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Revisiting and Validating Environmental Kuznets Curve (EKC) in Some Selected Developed Countries in Europe

Lakshmi Shine M[1] , and Susobhan Maiti[2]

[1, 2] Department of Economics, JAIN (Deemed-to-be University), Bangalore, India

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ABSTRACT- The Environmental Kuznets Curve (EKC) explores the relationship between economic growth and environmental degradation, proposing an inverted U-shaped curve. It says that the pollution initially increases with the rise in the income levels but declines after a surpassing a certain economic threshold. This study validates that EKC hypothesis in selected developed European countries focusing carbon dioxide (CO_2) and nitrogen dioxide (NO_2) emissions concerning Gross domestic product per capita (GDPPC). The secondary data were used from World Bank for the year 1990 to 2020. The analysis highlights that the existence of inverted U-shaped curve in some nations Austria, Belgium, and Denmark, where emissions rise during early stages of economic growth but eventually decline. However, the findings for NO2 emissions are mixed, with some countries exhibiting weak or no EKC patterns. This divergence is attributed to differences in industrial structures, energy efficiency, and the adoption of clean technologies. The study highlight's role of regulatory framework, public awareness and investment in achieving sustainable development. Countries with robust environmental policies and higher investments in green technologies, such as Denmark and Sweden, demonstrate more pronounced EKC trends. Conversely, nations reliant on fossil fuels and less stringent environmental policies exhibit weaker results. The outcomes highlight how important it is to balance the economic growth and economic sustainability in industrial countries through environmental policies, investments in cleaner technologies and sustainable conduct.

KEYWORDS- Environmental Kuznets Curve (EKC), Economic Growth, Carbon Emission, Environmental Degradation, European Countries

I. INTRODUCTION

Kuznets examines the relationship between economic growth and income inequality in his groundbreaking study. According to his main hypothesis, which is known as the Kuznets Curve, income inequality follows an inverted U-shaped curve as a nation's economy develops. As wealth builds up among industrialists and in metropolitan centres during the early phases of industrialisation, inequality tends to increase. Inequality gradually decreases as social programs are implemented and economic growth levels off. Kuznets states that individual may assume a long swing in inequality describing the secular structure widening in the early phases of economic growth and becoming balanced and then narrowing in the later phases. He also explains the income disparity in urban and rural and he also emphasises the governmental interventions in mitigating inequality (Kuznets, 1955). A conceptual framework that views the changes of environmental degradation with respect to economic expansion is referred to as the Environmental Kuznets Curve (EKC). This outcome arises from an interaction between social, technological, and economic factors with long-term implications for the environment. Simon Kuznets' work on the relationship between economic growth and income inequality provided the initial impetus for the EKC, which was first applied to tackle the environmental consequences of economic progress[4]-[6]. During the early 1990s, when economists and policymakers faced the impact of industrialization on environmental quality, the EKC was conceived. Grossman and Krueger's [16] work on the environmental impact of the North American Free Trade Agreement (NAFTA) provided the empirical basis for the EKC hypothesis. In their research, they found that at low GDPPC, many pollutants increased. The idea of EKC was born when economists and decision-makers were struggling in the early 1990s with the effects of industrialization on environmental quality. Grossman and Krueger's[16] study on the environmental implications of NAFTA was an empirical study supporting the EKC hypothesis. Based on their analysis, at low-income levels, some pollutants climbed with GDPPC, but as incomes went above a certain threshold, they started to decline. Income levels, but as incomes increased above a certain point, they started to decline. In subsequent research, the scope of EKC was extended to incorporate several environmental indicators, which included greenhouse gas emissions, deforestation, and pollution in air and water. Among those scholars who improved the theoretical foundations were Panayotou [17] and Shafik and Bandyopadhyay [18] They emphasized the contribution of public awareness, technological innovation, and the quality of institutions to develop EKC. Towards the end of the 1990s, the EKC had become one of the most popular concepts used for understanding the relationship between the ability to sustain the environment and economic development. Emissions of carbon dioxide (CO2) and nitrogen dioxide (NO_2) are two of the principal causes of environmental degradation. The two pollutants are very fundamental to the discussion of the EKC because they originate from energy production, transport, agricultural, and industrial activities. NO2 causes respiratory problems, acid rain, and air pollution, while CO2 is a major greenhouse gas that contributes to global warming. The historical trend of CO2 and NO2 emissions in developed European nations follows closely the

processes of urbanisation and industrialisation. The reliance on fossil fuels and energy-intensive sectors throughout the early stages of economic development led to significant increases in emissions. Emissions however stabilised or declined when those economies transitioned into the post-industrial phases which are characterised by leading edge technologies and severe environmental constraints. These dynamic stresses how useful the EKC can be in understanding environmental changes in industrialized nations.

Various researches have been conducted on European levels to analyse how the environmental indicators, which consist of CO2 and NO2 emissions, are linked to the GDP. EKC hypothesis presents a useful framework that will help in comprehending such processes. Empirical data supports an inverse U-curve relationship between emissions and the GDPPC for Sweden, France, and Germany. Economic growth is responsible for raising emissions at lower income levels due to the use of energy and industrial expansion. However, the inclusion of clean technology, energy efficiency measures, and sustainable behaviours decrease emissions as GDPPC rises above a critical level. The European Union (EU) has taken the lead in putting regulations in place to separate environmental deterioration from economic growth. The region's commitment to sustainability is also reflected in programs such as the European Green Deal, the Emissions Trading System (ETS), and investments in renewable energy. This act validates the EKC theory besides showing how institutional and policy frameworks influence environmental results. Emissions and economic growth have a mutual relationship. Economic activity pollutes through the use of energy, industrial production, and transportation. On the other hand, environmental degradation- in this case air pollution- has devastating economic implications due to the consequences on ecosystem services, labour productivity, and public health. Economic impacts of the emissions of CO2 and NO2 can be seen in Europe, mainly in the healthcare and tourism industries and in agricultural sectors.

For example, the health effect of air pollution, particularly NO2 emission, leads to low productivity and increased healthcare expenditure. There are also threats from infrastructure to water supplies and agricultural outputs due to CO2-induced climate change. All these issues illustrate why environmental factors must be included in the economic planning in order to achieve sustainable growth. The EKC hypothesis highlights that the structural changes and government interference due to economic growth are responsible for better environmental performance. An example of such change can be seen with the transformation of European economies from a manufacturing-based to a service-based economy along with investment in green technologies. This trend can be most appropriately presented with a couple of countries such as Denmark, Netherlands, and Austria, in which it is visible that environmental sustainability goes along well with economic growth.

However, the EKC curve is not self-created. It demands initiatives to deal with market imperfections which hinder environmental progress, for example, externalities and information asymmetry. Some policies in the areas of energy efficiency, pollution control, and renewable energy would ensure that growth positively impacts the environment.

II. REVIEW OF LITERATURE

The Environmental Kuznets Curve has been a staple of environmental economics for decades, discussing in detail the relationship between the growth of economies and how this growth affects environmental damage. Hettige et al. [7] started the debate as they discussed industrial water pollution in 12 countries. They could not find any inverted U-shaped EKC for industrial water pollution; rather, it decreased with income because of regulatory and market-driven changes in pollution intensity, whereas total industrial pollution remained stable. Years later, Sinha and Bhatt [13] analysed the EKC hypothesis in India for CO2 and NO2 emissions. Their results depicted an N-shaped curve, which means that emissions rose with GDP, declined at a midpoint, and increased again as income grew further. In the same year, Makarabbi, Khed, Balaganesh, and Jamaludheen[19] analysed the long-run impact of GDP, energy consumption, and FDI on CO2 emissions in India and found a cubic or N-shaped relationship instead of the classic EKC pattern. Geographically expanding the scope, Tjoek and Wu (2018) analysed CO2 and SO2 emissions in Southeast Asia. The authors found that CO2 emissions had an EKC-like trend, whereas SO_2 emissions showed irregular patterns. Armeanu et al. [2] analysed EU-28 countries and found EKC trends for several pollutants, and they emphasized the need for energy efficiency and green technologies. Kong and Khan [8] researched the EKC hypothesis of developed and developing countries that demonstrated a completely different set of emissions profiles. Advanced regulatory measures indicated the EKC curve with developed countries while developing nations continued with the persistent environment problems. Shahbaz and Sinha [12] concluded literature survey, noting that due to contextual, temporal, and methodological considerations, variations were found in outcomes of the EKC research.

Han, Gu, and Yang[6] conducted research on NO2 pollution in Chinese cities in 2021 and found no evidence of an EKC for NO2. On the contrary, the researchers established a positive correlation of emissions with industrialization and transportation growth while green spaces mitigate it. Aslam, Hu, Shahab, Ahmad, Saleem, Shah, Javed, Aslam, Hussain, and Hassan [3] analysed CO2 emissions in China during the same year, supporting a U-shaped EKC relationship, while calling for sustainable industrial practices and urbanization management. Soeharjoto, Salma, Tribudhi, and Masyhud [1] explored the case of ASEAN-6 countries and showed EKC features only in Singapore while other countries experience an increasing trend of emissions correlated with GDP growth and energy consumption[9][10]. In the Asia-Pacific region, Nguyen, Mayers, Nhan, Huong, and Duong[11] discussed CO_2 emissions to indicate an N-shaped EKC by emphasizing trade liberalization and renewable energy in reducing harmful effects on the environment[14]. For Indonesia, Yunita, Gunarto, Marselina, and Yuliawan [15] analysed how GDP growth repeatedly elevated CO_2 emissions without the EKC hypothesis, which indicates demographic as well as policy complexities in that country. Fazle Rabbi and Abdullah (2024) turn their attention to the Visegrád region, thus validating the EKC hypothesis for CO2 emissions, and underlining the pivotal role of technological innovations and sectoral policies.

Finally, Alam (2024) examined 24 OECD countries, confirming the inverted U-shaped EKC and advocating for energy efficiency and renewable energy transitions as essential strategies for sustainable development. These studies collectively illustrate the nuanced nature of EKC research, shaped by regional, economic, and methodological variations, while reinforcing the importance of aligning economic growth with environmental sustainability.

III. OBJECTIVE

Objective of this study is as follows: To examine whether Validate Environmental Kuznets Curve (EKC) in Some Selected Developed Countries in Europe exists or not.

IV. METHODOLOGY AND DATA SOURCE

To understand the distribution and variability in the data, the mean, minimum, and maximum values of GDPPC, CO2 emissions, and NO2 emissions were calculated for developed European countries like Austria, Belgium, Czechia, Denmark, Germany, France, Ireland, Iceland, Luxembourg, Netherlands, Norway, Poland, Portugal, Russian Federation, Slovenia, Sweden, Switzerland, United Kingdom. Using GDP and GDP² as independent variables and CO2 and NO2 emissions as dependent variables, quadratic models were applied to examine the relationship between GDPpc and emissions in an inverted U-shaped form.

$$CO_2 = \beta_1 + \beta_2 . Gdppc + \beta_3 . Gdppc^2$$
$$NO_2 = \beta_1 + \beta_2 . Gdppc + \beta_3 . Gdppc^2$$

All data is collected from well-established source such as the World Bank Development Indicators (WDI) from 1990 to 2020.

V. ANALYSIS OF THE RESULT

The result shows that only Belgium is following EKC for both the pollutants CO_2 & NO_2. It has an inverted U-shaped curve. The countries which don't follow EKC are Czechia, Iceland, Sweden, and United Kingdom. The countries which only follow EKC in CO_2 are Austria, Denmark, France, Ireland, Netherlands, Norway, Portugal, Russia Federation, Slovenia, and Switzerland. It may be no because of insufficient technological advancement, regulation gaps etc. The countries which don't follow EKC in NO_2 are Germany, Luxembourg, and Poland. In some countries the EKC is no because of industrial and environmental condition

Table 1: Descriptive statistics for CO_2, NO_2 and GDPpc

	CO_2				NO_2				GDPPC			
	Minimum	Maximum	Mean	CV	Minimum	Maximum	Mean	CV	Minimum	Maximum	Mean	CV
Austria	6.63	9.27	7.94	0.08	3759.74	5005.39	4286.74	0.09	21680.99	51919.98	37669.08	0.29
Belgium	7.39813	11.76	10.04	0.13	4564.19	9335.79	6682.90	0.25	20600.38	48303.4	35184.11	0.29
Czechia	8.30	14.82	11.34	0.12	4576.96	8050.78	5353.98	0.11	2896.60	23664.85	13257.63	0.56
Denmark	4.69	13.94	9.18	0.26	5096.90	7480.87	6019.67	0.12	26891.45	64322.06	45961.28	0.29
Germany	7.25	12.02	9.85	0.10	33815.11	67167.58	48263.18	0.23	22303.96	48023.87	35496.42	0.25
France	3.95	6.50	5.56	0.12	36202.72	64146.65	47632.65	0.20	21675.71	45515.96	32848.11	0.25
Ireland	6.76	11.59	9.29	0.15	9069.34	11015.29	10019.82	0.05	14031.3	85973.09	43305.02	0.50
Iceland	3.94	8.42	6.84	0.17	353.611	400.87	374.178	0.03	23579.8	74452.19	44030.3	0.36
Luxembourg	12.45	30.37	21.26	0.22	257.89	384.72	345.14	0.09	33465.48	123678.7	80509.71	0.41
Netherlands	7.47	11.17	9.89	0.07	8336.91	16777.35	12412.7	0.26	21290.86	57879.94	39411.27	0.31
Norway	6.41	8.89	7.70	0.06	3427.45	5182.27	4315.17	0.15	27963.7	103553.8	61278.25	0.42
Poland	7.36	9.19	8.19	0.06	22388.39	27269.34	24703.14	0.05	1731.21	15816.82	8593.375	0.56
Portugal	3.78	6.29	5.08	0.13	3092.12	4029.69	3576.01	0.09	7884.61	24949.04	16996.78	0.32
Russian	10.06	14.62	11.4	0.0	54215.5	108556.1	65370.8	0.2	1330.75	15941.45	6887.28	0.6

Federation			4	9	3		6	1				7
Slovenia	5.93	8.58	7.27	0.09	792.28	1124.91	854.557	0.07	7146.06	27595.6	17283.31	0.40
Sweden	3.24	7.19	5.34	0.21	5594.20	6489.06	6042.51	0.04	24425.28	61126.94	42712.34	0.28
Switzerland	4.04	6.71	5.69	0.12	2396.71	2896.80	2611.88	0.05	38865.02	90476.76	61599.93	0.31
United Kingdom	4.60	9.93	8.04	0.19	27696.69	59039.49	37007.93	0.26	18389.02	50397.69	34866.66	0.28

Source: Author's calculation

In table 1, descriptive statistics mean, maximum, minimum of CO_2, NO_2 and GDPpc for some European developed countries. Luxembourg emerges as the wealthiest country, with a maximum GDP per capita an average of 80,509.71, while maintaining relatively low NO2 emissions. Followed by Norway and Switzerland of GDP per capita an average of 61278.25 & 61599.93. Sweden has low average CO_2 levels of 5.34, while Russia (11.44), Luxembourg (21.26) and Czechia (11.34) have high average of CO_2 levels. Iceland (374.178), Luxembourg (345.14) and Slovenia (854.557) have low average of NO_2 levels. The other remaining countries have moderate average levels of CO_2 emission, NO_2 emission and GDPpc. The CV in CO_2 is generally low, that is the variation in CO_2 emission in each country is relatively small when compared to the average CO_2 emission level. The CV for NO_2 emission is more varied and, in some countries, its higher. There is great variability in NO_2 emission within these countries. The CV values for GDPpc are higher when compared to CO_2 and NO_2 emission. This shows that there are more fluctuations in GDPpc within the countries over the time period.

Table 2: Environmental Kuznets Curve Validation

	Dependent Variable: CO_2				Dependent Variable: NO_2			
Country	C	Gdp	Gdp^2	Validating EKC	C	Gdp	Gdp^2	Validating EKC
Austria	2.10 (1.01)	0.000354*** (2.95)	-4.87E-09*** (-3.04)	Yes	7274.94*** (14.76)	-0.13*** (4.68)	1.32E-06*** (3.48)	No
Belgium	9.90*** (4.09)	0.000152 (1.00)	-3.88E-09** (-1.79)	Yes	7242.94*** (2.81)	0.14 (0.90)	-4.22E-06** (-1.83)	Yes
Czechia	13.41*** (19.37)	-0.00015 (-1.13)	-1.78E-10 (-0.03)	No	6648.16*** (16.67)	-0.18** (-2.42)	5.23E-06** (1.80)	No
Denmark	10.45** (1.94)	0.000111 (0.42)	-2.77E-09 (-0.97)	Yes	10406.84*** (14.55)	-0.14*** (4.36)	1.07E-06*** (2.85)	No
Germany	12.60*** (5.12)	-5.81E-05 (-0.39)	-5.13E-10 (-0.24)	No	62775.7** (2.01)	0.20 (0.10)	-1.62E-05 (-0.62)	Yes
France	8.78*** (4.25)	-0.00014 (-1.05)	1.24E-09 (0.60)	Yes	107584.8*** (4.85)	-2.76** (-1.92)	2.70E-05 (1.22)	No
Iceland	8.87*** (5.79)	-3.75E-05 (-0.52)	-1.73E-10 (-0.22)	No	437.05*** (21.14)	-0.0030*** (-3.15)	3.24E-08*** (3.17)	No
Ireland	8.18*** (9.38)	0.000104** (2.40)	-1.46E-09*** (-3.12)	Yes	11174.88*** (38.09)	-0.039*** (-2.74)	2.46E-07 (1.56)	No
Luxembourg	32.73*** (4.57)	-0.00023 (-1.08)	8.98E-10 (0.68)	No	213.95 (6.02)	0.0027*** (2.66)	-1.23E-08* (-1.88)	Yes
Netherlands	9.89*** (5.87)	5.42E-05 (0.57)	-1.25E-09 (-1.02)	Yes	19694.76*** (5.31)	-0.10 (-0.51)	-1.78E-06 (-0.66)	No
Norway	7.46*** (10.69)	8.11E-06 (0.32)	-5.71E-11 (-0.29)	Yes	5540.52*** (9.94)	-0.01 (-0.94)	-1.61E-08 (-0.10)	No
Poland	9.50***	-0.00031***	1.37E-08***	No	25538.89***	0.065	-1.44E-05	Yes

	(31.06)	(-3.46)	(2.74)		(31.63)	(0.27)	(-1.09)	
Portugal	0.79 (0.55)	0.000598*** (3.15)	-1.84E-08*** (-3.23)	Yes	4505.64*** (8.71)	-0.06 (-0.95)	5.55E-07 (0.27)	No
Russian Federation	11.24*** (18.40)	7.72E-05 (0.39)	-4.78E-09 (-0.39)	Yes	68494.62*** (8.79)	-0.02 (-0.009)	-4.31E-05 (-0.27)	No
Slovenia	5.35*** (5.43)	0.000268** (2.01)	-7.81 E09** (-2.01)	Yes	1103.005*** (13.68)	-0.02** (-2.44)	6.13E07** (1.93)	No
Sweden	9.31*** (4.61)	-0.00011 (-1.05)	2.95E-10 (0.25)	No	6826.60*** (10.28)	-0.02 (-0.68)	9.05E-08 (0.23)	No
Switzerland	5.70*** (4.85)	3.64E-05 (0.90)	-5.40E-10* (-1.70)	Yes	3135.09*** (10.13)	-0.012 (-1.15)	5.62E-08 (0.67)	No
United Kingdom	14.87*** (4.86)	-0.00032 (-1.61)	3.21E-09 (1.09)	No	108321.2*** (12.37)	-3.55892*** (-6.34)	4.02E-05*** (4.80)	No

Source: Author's calculation

In table 2, as you can see only Belgium validates EKC in CO2 emission and NO2 emission. Some countries validate EKC in CO2 those are countries are Austria, Denmark, France, Ireland, Netherlands, Norway, Portugal, Russia Federation, Slovenia, and Switzerland. The countries which validate EKC in NO2 are Germany, Luxembourg, and Poland. In countries like Czechia, Iceland, Sweden and United Kingdom where there is no validation of EKC in CO2 emission and NO2 emission.

VI. CONCLUSION

It supports the Environmental Kuznets Curve (EKC) hypothesis for the case of CO2 in some European countries by confirming an inverted U-shaped relationship in which emissions increase with economic expansion before eventually declining above a critical income threshold. The result demonstrates that only Belgium complies with EKC for both CO2 and NO2. Its contour is inverted U-shaped. The United Kingdom, Iceland, Sweden, and Czechia are the nations that do not adhere to EKC. Austria, Denmark, France, Ireland, the Netherlands, Norway, Portugal, the Russian Federation, Slovenia, and Switzerland are the only nations that use EKC in CO2. It might not be because of regulatory loopholes, inadequate technology advancement, etc. The nations that do not adhere to EKC in NO2 include Poland, Germany, and Luxembourg. Due to industrial and environmental conditions, the EKC is absent in many nations.

VII. POLICY IMPLICATION

This study strongly suggests to invest in green technologies like solar, wind and hydroelectric power to reduce reliance on fossil fuel, Encourage Research and Development for cleaner industrial and transportation technologies. Make environmental regulations strict and implement carbon taxes and stricter emission level for industries and vehicles. It also suggests there should be more public awareness campaigns for pollutants and promotes sustainable urbanization like public transportation, electric vehicle.

VIII. LIMITATION

The study focuses only on developed European countries and only three variables were taken and other variables like population density, urbanization rates were excluded.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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