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The Environmental Kuznets Curve Hypothesis in the United States: A Review

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ABSTRACT

The economy of the United States (US) is highly developed. However, the US stands second in the World as per total CO_2 emissions and this economy has environmental problems. The Environmental Kuznets Curve (EKC) has been probed extensively in the US economy. However, a review study is missing in the US case. The present research has reviewed 60 papers on the EKC in the US. 41 studies have authenticated the EKC in the US economy. But, 19 papers did not substantiate it. 11 out of 60 studies used disaggregated state-level data and most of these studies validated the EKC. 49 papers investigated the EKC for aggregated US data and the probability of the existence of the EKC is found lower in these papers in contrast to disaggregated studies. Moreover, the EKC is substantiated in the 24 papers confirming a negative impact of renewable energy consumption (REC) on emissions. Moreover, logistic regression is utilized to test these findings. The results confirm that the possibility of EKC is 3.0885 times more if a study validates a negative impact of REC on emissions. The effect of disaggregated data is found statistically insignificant on the EKC validation.

Keywords: The Environmental Kuznets Curve, The United States, Disaggregated Data, Renewable Energy
JEL Classifications: O44, P18

1. INTRODUCTION

Global warming is a hot topic of environmental economics due to rising pollution emissions and global temperature. The United States (US) stands in 2nd position after China in total CO_2 emissions by emitting 4,535.30 million tons of CO_2 in 2020 (World Population Review, 2023) and is continuously trying to reduce the emissions. Environmental agreements like Paris Agreement and Sustainable Development Goals (SDGs) aim to control global warming by 2 centigrade. The increasing globalization and the target of achieving higher economic growth are continuously putting pressure on the environment (Tisdell, 2001). The ecological effects of growth give birth to the Environmental Kuznets Curve (EKC) (Panayotou, 1993; Grossman and Kreuger, 1991). It explains that the early growth of any economy could have the scale effect, which postulates the positive slope of the EKC due to increasing energy demand. In this stage, environmental degradation is increasing at a faster rate than that of economic growth (Dinda, 2004). However, the economies can adopt the path of the second stage of the EKC after reaching a mature level of economic growth. Here, the EKC would turn to have a negative slope due to achieving technique and composition effects in an economy, which should be dominant over the scale effect. Thus, economic growth must be higher than the pollution growth in an economy. Therefore, faster economic growth is pertinent to achieve environmental improvements (Bhagawati, 1993). However, the EKC would be shaped well in the presence of strong conditions of sustainable growth to surpass the weak conditions of sustainable growth and development (Tisdell, 2001).

The EKC is derived from Kuznets (1955), which discussed the nonlinear relationship between income inequality and economic growth. Grossman and Kreuger (1991) corroborated a nonlinear association between income and some pollution proxies, and Panayotou (1993) termed it the EKC. Earlier, the green agriculture sector would be shifted to dirty industrialization and depletion of resources started at the first phase of the EKC. Later, the industry would transform into a clean service sector (Arrow et al., 1995). On the whole, this process contains 3 types of effects. At first, economic growth requires the use of inputs, which generates waste and emissions and is called scale effects. Thus, environmental degradation and resource depletion start at this stage. Later, the structure of the economy may move towards clean sectors like the service sector, which accelerates clean composition effects (Komen et al., 1997). In this process, clean technologies may be adopted by industries, which accelerates the technique effects. Resultantly, the economy would be shifted toward the negative slope of the EKC (Vukina et al., 1999). Side by side, the Renewable Energy Consumption (REC) would also become a priority of the nations to combat the pollution levels. Thus, the demand for REC would accelerate the renewable market (Apergis and Payne, 2010). In this regard, Mahmood et al. (2023a) demonstrate a comprehensive literature review, which depicts that REC significantly helps to shape the EKC in its downward trend.

Figure 1 shows the trends of REC and primary energy consumption (PEC) in exajoules in the US and data on these variables are sourced from BP (2023). PEC shows fluctuations and REC has a mostly increasing trend during 1965-2021. On average, both variables show positive trends during 1965-2021. REC shows a clear positive slope, which explains that the US is continuously progressing towards REC.

After discussing the trends of REC and PEC. We display a scatterplot in Figure 2 in the relationship between gross domestic product (GDP) and CO_2 emissions in million tons in the US. The data is sourced from Global Carbon Atlas (2023) and World Bank (2023). The graph depicts an M-shaped relationship, which contains an inverted U-shaped relationship with different income levels. However, we may assume an inverted U-shaped on average. Thus, the graph provides some evidence of the EKC.

Figure 3 exposes a relationship between GDP per capita and tCO_2 per person in the US. Figure 3 also depicts a clear M-shaped relationship. Thus, we can see the presence of the EKC in the graph.

The graphical presentations exhibit the EKC. However, an exact conclusion about the EKC is well-investigated in the US empirical literature. This research is steered to review the most significant studies conducted in the US economy to test the EKC hypothesis. The EKC hypothesis has been reviewed (Naveed et al., 2022; Dinda, 2004; Shahbaz and Sinha, 2019; Saqib and Benhmad, 2021; Koondhar et al., 2021). Moreover, some papers have broadened the scope of research by conducting review studies on country-specific or regional EKC testing (AlKhars et al., 2022; Mahmood et al., 2023b; Miah et al., 2011). This present review study analyzes the EKC studies for the second-largest polluted economy of the US as per total CO_2 emissions, which is missing in the review literature. Thus, we contribute to the literature of review studies on the EKC.

Figure 1: Trends of primary energy consumption and renewable energy consumption

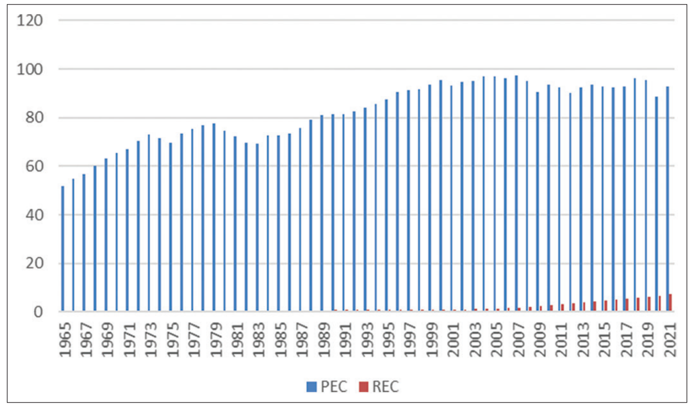


Figure 2: Scatterplot between gross domestic product and CO_2 emissions

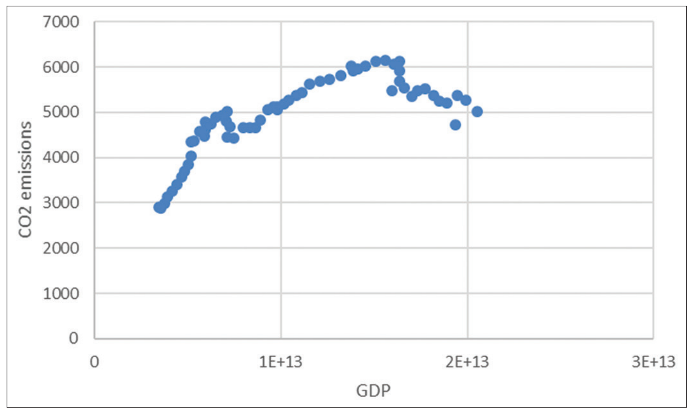
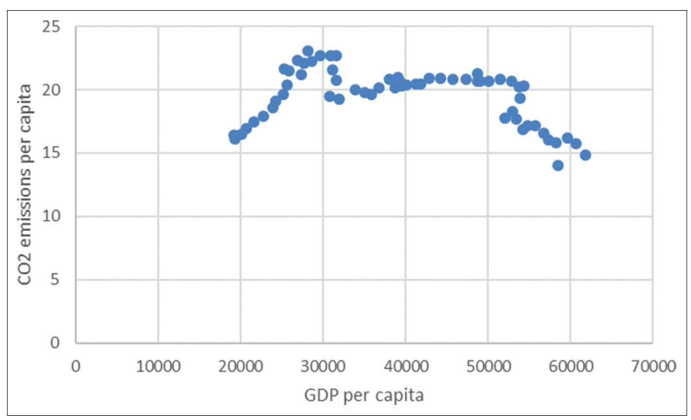


Figure 3: Scatterplot between gross domestic product per capita and tCO_2 per person



2. LITERATURE REVIEW

A lot of environmental literature has been conducted on the US economy. We focus on studies testing the EKC in the context of the US. For instance, List and Gallet (1999) tested the EKC in the US states and validated it in per capita income and emissions nexus. Khanna and Plassmann (2004) explored the EKC in the US using five pollution proxies in the year 1990 and found that household income was not mature enough to support the EKC. Thus, the EKC was not substantiated. Paudel et al. (2005) analyzed Louisiana state of the US and originated the N-shaped EKC in models of water pollution. However, specification tests could not validate these findings. Tevie et al. (2011) investigated the 48 US states in a model of biodiversity risk and could not validate the EKC. Moreover, population density increased biodiversity risk. Roach (2013) probed and validated the EKC in the US from 1980-2010 by using state-level data on CO_2 emissions. Howell et al. (2014) investigated the US counties and validated the EKC in a model of toxics. However, income raised air emissions.

Pao et al. (2015) investigated the US and validated the EKC. Moreover, all types of energy usage accelerated economic growth and emissions. Keene and Deller (2015) validated the EKC in a model of $PM_{2.5}$. Moreover, social capital also reduced $PM_{2.5}$. However, this effect was found weak in rural areas. Jebli et al. (2016) scrutinized some economies including the US and validated the EKC. Moreover, REC mitigated CO_2 emissions. Congregado et al. (2016) explored the US from 1973 to 2015 by using quarterly data and validated the EKC caring structural breaks. Baek (2016) investigated the US from 1960 to 2010 and validated the EKC. Moreover, REC and nuclear energy mitigated CO_2 emissions. Dogan and Turkekul (2016) explored the US from 1960 to 2010 and could not validate the EKC. Furthermore, trade reduced CO_2 emissions and energy usage and urbanization raised emissions. Financial Market Development (FMD) could not affect emissions. Moreover, bidirectional causalities were found among the investigated variables. Al-Mulali et al. (2016) explored various regions including the US in analysis from 1980-2010 and validated the EKC in a region with the US. Moreover, REC mitigated CO_2 emissions.

Clement et al. (2017) collected data on carbon footprint from 28,321 households and could not validate the EKC with the relationship of household income. Thus, a positive relationship was reported. Shahbaz et al. (2017) examined the US from 1960 to 2016 and validated the EKC with inverted U and N-shaped relationships. Moreover, biomass energy and trade variables also helped to reduce CO_2 emissions. Dogan and Ozturk (2017) analyzed the US from 1980 to 2014 and could not find the EKC considering structural breaks in analyses. However, REC mitigated and non-REC increased CO_2 emissions. Apergis et al. (2017) explored 48 US states from 1960 to 2010 and found the EKC in only 10 states. The EKC was not substantiated in the rest 38 states. Anastacio (2017) examined 3 North American countries including the US from 1980 to 2008 and found the EKC. Moreover, energy variables and income caused CO_2 emissions. Anastacio (2017) investigated 3 North American countries including the US from 1980 to 2008 and validated the EKC. Moreover, energy variables and income levels caused CO_2 emissions.

Aslan et al. (2018) scrutinized the sectoral level emissions in the US from 1973 to 2015 and validated the EKC in all sectors except the commercial and transport sectors. Polemis (2018) investigated US states from 1987 to 2012 and validated the EKC between industrial production and chemical toxins by using parametric and semi-parametric techniques. Tzeremes (2018) explored 50 US states from 1960 to 2010 and could not validate the EKC in most states. Moreover, bidirectional causality was corroborated between energy usage and CO_2 emissions. Aslan et al. (2018) examined the US from 1966 to 2013 and confirmed the EKC with a positive slope in the years 1982-1996 and a negative slope in the years 1996-2013. Ansari et al. (2019) analyzed top emitters from 1971 to 2013 and found the EKC in the US. Moreover, trade and energy usage contributed to CO_2 emissions. Farhani and Balsalobre-Lorente (2020) explored the EKC in 3 large economies including the US from 1965 to 2017 and validated the EKC in the US in CO_2 emissions and gas consumption models. Song et al. (2019) examined China and US from 1965 to 2016 and endorsed the EKC. Isik et al. (2019) analyzed 50 states of the US from 1980 to 2015 and validated the EKC in half of the investigated states. Moreover, fossil fuels raised and REC mitigated CO_2 emissions in some states as well. Bulut (2019) explored the US from 2000 to 2018 by using quarterly data and validated the EKC. Further, REC mitigated CO_2 emissions as well.

Balcilar et al. (2020) explored G7 economies including the US and could not find EKC in five countries including the US. Kim et al. (2020) investigated the US from 1973 to 2016 using monthly data and found the EKC. Moreover, biomass energy reduced CO_2 emissions. Destek et al. (2020) explored the EKC in G7 economies including the US from 1800 to 2010 and found W-shaped in the US in total sample and inverted U-shaped in pre-1973 testing. Gormus and Aydin (2020) examined 10 innovative economies including the US from 1990 to 2015 and could not find the EKC in the US. Moreover, innovation and REC reduced emissions. Cary (2020) collected sector-specific data from the US and validated the EKC with different data. Gyamfi et al. (2020) examined G7 economies from 1980 to 2018 including the US and endorsed the short-term EKC. Additionally, trade and energy usage accelerated emissions. Mahmood (2020) examined North America including the US from 1990 to 2014 and the EKC was substantiated at 15,665 dollars. Thus, the US was founded on 2[nd] stage. Moreover, FMD increased and Foreign Direct Investment (FDI) reduced CO_2 emissions. Nevertheless, trade showed a nonlinear effect on CO_2 emissions.

Khan et al. (2021) scrutinized the US from 1985 to 2020 and FMD, urbanization, globalization, and energy usage increased CO_2 emissions. However, institutional quality reduced CO_2 emissions. Sun et al. (2021) investigated the US utilizing quantile regression and substantiated the EKC. Furthermore, eco-innovation reduced CO_2 emissions and globalization increased CO_2 emissions. Usman et al. (2021) examined the US from 1985 to 2014 by using quarterly data. The authors found the EKC in the ecological footprint model but not in CO_2 emissions model. Energy usage increased and innovation reduced CO_2 emissions. The effects on ecological footprints remained insignificant. Ahmed et al. (2021) explored the US from 1985 to 2017 by using quarterly data. Increasing and decreasing policy uncertainty reduced CO_2 emissions. Further, the EKC was validated. Alola and Ozturk (2021) explored the US from 1984 to 2017 and corroborated the EKC. Moreover, renewable energy production reduced energy carbon emissions. Nathaniel et al. (2021) investigated G7 including the US and originated that nuclear energy mitigated CO_2 except for US and Canada. The EKC was validated in the US and 3 other countries. Khan and Hou (2021) investigated the US from

1980-2015 and found the EKC. Moreover, environmental diplomacy, investment, and income increased CO_2 emissions and REC reduced them. Pata (2021) analyzed the US from 1980 to 2016 and found the EKC. Moreover, globalization and REC mitigated and non-REC raised emissions. Isik et al. (2021) investigated the Armey hypothesis in the US and found the Armey in 7 states with a turning point of 15% government spending, which would support growth without harming the environment. The EKC was also validated.

Caglar and Mert (2022) examined the US including 4 other countries from 1965 to 2020 and found the carbon hysteresis hypothesis. Thus, emissions were increasing. Jeon (2022) examined 48 US states from 1997 to 2017 and found the EKC in the US. Moreover, REC and energy prices reduced CO_2 emissions. However, heating days increased emissions. Huang et al. (2022) examined China, the USA, and Japan using 18 years of data based on the EKC and found that the transport sector contributed to carbon emissions. Ongan et al. (2022) probed and found the Armey curve in the US and proposed a new methodology to validate the EKC. Nevertheless, the EKC was not found. Hongqiao et al. (2022) analyzed the EKC in the US from 1971 to 2018 utilizing augmented regressions and exposed that environmental innovations mitigated CO_2 emissions. It also helped to validate the EKC. Moreover, REC and trade globalization mitigated emissions but FMD increased emissions.

Aslan et al. (2022) explored the US from 1972 to 2020 and corroborated the EKC. Conversely, the EKC was not validated in disaggregated sector-specific CO_2 emissions' models. Trade and economic growth had negative and energy consumption had a positive effect on CO_2 emissions. Liu et al. (2022) scrutinized the EKC in G7 including the US in analysis from 1890 to 2015 and found the EKC in the case of France. However, the EKC could not be validated in other G7 countries including the US. Abid et al. (2022) analyzed G8 during 1990-2019 and FMD, innovation, and FDI mitigated CO_2 emissions. However, urbanization and energy usage increased CO_2 emissions. Caglar et al. (2022) analyzed the US from 1980 to 2017. Income and bio-capacity increased the ecological footprint and REC reduced it. Moreover, increasing natural resource rents reduced ecological footprints, and its decreasing series mitigated ecological footprints. Saqib et al. (2022) explored G7 and E7 countries including the US from 1990 to 2019 and found that sustainable energy has a positive effect on growth in G-7. The authors also estimated a threshold point of energy to have pleasant growth effects. Mahmood (2022) explored 28 nuclear economies including the US from 1996 to 2019 and validated the EKC. Further, nuclear energy mitigated CO_2 emissions.

Pata et al. (2023) investigated and confirmed the EKC in the US from 1965 to 2018. Further, biomass improved and economic growth mitigated the load capacity factor. However, FMD could not affect it. Aldieri et al. (2023) investigated the US from 2005 to 2017 and found the EKC. Innovation and its spillovers supported economic growth and thus contributed to sustainable growth. Dai et al. (2023) explored the US from 1970 to 2019 and found the EKC. Transport REC reduced CO_2 emissions. However, transport fuel usage and infrastructure accelerated emissions. Duran et al. (2023) explored nuclear countries including the US during 1990-2020 and validated the EKC. Nuclear energy and REC reduced ecological footprint and non-REC raised it. Bunnag (2023) examined the US from 1979 to 2021 and could not find the EKC. Moreover, energy usage raised and FDI mitigated CO_2 emissions.

The reviewed literature exposed that 41 out of 60 studies validated the EKC in the US economy. We also observe that REC has played its role in shaping the second phase of the EKC as the EKC was mostly validated in the presence of positive environmental effects of REC in the model. Moreover, the disaggregated state-level data was also helpful to authenticate the EKC.

3. SUMMARY OF LITERATURE AND ANALYSIS

Table 1 exposes a summary of 60 EKC studies. 41 studies found the validity of the EKC and 19 papers did not find it. 11 papers used disaggregated state-level data and most of such studies validated the EKC. 49 studies used aggregated country-level data of the US economy and the proportion of the validity of the EKC was relatively lower than the studies using disaggregated data.

Some studies included the REC in the EKC model and REC mitigated emissions in 24 papers. The EKC was substantiated more frequently in the papers validating the negative effect of REC on emissions. 36 studies did not include REC in the model or could not find a negative impact of REC on emissions. These studies have a low tendency to validate the EKC.

We observe from Table 1 that the studies validated the EKC in a greater amount using disaggregated data and/or establishing a negative effect of REC on emissions. These facts are tested in logistic regression. Table 2 depicts logistic regression. The results show that if a study find that REC has mitigated emissions, then the possibility of the EKC is 3.0885 times higher ($e^{1.1277}$). However, the role of disaggregated data is found statistically insignificant.

Table 1: Summary of the literature

Valid EKC	Papers	REC mitigated emissions	Papers	Disaggregated data is used	Papers
Yes	41	Yes	24	Yes	11
No	19	No	36	No	49
Total	60	Total	60	Total	60

REC: Renewable energy consumption

Table 2: Regression results

Variable	Coefficient	SE	Z-statistic	P-value
REC mitigated emissions	1.1277	0.6519	1.7298	0.0837
Disaggregated data is used	0.0749	0.7701	0.0973	0.9225
Intercept	0.4665	0.3775	1.2358	0.2165

SE: Standard error, REC: Renewable energy consumption

4. CONCLUSION

The US economy is the second largest polluter in the world as per total CO_2 emissions. A large pool of research papers has investigated the EKC in the US. The present study reviews 60 papers examining the EKC in the US, which is missing in the current review literature. 41 out of the 60 studies substantiated the EKC. However, 19 papers did not find it. 11 papers used disaggregated state-level data. These studies mostly found the EKC in the US. However, 49 studies used national data from the US, and the authenticity of the EKC was lower in these studies compared to the studies utilizing disaggregated data. Moreover, the US literature has also included REC in the EKC model and 24 studies found a negative impact of REC on emissions. These studies found the EKC more often compared to studies not validating the negative effect of REC on emissions. These findings are tested through logistic regression. The results confirm that REC reducing emissions raises the confirmation of EKC. Its chance is found 3.0885 higher if REC mitigated emissions. However, the disaggregated data could not affect the existence of the EKC in logistic regression. Based on logistic regression results, we recommend using REC in the EKC model in the US, which could help in finding the EKC in a model.

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