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Combined cycle gas turbine system optimization for extended range electric vehicles

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Abstract

The relationship between income growth and environmental quality has been frequently investigated in the literature. These investigations are not unified on a single point and have yielded in a broad spectrum of conflicting results. Major portion of the literature argues that there exists an inverted U-shaped relationship between per capita income and environmental quality. While another stream of research opposes these findings and rejects environmental Kuznets curve (EKC). To investigate these variations, the present study synthesizes the existing findings and conducting meta regression analysis on a broad level. The contribution of this study is twofold; first, a framework, Preferred Reporting Items for Meta Regression Analysis (PRIMRA), has been developed, which is aimed to provide a pathway for future meta-analyses. This study itself has been carried out in the light of this framework. Second, this is the very first attempt to synthesize EKC literature by using quantitative methods on a broad level. Reviewing 101 research papers published during 2006-2019, we have found a strong evidence in support of EKC. It has been found that this relationship is a long run phenomenon and irrelevant to the choice of econometric tools employed or type of data used. Although the results show variations with the choice of environmental degradation indicators.

Keywords: CO_2 Emission; Economics growth; EKC; Meta-Analysis; PRIMRA; Multinomial Logistic Regression;

1. Introduction:

Environmental Kuznets Curve (EKC *henceforth*) is mostly debated and frequently cited in literature for three decades. EKC explains how economic activities affect the environmental quality both in short as well as in long run. The EKC has been originated from the seminal work of Grossman and Krueger (1991), who found an inverted U-shape relationship between SO_2 and income per capita. In the beginning, until an income turning point (ITP *henceforth*), economic growth may require excessive resource utilization, including energy (Pham et al. 2020), paired with deforestation (khan et al. 2019), which causes pollution but beyond that point environmental quality improves with further increase in income (Grossman and Krueger 1995; Selden and Song 1994; Harbaugh et al. 2002). Hence, the relationship between environmental quality and income growth is of quadratic nature (Panayotou 1993; Destek and Sarkodie 2019) and can be placed in a key position for policy implications. However, this theory cannot be applied for all types of pollutants and environmental effects (Stern 2003). On the other hand, there are also some factors like financial development, foreign direct investment (Nasir et al. 2019), population, international

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trade and technological development which can affect environment both in the short as well as long run (Pham et al. 2020).

Since its inception EKC has been an area of continuous debate specially in the recent past. Many researchers have investigated its validity for different countries and regions. Anyhow concern about its empirical validity is still ambiguous. Studies conducted have used different methodologies, data sets and environmental damage indicators and yielded in broad spectrum of conflicting results (Li et al. 2007; Ahmad and Long 2012). Around 57% of literature confirms the empirical validity of EKC hypotheses (see for example, Dinda and Coondoo 2006; Tamazian et al. 2009; Shahbaz et al. 2012; Tiwari et al. 2013; Farhani et al. 2014; Apergis and Ozturk 2015; Moutinho et al. 2017; Pata 2018; etc.) and favored EKC for environmental policy formulations. On the contrary, there are also various studies (43% literature) that found no or very weak relationship. These studies oppose EKC for any policy implications (Pao et al. 2011; Begum et al. 2015; Jebli and Youssef 2015; Al Mulali et al. 2016; Dogan and Turkekul 2016; Liu et al. 2017; etc.).

The empirical literature on EKC hypotheses yields mixed results and raises controversies whether it can be used for policy implications or not? The portion of literature which validates its existence, draw inferences that society can cover most environmental problems with the income growth (Dinda and Coondoo 2006) while studies including Selden et al. (1999); Pao et al. (2011); and Liu et al. (2017) oppose the interpretation of EKC as a substitute for environmental policy formulation. The above-mentioned controversies raise uncertainties and questions the reliability of the results. As both streams of literature use different tools and techniques, and this could be the main reason for conflicting results. Many studies which reject EKC hypotheses are based upon single country analysis (Pao et al. 2011; Begum et al. 2015; Zambrano et al. 2018). In the same way, results for different econometric techniques deliver different results. Thus, these critiques leave room for further verification of the existing literature on aggregate level. A detailed investigation is needed to explore that what has been achieved through the past researches and what are yet to be done.

Cavlovic et al. (2000) carried out first meta-analysis for EKC in order to synthesize literature and to predict new ITPs. By employing generalized least square method they found that results are sensitive to the selection of methodology and pollutant types. Extending the previous work, Li et al. (2007) considered relatively large data base of 78 studies and conducted the second meta-analysis. They found that there is no monotonically decreasing relationship between income

growth and environment which can provide basis for existence of EKC. These findings increase doubts on the use of EKC for policy implications. But anyhow the results of Li et al. (2007) cannot be relied as it suffers several methodological weaknesses. First, the number of studies they reviewed do not cover major part of literature. Because the frequency of studies is greater in the recent past. Second, no pre-estimation and post-estimation tests have been employed to validate their results. In order to cover these literature gaps, a more detailed and accurate investigation is needed to find either the theory of EKC is a myth or reality.

Extending the previous works, the objective of this study is to investigate the systematic variations among existing findings. For this purpose, it is aimed to conduct meta regression analysis on a broad level. The study aims to synthesize the previous results in the literature and draw some economically meaningful inferences. This is the first comprehensive study in the domain of EKC which covers large number of published articles during 2006-2019 and adapt quantitative tools for analysis. The present study is contributing to the literature in two aspects; first, following Moher et al. (2009), the study introduces a new framework, Preferred Reporting Items for Meta Regression Analysis (PRIMRA), that is expected to help researchers in future while conducting meta-analysis and quantitative reviews. The PRIMRA framework is an extension to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) and illustrates five simple steps about how to conduct meta-analysis. The methodology portion of this study has been covered by this framework. Second, in most cases the quantitative investigations are preferred over descriptive and qualitative investigations. So, this study is a quantitative examination of EKC literature which eliminates doubts over its validity. The results of the study identify that how EKC is affected by choice of control variable and methodological choice. The utilization of pre-estimation econometric test to select the model and post-estimation econometric tests to validate the reliability of results will help to address the problem well. The results of this study are expected to contribute the future researches especially, not limited to, in the same domain growth and environmental economics. Academic researchers as well as policy makers can also be benefited from the findings of this study.

2. Meta Regression Analysis:

Meta-analysis is a statistical approach which models the relevant empirical literature that appear as observations in the data set (Li et al. 2007). This is a formal method to amalgamate the outcomes of identical empirical studies and through light on the systematic variation in variables and results

(Cavlovic et al. 2000). The main purpose of meta-analysis is to deduce meaningful inferences related to literature. While, meta-regression analysis is an extension to the meta-analysis which inquires the degree to which the statistical disparity among studies can be linked to common characteristics (Thompson and Higgins 2002). Meta Regression analysis provides opportunity to "analyze the analysis" instead of relying on individual studies results. Studies are objectively collected from related literature but only some response variables and summary statistics are chosen subjectively. The main advantage of this methodology is the wide coverage of analysis based upon statistical tools and hypothesis testing. Contrary, there is a little possibility of selection bias and essential fluctuations across sample studies which may not be compliant to simple categorization. Moreover, only quantitative studies can be taken into consideration rather than qualitative studies. Because qualitative studies cannot be used to fetch data from.

3. Preferred Reporting Items for Meta Regression Analysis:

Preferred reporting items for systematic reviews and meta-analysis (PRISMA) is a framework developed by Moher et al. (2009). This framework is aimed to assist researchers and practitioners to yield improved and more appealing reviews. In the literature it has been frequently used for systematic reviews of published studies. This provides some useful steps in order to conduct quality reviews. Following Moher et al. (2009), we have developed a similar framework called Preferred Reporting Items for Meta Regression Analysis (PRIMRA) which is anticipated to facilitate the quantitative aspect of Meta-analyses. This framework is an extension to PRISMA and provides guidelines to conduct quantitative meta-analysis. PRIMRA is comprised of five steps and is aimed to assist the researchers and practitioners in conducting more appealing and comprehensive reviews of literatures. Figure 1 illustrates the five steps of this framework in brief while each step has been discussed in detail below.

3.1 Identifying literature

The first step comprises of whole PRISMA process from identification until inclusion of subjective studies. Searching for the relevant literature is considered as time consuming step of the whole process (Sebri 2015). The EKC has been emerged for thirty years, but the frequency of publications has increased in the recent decade and specially in the past five years as indicated in figure 2. Further, Li et al. (2007) examined studies from 1992 until 2005 that's why we have considered the time period onward until 2019. Following the methodology of Sarkodie and Strezov

(2019), studies published in peer reviewed journals have searched through web of science, PubMed and general google search. Papers included in the study are mainly published in Elsevier, Springer, Taylor & Francis and Willey online. Sarkodie and Strezov (2019) argues to define clear keywords and timespan for searching literature. So, to search for targeted literature we have used keywords like Environmental Kuznets curve, income growth and emission, economic growth and CO_2 emission, economic growth and environmental quality, income turning points, EKC and turning point.

Figure 1: Preferred Reporting Items for Meta Regression Analysis (PRIMRA)

Step 1: Identifying Literature			
Identification	**Screening**	**Eligibility**	**Included**
Web of Science, PubMed, Google search	Thoroughly read abstracts and Removed duplicate	Theoretical studies dropped and empirical studies downloaded	Studied all papers in detail and included if found relevant

Step 2: Determining Variables				
Dependent Variable	**Independent Variables**			
IMPACT	Data	Control	Methodology	Env. Indicators

Step 3: Identifying Individual Observations

- Each study is considered as a unit and not limited to only one observation
- Total number of studies included are 101.
- Total number of observations extracted are 504.

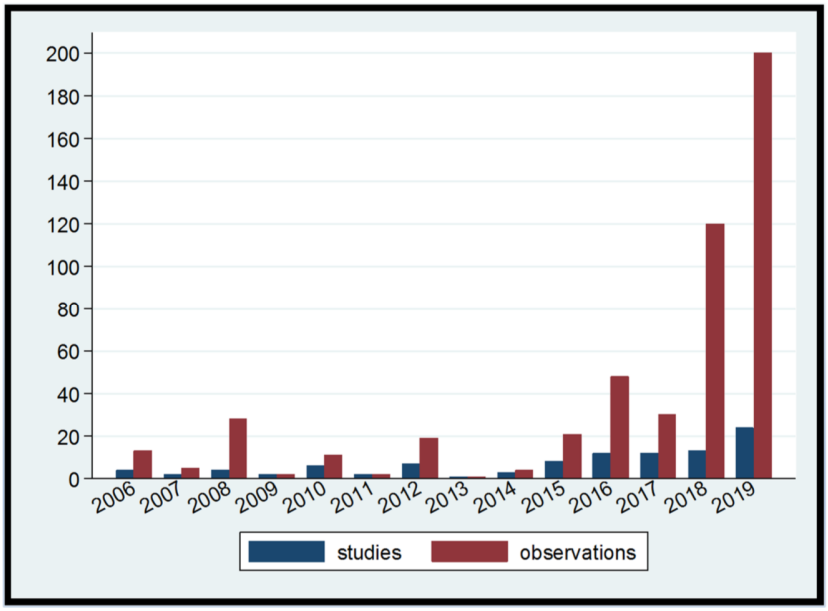
Step 4: Data Coding and Extraction				
Dependent Variable	**Independent Variables**			
IMPACT	**Data**	**Control**	**Methodology**	**Env. Indicators**
Improve = 1 Degrade = 2 None = 3	Time = Real OBS = Real Panel = (0,1) CC = (0,1) Income= (0,1) Emission = (0,1)	GDP = (0,1) TR = (0,1) EC = (0,1) POP = (0,1) FD = (0,1) FDI = (0,1) INST = (0,1)	1) METH ARDL = 1 GMM = 2 FM/DOLS = 3 MG/PMG = 4 Other = 5 2) SIG JJ = 1 Pedroni = 2 D-H = 3 VECM = 4 Other = 5 3) Test = (0,1)	1) Eco Bio Anthro = 1 Chemical = 2 Eco Bio= 3

Step 5: Estimation Approach and Execution		
Model Selection	**Model Estimation**	**Results Validity**
Likelihood Ratio Test	Multinomial Logistic Regression	Wald Test, Hausman and McFadden Test

Initially, 213 papers from PubMed and 475 papers in web of science were found with some addition from general google search (majority of them were common). At first attempt their abstracts were reviewed and if found relevant, then downloaded and studied in detail. Only studies carried out for the empirical validation of EKC are included because theoretical studies cannot be used to extract data for different variables used in our analysis. At the end only 101 studies were left which fulfill the whole criteria we selected. The per year frequencies of studies are presented in figure 2. The whole sample size provides 504 observations and are explained with detail about

selection criteria in section 3.3. Our study aims to provide more detailed and comprehensive data set as against those in literature (25 research papers by Cavlovic et al. 2000; 77 by Li et al. 2007 and 40 by Sebri 2015). More than half of our data set validates EKC (see figure 3).

Figure 2: Year wise distribution of studies and observations



3.2 Determining variables

Selecting variables is in fact the most difficult task in this whole process. Utmost care was taken in selection, specifically how to measure all these, in order to formulate more convincing database. This study follows Li et al. (2007), so some variables are taken and defined in the same way. But major changes are being made specially in variables measurement and categorization. The detailed list of variables with descriptive statistics is presented in table 1.

Based upon the behavior of beta (β) coefficients, the income environment nexus can be grouped in seven categories: (1) Monotonic increasing, (2) Monotonic decreasing, (3) True EKC relation, (4) Inverse EKC, (5) Cubic relation, (6) Insignificant relationship, (7) None. Insignificant relationship means that estimated coefficients appear insignificantly with consistent signs for an EKC, while, none refers to no relationship either significant or insignificant. In a nutshell, these categories can be summarized as either improvement or worsen. Improvement refers to significant monotonic decreasing and inverted U-shaped relationship, meaning that economic growth leads to improve quality of environment. While significant monotonic increasing, U-shaped or N-shaped