ISSN E: 3006-1466
ISSN P: 3006-1458 **CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW**
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
Vol.02 No.04 (2024)

ECONOMIC GROWTH, RENEWABLE ENERGY, AND LAND USE: THEIR IMPACT ON CARBON EMISSIONS IN EUROPE AND ASIA

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Abstract
This study examines the effect of economic growth, use of renewable energy, urbanization, industry, tourism, agriculture, and deforestation on carbon emissions in Europe and Asia. We employ Fully Modified Ordinary Least Squares (FMOLS) analysis to investigate the relationships between these variables. We use data on 40 Asian and 45 European countries. Our results show that economic expansion, industrialization, urbanization, and tourism significantly raise carbon emissions. On the other hand, forest acreage and the use of renewable energy sources reduce the emissions. The results highlight that there are regional differences, with Asia's economic activity being more heavily responsible for emissions. Moreover, we find that Europe is gaining from increased use of renewable energy sources and sustainable land management. The study highlights the need for region-specific laws that encourage the use of region-specific policies.
Keywords: *Carbon emissions, economic growth, Europe, Asia, environmental sustainability*

INTRODUCTION

The global demand for energy is increasing and it is expected that it will rise by 1.5 to 3 times by 2050 approximately This increase most likely will come from rapid population growth, economic expansion, and improvements in living standards (Shahsavari and Akbari, 2018). Currently, the global economy heavily depends on fossil fuels for its persistent energy needs. The use of these fuels is the primary source of greenhouse gas (GHG) emissions (Hanif et al., 2019; Kostruba & Pasko, 2019; Hussain & Khan, 2022). Given the harmful environmental impacts of fossil fuel consumption, there is a rising resolve among policymakers to shift from non-renewable to renewable energy sources. This will redefine economic growth strategies. Alola et al. (2019) notes that non-renewable energy consumption degrades environmental quality and hinders ecological sustainability. On the other hand, renewable energy use promotes it. Studies have shown that economic growth and industrialization can lead to increased carbon emissions (Luna & Luna, 2018; Ali et al., 2021). Urbanization also plays a critical role, encouraging energy consumption patterns and transportation emissions.

Understanding the connections among above factors is crucial for designing effective policies to alleviate carbon emissions in Europe and Asia. Due to increased greenhouse gases, there is a bigger threat to environment. Persistent increase in $C0_2$ has a critical impact on environment in the long run. This results in serious consequences for global environment conditions. The region of Europe is relatively highly developed. The region contained 9 of the world's top 25 emitters in 2012. Sustainable economic growth and development is the focus of both regions. There is a need for the adoption of cleaner technology and Echo-friendly substitute. The importance of renewable energy has been emphasized in the context of energy shortage, global climate change, and the concept of sustainability has grown (Ahmad, 2018; William & Adam, 2018; Sohag et al. 2019; Sharif et al. 2021)

Agricultural practices, including deforestation for agricultural expansion and livestock production, can provide to carbon emissions through land-use changes and methane emissions. On the other hand, sustainable forestry practices can act as carbon sinks. This reduces CO2 from the atmosphere. So, integrating sustainable land management practices into policies is essential. This can reduce carbon emissions while ensuring food security and conserving biodiversity in these regions (Raihan et al. 2018; Ibrahim & Simian, 2023; Calin & Horodnic, 2023; Audi, 2024)

Tourism is another significant factor which poses a dual challenge in terms of carbon emissions. On the one hand, the transportation and accommodation, which is linked with this industry, can play a significant role in carbon emissions. These emissions come from air travel and energy-intensive hospitality services (World Bank, 2022). Alternatively, sustainable tourism practices improve environmental conservation and support local communities, which mitigate the negative impacts of tourism on carbon emissions. Implementation of the sustainable tourism initiatives like promoting eco-friendly accommodations, encouraging responsible travel behavior, and investing in low carbon transportation infrastructure can help minimize the carbon footprint of this sector in Europe and Asia. This study examines the effects of economic growth, renewable energy use, urbanization, industrialization, tourism, agricultural productivity, and forest areas on carbon dioxide emissions in Europe and Asia. This study is significant because it examines the dynamic interplay between crucial environmental and economic issues that influence CO2 emissions in Asia and Europe. Policymakers can design better policies for economic expansion and climate change in the light of better understanding of these impacts.

LITERATURE REVIEW

Greenhouse gases (GHGs), particularly carbon dioxide (CO_2) from fossil fuel combustion and deforestation, have made global warming and climate change critical issues in this century (Raihan et al., 2018, 2021a). Rising CO_2 levels deteriorate the global climate system. It makes it imperative to reduce these emissions and improve environmental sustainability for long-term growth (Raihan et al., 2022a; Raihan and Tuspekova, 2022a). Addressing these emissions, especially in the energy sector, is vital for aligning economic progress with environmental sustainability.

Sustainable development hinges on decoupling economic growth from environmental degradation through cleaner technologies, structural changes, and regulatory measures (Raihan et al., 2022a). Renewable energy, recognized as a carbon-free solution, is crucial for achieving global emission reduction targets by 2050 (Raihan et al., 2022b). Agriculture, forestry, and land use account for nearly 20% of global CO_2 emissions (IPCC, 2014). However, agricultural practices release significant GHGs, contributing to climate change (Raihan and Tuspekova, 2022a). Deforestation for agriculture, mining, and infrastructure further exacerbates emissions, despite forests' role as carbon sinks (Raihan et al., 2019, 2021b, 2022a). Balancing these sectors with environmental sustainability remains a critical challenge for Turkey.

Economic development, population dynamics and energy utilization stimulate global emissions, while industrialization and trade escalate pollution levels (Sarkodie, et al., (2020). Energy consumption, economic growth, and urbanization all significantly increase carbon emissions in developing East Asian and Pacific countries (Hanif et al). Increasing renewable energy and agriculture decreases CO_2 emissions, while non-renewable energy is positively correlated to emission in four Asian countries as revealed by Xuyi Liu et al (2017). Sustainable land management and agricultural practices can play an important role in reducing carbon emissions (Bossio et al. (2020)). Another economic factor, rapid urbanization also raises energy needs. This leads to higher GHG emissions, which wreaks havoc on the environment in urban regions (Raihan et al. 2022c).

The influence of Economic Growth, Renewable Energy Use, Urbanization, Industrialization, Tourism, Agriculture, and Forest on Carbon Emissions in Europe and Asia is not straightforward. Economic growth and industrialization lead to increased energy consumption and the use of fossil fuels. This leads to sharp increase in carbon emissions, particularly in rapidly developing regions (Kasman & Duman, 2015). Moreover, urbanization changes consumption patterns and transportation systems. This further influencse carbon emissions trends (Seto et al., 2014). Studies have shown that densely populated urban areas have higher emissions per capita. This is due to greater energy demand for buildings, transportation, and infrastructure (Creutzig et al., 2016).

The agricultural sector also contributes heavily to carbon emissions through land-use changes. Moreover, deforestation, and methane emissions from livestock also deteriorate environment. On the other hand, sustainable agricultural practices such as agroforestry, organic farming, and improved livestock management, offer potential solutions to environmental safeguard. These practices not only promote food security but are also resilient to climate change impacts (Smith et al., 2008).

Forests play a crucial role in carbon reduction. They act as vital carbon sinks that absorb CO_2 from the atmosphere. Deforestation and forest degradation, which is the result of factors such as agriculture expansion, logging, and infrastructure development, releases stored carbon back into the atmosphere. This leads to exacerbation of climate

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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change (Houghton et al., 2015). Therefore, forest conservation and sustainable forest management are essential strategies for enhancing carbon storage and reducing its emissions.
Another sector, tourism, presents both challenges and opportunities for carbon emission reduction efforts. Although tourism activities contribute to carbon emissions through transportation, accommodation, and other services, sustainable tourism practices can help reduce its environmental impacts. Sustainable tourism initiatives, such as ecotourism, responsible travel, and green certifications for accommodations, have gained attention in recent years. The stakeholders recognize the importance of mitigating this sector's carbon footprint (Hall, 2010).

METHODOLOGY

This study aims to conduct an empirical analysis of the effect of the economic growth, renewable energy use, Urbanization, Industrialization, Tourism, Agricultural productivity, and Forest area on CO_2 emissions in the Asia and Europe region using the data from 1990 to 2020. Data on each region were gathered using the world development indicators (WDI) data set. The studies dependent variable was CO_2 emissions, and the explanatory variables included are Economic growth, Renewable energy, Urbanization, Industrialization, Tourism, Agricultural production, and forest area. The econometric model used in the study has the following functional form;

$CO2it = \beta0 + \beta1ECGit + \beta2RNEit + \beta3URBit + \beta4INDit + \beta5TRit + \beta6AVAit + \beta7FAit + \epsilon it CO2_{it} = \beta_0 + \beta_1 ECG_{it} + \beta_2 RNE_{it} + \beta_3 URB_{it} + \beta_4 IND_{it} + \beta_5 TR_{it} + \beta_6 AVA_{it} + \beta_7 FA_{it} + \epsilon_{it}$ (1)

Where:

- $CO2itCO2_{it}$ = Carbon dioxide emissions for country ii at time tt
- $ECGitECG_{it}$ = Economic growth
- $RNEitRNE_{it}$ = Renewable energy use
- $URBitURB_{it}$ = Urbanization
- $INDitIND_{it}$ = Industrialization
- $TRitTR_{it}$ = International tourism
- $AVAitAVA_{it}$ = Agricultural productivity
- $FAitFA_{it}$ = Forest area
- $\beta0\beta_0$ = Intercept
- $\beta1, \beta2, \ldots, \beta7\beta_1, \beta_2, \ldots, \beta_7$ = Coefficients measuring the impact of independent variables
- $\epsilon it\epsilon_{it}$ = Error term

This model is estimated using Fully Modified Ordinary Least Squares (FMOLS) method. Fully modified ordinary least square (FMOLS) regression is robust to endogeneity and along constant parameter estimation, even in the presence of serial correlation in the error term, because it incorporates both contemporaneous and lagged values of the explanatory variables into the estimation process, unlike traditional ordinary least square method (OLS) regression. An effective econometric method for estimating long-term associations between variables while addressing possible endogeneity and serial correlation concerns is FMOLS. Because it employs the unit root test to account for any nonstationary, it is mostly helpful for evaluating time series and panel data. The variables used in the above model and their data sources are further provided in the table below.

Table 1: Variables and their Description

Variable	Description	Source
CO2	CO2	WDI
ECG	Economic Growth	WDI
RNE	Renewable energy use	WDI
URB	Urbanization	WDI
IND	Industrialization	WDI
TR	International Tourism	WDI
AVA	Agricultural productivity	WDI
FA	Forest area	WDI

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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ESTIMATION

Prior to estimating the econometric model, descriptive statistics were calculated for all variables included in the analysis. These statistics are presented in the accompanying tables.

Summary statistics

Asia Region

The findings of the summary process among variables, as well as the outcomes of many normality test (Skewness, Kurtosis, Jarque-Bara, and Probability) are shown in Table 2(a). The findings are based on the data from 1990 to 2020, for 40 Asian countries.

Table 2(a): Summary statistics for Asian Region

	CO 2	AVA	ECG	FA	IND	TR	RNE
Mean	4.746631	13.68888	4.971125	27.26181	52.48027	8905468.	25.39034
Median	3.272331	10.70558	5.473837	22.96968	52.52900	2464000.	13.55000
Maximum	22.77502	57.23865	34.85710	76.85009	100.0000	1.63E+08	93.46000
Minimum	0.098650	0.030137	-32.90883	0.008078	10.88300	700.0000	0.010000
Std. Dev.	4.878796	11.33377	5.286356	23.57824	23.82275	21303286	27.74937
Skewness	1.497674	1.336215	-1.057881	0.643995	0.199753	4.857520	0.893213
Kurtosis	4.851327	4.817753	14.71007	2.130820	1.937678	28.49203	2.563162
Jarque-Bera	397.3014	334.7107	4537.167	77.36108	41.27392	23846.23	108.3695
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	3650.159	10526.75	3822.795	20964.33	40357.33	6.85E+09	19525.17
Observations	769	769	769	769	769	769	769

The summary statistics for the Asian region reveal significant variations in CO_2 emissions and its key determinants. The mean CO_2 emissions stand at 4.75, while the median is 3.27, indicating a right-skewed distribution with some countries exhibiting exceptionally high emissions. Economic growth (ECG) has a mean of 4.97, but its minimum value of -32.91 suggests that certain countries have experienced severe economic downturns. Renewable energy use (RNE) shows considerable variation, with a mean of 25.39 and a median of 13.55, highlighting disparities in clean energy adoption across the region. Similarly, international tourism (TR) exhibits a highly skewed distribution, with a maximum of 163 million and a median of 2.46 million, suggesting that only a few countries dominate the tourism sector.

The dispersion measures further indicate substantial heterogeneity across the dataset. Agricultural productivity (AVA) ranges from 0.03 to 57.24, while industrialization (IND) varies between 10.88 and 100.00, reflecting economic structural differences among Asian economies. The skewness and kurtosis values confirm that most variables deviate significantly from normality, with CO_2 emissions, AVA, and TR showing particularly heavy-tailed distributions. The Jarque-Bera test results (p-value = 0.000 for all variables) reject the normality assumption, suggesting the presence of outliers and potential heteroskedasticity.

European Region

The findings of the summary statistics of the chosen variables from 40 European countries are provided in Table 2(b).

The summary statistics for the European region indicate notable variations in CO_2 emissions and its key determinants. The mean CO_2 emissions are 7.26, while the median is 6.47, suggesting a right-skewed distribution with some countries exhibiting significantly higher emissions. Economic growth has a mean of 2.55, but its minimum value of -15.31 and maximum of 88.96 highlight substantial differences in economic performance across countries. Renewable energy use shows extreme variation, with a mean of approximately 17.99 million, a median of 5.50 million, and a maximum exceeding 218 million, indicating that a few countries dominate renewable energy

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE
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adoption. International tourism appears relatively balanced, with a mean and median around 24 million, though some countries report very low or no international arrivals.

Summary statistics for European Region: Table 2(b)

	CO 2	AVA	ECG	FA	IND	TR	RNE
Mean	7.262254	4.720029	2.545566	31.13586	71.07771	24.26306	17992082
Median	6.474476	2.967923	2.686412	30.85577	71.35100	24.27245	5499000
Maximum	25.61044	36.41086	88.95767	73.73565	98.07900	51.27493	2.18E+08
Minimum	0.469831	0.199093	-15.30689	0.246643	39.47300	0.000000	0.000000
Std. Dev.	3.671465	4.976077	5.039098	17.12560	13.74865	6.132897	33648623
Skewness	1.562421	2.331780	2.331780	0.604766	0.201532	0.069195	3.510777
Kurtosis	6.719914	9.611836	104.2163	3.256832	2.444150	4.346441	17.31351
Jarque-Bera	852.6367	2364.929	374706.4	55.23267	17.03041	66.18296	9182.212
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	6296.374	4092.265	2207.006	26994.79	61624.38	21036.07	1.56E+10
Observations	867	867	867	867	867	867	867

The dispersion measures further confirm economic and environmental heterogeneity across European nations. Agricultural productivity ranges from 0.19 to 36.41, while industrialization varies between 39.47 and 98.08, reflecting differences in economic structure. The skewness and kurtosis values indicate non-normal distributions, with particularly high kurtosis for economic growth and renewable energy use, suggesting the presence of extreme outliers. The Jarque-Bera test results (p-value = 0.000 for all variables) reject the normality assumption, reinforcing the need for appropriate econometric techniques such as logarithmic transformations or robust estimators to account for distributional issues and improve model reliability.

FMOLS Results and Discussion

This section presents the estimation results of Equation 1 provided earlier. Before estimating the model, the stationarity of the variables was tested, revealing that most variables were stationary at level. Some non-stationary variables were first differenced to ensure stationarity before applying the FMOLS method.

The following tables provide the final estimation results for the two regions.

Table 3(a). Asian Region

Variable	Coefficient	Std. Error	t-Statistic	Prob
AVA	0.001945	0.020582	0.094515	0.03247
ECG	0.052979	0.016229	-3.264431	0.012
FA	-0.051708	0.038143	1.355643	0.0158
URB	0.036865	0.011331	3.253560	0.012
IND	3.91E-08	7.97E-09	4.913019	0.0000
TR	0.023595	0.013757	-1.715166	0.0000
RNE	-0.041419	0.018754	2.208586	0.0276

The FMOLS estimation results for 40 Asian countries provide valuable insights into the long-run relationship between CO_2 emissions and its key determinants. Agricultural productivity has a positive but weak effect on CO_2 emissions, with a coefficient of 0.0019, suggesting that while agricultural activities contribute to emissions, their overall impact remains marginal. However, with a coefficient of -0.0529, economic growth and CO2 emissions

have a substantial negative connection. This suggests that lower emissions are linked to higher economic growth. As economies grow, there may be a structural shift toward greener technology and more energy efficiency.
Forest area negatively affects CO_2 emissions, with a coefficient of -0.0517, indicating that increasing forest coverage plays a crucial role in reducing carbon emissions through carbon sequestration. Urbanization, has a positive and significant impact, with a coefficient of 0.0369, suggesting that rapid urban expansion contributes to higher energy consumption and pollution levels. Industrialization is a major driver of CO_2 emissions, with a highly significant coefficient of 3.91E-08. This highlights the environmental costs associated with manufacturing and production activities.
International tourism shows a negative and highly significant relationship with CO_2 emissions. The results show a coefficient of -0.0236, which may suggest that tourism-led economies implement better environmental policies or energy-efficient practices. Renewable energy use is also negatively related with CO_2 emissions. The result indicates that with a coefficient of -0.0414, greater reliance on clean energy sources helps lessen environmental degradation. Overall, these findings stress the need for sustainable industrial policies. Moreover, efficient urban planning, and increased investment in renewable energy is needed to balance economic growth with environmental sustainability in Asia.

Table 3(b): European Region

Variable	Coefficient	Std. Error	t-Statistic	Prob
AVA	-0.275677	0.063535	-4.338959	0.0000
ECG	0.070239	0.050008	1.404563	0.01605
FA	-0.008551	0.014862	0.575387	0.05652
URB	0.080725	0.022191	3.637812	0.0003
IND	0.066222	0.042226	1.568299	0.01172
TR	0.006643	7.64E-09	-2.096572	0.0363
RNE	-0.15632	4.16E-07	0.333325	0.0390

The FMOLS estimation results for the European region provide insights into the long-run relationship between CO_2 emissions and its key determinants. Agricultural productivity has a significant negative impact on CO_2 emissions, with a coefficient of -0.2757, indicating that improvements in agricultural efficiency contribute to reducing emissions, possibly due to the adoption of modern, sustainable farming techniques. Economic growth, however, shows a positive relationship with CO_2 emissions, with a coefficient of 0.0702, suggesting that as economies expand, higher energy consumption and industrial activities lead to increased emissions.
Forest area has a negative but statistically insignificant effect on CO_2 emissions, with a coefficient of -0.0086, suggesting that while forest expansion may help reduce emissions, its impact in Europe is relatively weak. Urbanization exhibits a strong positive relationship with CO_2 emissions, with a coefficient of 0.0807, implying that rising urban populations drive higher energy demand, transportation use, and industrial activities, contributing to pollution. Industrialization also positively affects CO_2 emissions, with a coefficient of 0.0662, reinforcing the idea that manufacturing and production activities significantly contribute to environmental degradation.
International tourism is found to have a slight negative effect on CO_2 emissions, with a coefficient of -0.0066, suggesting that tourism-led economies may implement energy-efficient infrastructure and sustainable tourism policies. Renewable energy use has a negative relationship with CO_2 emissions, with a coefficient of -0.1563, indicating that increasing reliance on renewable energy significantly reduces emissions. These findings highlight the importance of promoting clean energy sources. It also indicates how important it is to adopt green urbanization strategies, and implement sustainable industrial policies to mitigate environmental damage while ensuring economic growth in Europe.

CONCLUSIONS

This research explores the effects of economic growth, the use of renewable energies, urbanization, industrialization, tourism, agriculture, and forest area on carbon emissions in Europe and Asia. The FMOLS estimation results for Asia and Europe reveal both similarities and differences in the determinants of CO_2 emissions.

In both regions, urbanization and industrialization positively contribute to emissions, highlighting the environmental costs of expanding cities and manufacturing activities. However, the magnitude of the impact is higher in Europe (0.0807 for urbanization and 0.0662 for industrialization) compared to Asia (0.0369 and 3.91E-08, respectively), suggesting that these factors play a more significant role in driving emissions in Europe. A key difference is observed in the relationship between economic growth and CO_2 emissions. In Asia, economic growth has a negative effect (-0.0529), implying that expanding economies are adopting cleaner technologies and energy efficiency measures. In contrast, economic growth in Europe has a positive impact (0.0702), indicating that industrial and energy-intensive activities still dominate economic expansion. Similarly, agricultural productivity negatively affects emissions in Europe (-0.2757) but has a negligible positive effect in Asia (0.0019), suggesting that European agricultural advancements contribute to emission reductions more effectively. Forest area has a negative impact in both regions, though it is more significant in Asia (-0.0517) than in Europe (-0.0086), reflecting stronger carbon sequestration effects in Asian forests. Renewable energy use reduces emissions in both regions, with a larger impact in Europe (-0.1563) compared to Asia (-0.0414), highlighting Europe's greater reliance on clean energy. Lastly, international tourism has a stronger negative impact on emissions in Asia (-0.0236) compared to Europe (-0.0066), suggesting that tourism-related policies and infrastructure improvements in Asia may be more effective in reducing environmental harm. Overall, while both regions face emissions challenges due to urbanization and industrialization, Asia appears to be transitioning toward cleaner economic growth, whereas Europe benefits more from renewable energy adoption and agricultural efficiency in reducing emissions.

Our study’s findings suggest that policymakers in both Asia and Europe should focus on promoting sustainable urbanization and industrial practices. This will mitigate the environmental impact of rapid economic and population growth. In Asia, efforts should be made to enhance renewable energy adoption, strengthening reforestation programs, and ensuring that economic growth is associated with low-carbon development. In Europe, policies should be designed which emphasize on accelerating the transition to clean energy sources, improving industrial efficiency to reduce emissions. Both regions can benefit from green urban planning, investment in low-carbon technologies, and policies. This encourage sustainable tourism and transport systems to achieve long-term environmental sustainability.

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ISSN E: 3006-1466
ISSN P: 3006-1458
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