume: 04, Issue: 10 "October 2019"

DECODING THE ENVIRONMENTAL KUZNETS CURVE: A CRITICAL REVIEW

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ABSTRACT

The Environmental Kuznets Curve hypothesis states that there is a hump shaped or an inverted U-shaped relationship between the degradation of environment and economic growth. It is stated that in the initial stages of economic growth, the quality of the environment deteriorates and after a certain level of income, that is the turning point, the increase in economic growth is associated with a better environmental quality. This is an attempt to critically review the study of Environmental Kuznets curve by Grossman and Krueger (1995).

Keywords: Kuznets Curve, Environment, Economic Growth, Urban, GDP

1. INTRODUCTION

The Environmental Kuznets Curve hypothesis has been studied for nearly quarter of a century. The early studies include works by Grossman and Krueger (1991), Shafik and Bandopadhyay (1992), Seldon and Song (1994), Panayotou (1993), Cropper and Griffiths (1994) to mention a few. One of the studies in this field is "Environment and Economic Growth" by Grossman and Krueger (1995). The paper examines the relationship between environment and economic growth for which the indicators taken are urban air and water quality. The increasing concern about the environment has been the motivation for many economists to study the causes of variations in the deterioration of the quality of the environment. This critical review tries to examine the finding of paper by Grossman and Krueger (1995) and attempts to analyze the summary, the methodology and the findings of the paper by Grossman and Krueger (1995).

2. PRELEMINARIES

The authors, Grossman and Kruger examine the following reduced form equation:

$$\boldsymbol{Y_{it} = G_{it} + G_{it}^2\beta_2 + G_{it}^3\beta_3 + \overline{G_{it-}}\,\beta_4 + \overline{G_{it-}^2}\,\beta_5 + \overline{G_{it-}^3}\,\beta_6 + X'_{it}\beta_7 + \epsilon_{it}} \quad \text{--- } \textbf{\textit{(1)}}$$

ISSN: 2455-8834

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Where $\boldsymbol{Y_{it}}$ represents water or air pollution at station "i" in year "t"

$\boldsymbol{G_{it}}$ represents the GDP per capita for the country in which station "i" is located in year t

$\overline{\boldsymbol{G_{it-}}}$ represents the average GDP per capita over the prior three years

$\boldsymbol{X'_{it}}$ is the vector of covariates

$\boldsymbol{\epsilon_{it}}$ is the error term

β's are the parameters to be estimated

The graph depicting the relation between the environmental indicators and the GDP plots the following equation:

$$\widehat{\boldsymbol{Y}}_{it} = \boldsymbol{G_{it}}(\widehat{\boldsymbol{\beta}}_1 + \widehat{\boldsymbol{\beta}}_4) + \boldsymbol{G^2_{it}}(\widehat{\boldsymbol{\beta}}_2 + \widehat{\boldsymbol{\beta}}_5) + \boldsymbol{G^3_{it}}(\widehat{\boldsymbol{\beta}}_3 + \widehat{\boldsymbol{\beta}}_6) + \overline{\boldsymbol{X}}'_{it}\widehat{\boldsymbol{\beta}}_7 \quad \text{---} \ \textit{(2)}$$

All variables have been defined above. Grossman and Krueger plotted the graphs by multiplying GDP per capita, it's square and cube by the summation of the estimated coefficients for current and lagged income. Further, the product of the average of the variables and their coefficients were added to obtain equation ***(2)***.

3. SUMMARY

This section gives a brief summary of the paper, "Environment and Economic Growth" by Grossman and Krueger (1995). There are three parts to the summary. Section 3.1 talks about the environmental indicators chosen for the study and their respective data sources. Section 3.2 discusses the methodology used by the authors. Section 3.3 corresponds to the main results and findings of the paper.

3.1 INDICATORS OF THE ENVIRONMENT

This paper by Grossman and Krueger (1995) aims to study the reduced form relationship between per capita income and four types of environmental indicators: (i) urban air-pollution, (ii)the state of oxygen regime in river basins, (iii)faecal and (iv) heavy metal contamination of river basins. The response of every dimension of environmental quality on the economic growth is different. This, as per the authors, required an explicit study of environment and economic growth. The lack of availability of statistical data restricts the scope of such a study. Global Environmental Monitoring System (GEMS), a combined project of World Health Organization and United Nations Environmental Program, has taken panel data comprising of a cross-section

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of countries, both developed and developing, for a time period of about twenty years to monitor the urban air and water quality. This data set forms the basis of the study of this paper.

The GEMS/Air Project studied the urban air pollution. Sulphur dioxide and suspended particles were taken as a form of the same. The sites that were monitored were emblematic of the economic and geographical conditions of different parts of the world (Bennett et al.1985).

The paper has concentrated on the dimensions of water quality of river basins which are important sources of water supply for municipality, irrigation, industries etc. The authors have chosen three categories of indicators relating to water quality which include (i) state of oxygen regime, (ii) pathogenic contamination and (iii) heavy metals (Grossman and Krueger 1995).

State of oxygen regime**:** Contamination of the rivers results in high concentration of organic carbon, nitrogen and phosphorous and reduces the requisite oxygen level which can prove to be fatal for the fish and other aquatic life. Direct measure of the state of oxygen regime as used by GEMS/water project is dissolved oxygen. Other inverse measures used are contamination by organic compounds, one measure of which is biological oxygen demand (BOD) while the other is chemical oxygen demand (COD) (Grossman and Krueger 1995). The authors aim to study the relationship between income level and the three indicators of state of oxygen regime as mentioned above.

Pathogenic Contamination**:** Pathogenic Contamination occurs due to discharge of raw untreated sewage and causes a large number of diseases. The GEMS/Water project considered the data set of 42 different countries and focused its study on faecal coliform as an indicator of pathogenic contamination.

Heavy Metals**:** Heavy metals like lead, cadmium, arsenic, mercury that are discharged by the industries, mining, agriculture etc. were considered for the study. They contaminate drinking water and bio accumulate in the fish which is later consumed by humans. This leads to various health risks like kidney and brain damage, cancer etc. The GEMS/water project considered the data set for 10 countries.

3.2 METHODOLOGY

This section briefly reviews the methodology adopted by Grossman and Krueger (1995) for their study. The authors, in order to understand the relation between environmental pollution and economic growth preferred to use the estimated reduced form equation rather than the structural equation owing to the fact that reduced form is indicative of net effect of national income on pollution levels.

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Grossman and Kruger estimated the reduced form equation ***(1)*** using Generalized Least Square estimation method (GLS) to avoid the problem of omitted variable bias. So, the error term can be written as follows: $\varepsilon_{it} = \alpha_i + \varepsilon_{it}^{'}$ where $\varepsilon_{it}^{'}$ is the set of idiosyncratic factors and α_i represents the random component.

In the case of air pollutant, median of daily concentration of the pollutant was considered as the dependent variable rather than the mean. Whereas in the case of water pollutants, mean value of the pollutant is chosen as the dependent variable. The dependent variables are measured as concentration levels except for total and faecal coliform which is measured as log(1+Y), where Y represents the level of concentration.

The key variable, GDP per capita, measured at country level and was taken from the Summers Hestons (1991) data set. In order to adjust for the year in which measurement was recorded, linear time trend was taken as a separate regressor. In addition to this, the authors also included mean annual water temperature in the river where the station was situated. The authors took various covariates including that of income and time and since the correlation between national income and the covariates is zero, it does not affect the unbiasedness of the estimators. The set of covariates in the case of water pollutants was limited. The authors also took dummy variables for the environmental indicators. For air pollution, the authors used dummy variables which indicated where the station was situated, land use pattern, population density and the type of measuring device used to account for the pollutant.

3.3 RESULTS

This section states the findings of the study by Grossman and Krueger (1995). The authors graphed the estimated reduced form equation ***(2)*** for each pollutant. They analysed the shape of the graph, turning point on the graph at which GDP per capita reaches its highest value for each pollutant and concluded that there is strong multicollinearity between current and lagged GDP per capita and its powers. Current and lagged GDP per capita were found to be individually highly significant. It was observed that the pollutants were sensitive to income changes.

In the case of urban air pollutants, sulphur dioxide and smoke depict an inverted U-shaped curve with turning points at $4000 and $6000 respectively. However, for heavy particles, the curve was downward sloping. For all the three indicators, income was found to be jointly significant.

In the case of water quality indicators, the following results were found: For state of oxygen regime, both BOD and COD had inverted U-shaped graph whereas dissolved oxygen has a U-shaped graph. The turning points for these indicators come much later than that of the air

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pollutants. The income terms are jointly significant at less than10% for BOD and at 22% for COD (Grossman and Krueger 1995).

For indicators relating to faecal contamination of rivers, the income terms are jointly significant at one percent level of significance, lagged incomes are significant but current income terms are not. Faecal contamination falls sharply when the real income reaches $8000. Total coliform concentrations depict a N-shaped graph. Current income holds more significance statistically than past income for this indicator. Turning point in this case was found out to be $3000.

For heavy metals, in case of lead, the graph is downward sloping, for cadmium it is flat and for arsenic it is inverted U-shaped (Grossman Krueger 1995).

The authors state that there is no or very little supporting evidence of the fact that environment quality degrades with economic growth. Rather, with economic growth, initially there is environment degradation which is followed by improvement in the environment owing to better and greener technology of production and demand for a cleaner environment. The turning points vary for different pollutants but it is observed that they occur at an income level of less than $8000.

4. CRITIQUE

This section aims to critically examine the main findings and methodology and various other aspects of the paper by Grossman and Kruger (1995).

The GEMS data used in the study, by Grossman and Krueger (1995), does not include all the aspects of the quality of environment. The paper has excluded the effects of growth on industrial waste, soil degradation, deforestation and biodiversity loss. Instead, the study is centred around the indicators of air and water quality. Some important urban air contaminants such as nitrogen oxide, carbon monoxide and lead are excluded from the sample study by Grossman and Krueger. Important pollutants that deplete the ozone layer like chlorofluorocarbons, carbon dioxide, methane, tropospheric ozone are not included in the study. There have been no findings which state that the hump shaped curve applies for greenhouse gases (Common 1995). For water quality, only the river basins were included and observations from lakes and groundwater stations were found to be too small and therefore excluded. GEMS data set pertains to various cities. It has completely overlooked rural areas and the pollution effects on ecosystems, both agricultural and natural (Stern 1996).

The paper has concentrated on pollution in the urban areas. Decline in the urban pollution is not indicative of the fact that over all pollution has decreased. City population density has been included in the paper as an explanatory variable. Both time trend and trade intensity have a negative coefficient in the sulphur dioxide regression (Grossman and Krueger 1995). No economically feasible explanation is given for this. The indicator sulphur dioxide is a poor choice of overall environmental impact because its emission decreases with the development.

The paper has used city averages for some variables and country averages for some. Pollution measures are for specific cities, sites or river basins. There are no aggregates of national pollution levels. For level of income, GDP per capita has been used, which is a country average, instead of local income. This has resulted in distortions.

The study uses mean per capita income levels. But the income is not evenly distributed, in fact it is skewed with more people below the mean income than those above it. Median income would be a better choice as it is lower than mean income and more representative of the data (Stern 1996).

The authors, Grossman and Krueger, estimated a reduced form equation to understand the relationship between environmental pollution and economic growth. Torras and Boyce (1998) are in agreement with the use of reduced form approach used by Grossman and Krueger for their study. They claim that this approach gives the extent of net effect of per capita income on pollution. A limitation of this is that it is unclear why the estimated relationship between pollution and income exists. Like Grossman and Krueger (1995), Torras and Boyce (1998) also make use of cubic functional form of income because it allows possibility of a downturn of pollution level followed by a rising trend.

The aspect of the rate of economic growth has been overlooked by Grossman and Krueger (1995). A study by Panayotou (1999) introduces the rate of economic growth and policy variables in a reduced form equation and also decomposition equation which eventually breaks the income effect into scale, structure and abatement effects.

There have been variations in the findings of the different studies that were conducted on environment and economic growth. Sensitivity analysis of Grossman and Krueger's (1995) results were carried out by Harbaugh (2002) and the pollution data set used was larger. This resulted in change of the signs of the coefficients and the peaks and the troughs of the graph altered drastically. It was deduced that by adding explanatory variables, replacing time trends with time dummies and doing away with outliers changed the shape of Environmental Kuznets Curve (Stern 2004). Studies empirically state that environmental quality improves at higher income levels only for some indicators. The inverted U-shape cannot be generalised for every

ISSN: 2455-8834

Volume: 04, Issue: 10 "October 2019"

type of emission. The Environmental Kuznets curve is valid only for sulphur dioxide and suspended particulate matter. It was found that when levels of income are very high, sulphur dioxide graph again rises, but very few findings were recorded at income levels above $16000. Stagi (1999) found that sulphur dioxide emissions in the OECD countries had fallen even in the initial stages of growth of the GDP per capita. For dioxides of carbon and nitrogen, there were mixed results. Other contaminants followed N-shaped curve or monotonicity rather than a U-shaped curve (Dinda 2004). DeBruyn and Opschoor (1997) and Sengupta (1997) also found the N-shaped curve in their study. This may be because the abatement costs after a certain level are no longer cost-effective. David Stern (1996) is of the opinion that because the study by Grossman and Krueger (1995) did not use a logarithmic dependent variable, therefore it is ambiguous if the decline slows at higher levels of income or reverses. There are variations in the studies by Cole (1997) and Grossman and Krueger (1995). The latter estimated standard errors at the turning point level of income to get accuracy. Cole followed the same methodology, but the turning points for urban air pollution were found to be much higher than those by Grossman and Krueger.

The hump shaped Environmental Kuznets Curve is explained by scale effect and technique effect. The former means that the negative consequences on the environment are due to increase in economic activity while the latter implies that increase in income leads to a demand for cleaner production methods. (Antweiler et al. 2001). Grossman and Krueger (1995) do not provide separate estimates of technique and scale effect. Antweiler (2001) argues that income per capita is not a measure of scale and that the paper by Grossman and Krueger does not give the relative strength of scale and technique effects.

The paper by Grossman and Krueger (1995) acknowledged the need for structural and analytical approach to the relationship between the pollution and income and inclusion of policy variables. But no attempt to empirically prove this was undertaken.

Torras and Boyce (1998) claim that literacy, political rights, civil liberties and equitable distribution of income have a profound effect on the quality of environment in low income countries. They interpret that literacy and rights are strong forecasters of the level of pollution. It cannot be assumed that further increase in the per capita income will continue to have positive effects on environmental quality. This viewpoint is shared by Panayotou (1999). He states that good policies and institutions may actually flatten the Environmental Kuznets Curve. Economic growth does not always lead to better quality of environment. Implementation of strong and effective policies can achieve this. Countries where corruption is high do not have good environmental quality as opposed to less corrupt countries (Cole 2007).

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There is a possibility that the inverted U-shaped pattern maybe observed because countries stop producing goods where pollution is a major by product and instead start importing such products. If this is the cause, then the development patterns will not follow the past course. Tobey (1990) points that "environmental dumping" takes place but is not important. It is too insignificant to account for decrease in pollution that is associated with economic growth. Neumayer (2003b) talks about "pollution haven hypothesis", that is developed countries have better quality of environment because they have exported the polluting industries to the developing nations. This aspect has not been studied by Grossman and Krueger (1995).

5. CONCLUSION AND FURTHER RESEARCH DIRECTION

Panayotou (1999) has referred to the study of the Environmental Kuznets Curve following a conventional reduced form approach as "black box". Studies still continue as many questions remain unanswered. Recent works include McPherson and Neiswiadomy (2005), Carson (2010), Karka and Zervas (2013), Wagner (2015), David Stern (2015) etc. Various studies have concluded that it is not sure if the Environmental Kuznets curve hypothesis holds true in all the countries. It was found that cities like Bangkok, Shanghai, Mexico City are more polluted now as compared to two or three decades ago. This raises the question- Do higher income levels improve or deteriorate the environment. There is still no unanimity in the determinants of the changes in environmental degradation. Evidence has been found that pollution rises with per capita income increase if other factors are held constant. If there is a change in other factors, it may lead to decrease in pollution. It has been deduced that the inverted U relation does not hold true for all types of emissions. Pollutants that require more dispersion costs like carbon dioxide are increasing functions of income (Arrow et al. 1995). Economic growth is not a necessary condition for improved quality of environment (Arrow et al. 1995). Grossman and Krueger (1995) also state that economic growth will not lead to better environment unless it is accompanied by strong environmental policies. Economists are of the view that there may be an inverted U-shaped relationship between contaminants and income. But in the past decade it is deduced that economic growth has a monotonic positive effect on sulphur and carbon emissions. Stern (2015) claims that convergence approach is important for explaining pollution emissions. The paper has made an initial headway into the subject of environment and economic growth but much work still needs to be done.

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