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Renewable Energy and CO_2 Emissions in Upper-Middle Income Transition Countries

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ABSTRACT

The aim of this study is to examine the relationship between renewable energy consumption and CO_2 emissions in a sample of 12 upper middle income transitioning countries using data from 1995 to 2022. This study relies on a number of panel data estimation methods such as OLS, fixed effects regression and cointegration techniques. Across all estimations with find that renewable energy decreases CO_2 emissions even after controlling for economic growth and trade openness. In addition, the results from Dumitrescu and Hurlin (2012) suggest that there is unidirectional causality from renewable energy to CO_2 emissions in our sample. This study offer a number of policy implications and avenues for future research.

Keywords: Renewable Energy, CO_2 Emissions, Transition Countries, Panel Data
JEL Classifications: Q2

1. INTRODUCTION

Global energy consumption is expected to rise by over 50% by 2050, with emerging and developing economies projected to account for 85% of the additional demand growth over the next 3 years[1]. Consequently, ensuring energy security is crucial for sustaining long-term economic growth. Simultaneously, there is an urgent need to reduce global carbon dioxide emissions (CO_2e) to "net zero" in order to limit global warming to 1.5°C above pre-industrial levels (IEA, 2021). According to the World Health Organization, climate change is projected to result in approximately 250,000 additional deaths annually between 2030 and 2050 due to malnutrition, malaria, diarrhea, and heat stress. Furthermore, by 2030, the direct health-related costs of climate change are estimated to range between US$2 billion and US$4 billion per year[2]. Moreover, transitioning away from fossil fuels could prevent the 1.2 million annual deaths attributed to exposure to fossil fuel-related ambient particulate matter, while also reducing the global health costs associated with air pollution, which are estimated at US$8.1 trillion per year, equivalent to 6.1% of global GDP[3]. Today, renewable energy has become the most affordable source of power in most regions worldwide. The costs of renewable technologies are declining rapidly, with the price of electricity from solar energy dropping by 85% over the past decade. Similarly, the costs of onshore and offshore wind energy decreased by 56% and 48%, respectively[4].

In this vein, development of the renewable energy sector has been widely acknowledged by international organizations, as there is ample empirical evidence that renewable energy mitigates CO_2 emissions and promotes economic growth (Madaleno and Nogueira, 2023). According to the World Bank, renewable electricity production has been increasing over the past two

1 https://www.iea.org/news/growth-in-global-electricity-demand-is-set-to-accelerate-in-the-coming-years-as-power-hungry-sectors-expand
2 https://www.un.org/en/climatechange/science/climate-issues/health
3 https://www.un.org/en/climatechange/science/climate-issues/health
4 https://www.un.org/en/climatechange/raising-ambition/renewable-energy

decades reaching 28% in 2021. At the same time, renewable energy production has not been even across regions, for example, 28% in middle income, 27% in high income, 20% in South Asia and 4% in Middle East and North Africa[5]. This disparity underscores significant untapped opportunities for expanding the use of renewable energy, emphasizing the need for further evaluation and promotion of its benefits. Empirical research examines various potential implications of renewable energy consumption such as reduction in income inequality (Topcu and Tugcu, 2020), human development progress (Kaewnern et al., 2023), poverty alleviation (Zhao et al., 2022), reduction in migration (Melkior et al., 2018) and life satisfaction (Omri et al., 2022).

The primary objective of this study is to examine the impact of renewable energy (RE) consumption on CO_2 emissions across 12 upper-middle-income transition economies over the period 1995-2022. To account for the panel data structure of our sample, we employ several estimation techniques, including cointegration analysis and fixed effects regression models. This paper makes several important contributions to the existing literature. First, unlike previous studies that primarily focus on specific geographic regions (Apergis and Payne, 2014; Dong et al., 2018; Irmatova et al., 2025), our analysis covers countries undergoing significant economic transitions, including structural shifts in GDP composition. Notably, the average annual growth rate of urbanization-driven GDP in our sample is 4.2%, exceeding the global average of 3.4%. Second, we further investigate whether other economic variables moderate the relationship between renewable energy consumption and CO_2 emissions. Third, by focusing specifically on upper-middle-income countries in transition, our study sheds light on how renewable energy policies can be tailored to economies at a critical stage of industrialization and urbanization. This focus helps fill an important gap in the literature, as upper-middle-income countries are often underrepresented in cross-country renewable energy and emissions research despite their growing role in global energy demand and carbon output.

Renewable energy can reduce CO_2 emissions and promote economic growth in upper middle income countries through several related channels. By replacing fossil fuels with cleaner energy sources such as solar, wind, hydro, and geothermal power, countries can significantly lower their carbon emissions (Ozturk and Acaravci, 2010; Ozturk and Yuksel, 2016), as these sources produce little to no direct emissions during operation. Moreover, the shift to renewable energy can stimulate economic growth by creating new jobs in the renewable energy sector, including in research, manufacturing, installation, and maintenance. For example, Bulavskaya and Reynes (2018) shows "that transition to renewable energy may have a positive impact on the Dutch economy, creating almost 50 000 new jobs by 2030 and adding almost 1% of gross domestic product" (P. 528). In a different study, Elfani (2011) reports that renewable energy sector development can create up to 190,000 jobs in Indonesia in the long run. It can also enhance energy security by reducing reliance on imported fossil fuels, which can be costly and subject to volatile global markets. Additionally, the development of renewable energy infrastructure can spur innovation and foster new industries, driving long-term economic development. In upper-middle-income transition countries, investing in renewable energy not only contributes to mitigating climate change but also opens up opportunities for sustainable economic growth, job creation, and increased competitiveness in the global green economy.

The rest of the paper is structured as follows: Section 2 reviews related empirical literature with the focus on UMIT countries. Section 3 discusses data and Section 4 presents main results. Section 5 concludes the study and offers policy implications.

2. REVIEW OF RELATED LITERATURE

Extensive research has been conducted on the link between renewable energy consumption or production and CO_2 emissions (Dong et al., 2018; Bilgili et al., 2016). The majority of studies, departing from the Environmental Kuznets Curve framework, have concentrated on the potential for successfully replacing fossil fuels with renewable energy sources to lower CO_2 emissions, as economic growth alone cannot explain CO_2 emissions. The effect of renewable energy on CO_2 emissions was examined for various regions, for example, G20 (Jamil et al., 2022), BRICS (Sebri and Ben Salha, 2014), OECD (Chiu and Chang, 2009), Belt and Road countries (Wang et al., 2021), Central America (Apergis and Payne, 2014), among others. Apart from that renewable energy-emissions nexus was examined in the context of specific criteria for grouping countries such as rapidly urbanizing (Kuldasheva and Salahodjaev, 2023), tourism dependent (Kuldasheva et al., 2023), major energy consuming (Saidi and Omri, 2020) or top renewable energy consuming countries (Dogan and Seker, 2016).

One of the earlier studies examined the relationship between renewable energy and CO_2 emissions in Turkey, in the context of the EKC framework. For example, Bölük and Mert (2015) confirm the existence of EKC type relationships in Turkey over the period 1961-2010, using ARDL estimator. The study shows that renewable energy has a negative effect on environmental degradation in 1 year. A number of other studies also examine the relationship between renewable energy and CO_2 emissions for Turkey and the results are mixed. For example, Bulut (2017) explores the effect of renewable and non-renewable use on CO_2 emissions in Turkey over the period 1970-2013, using fixed parameter and time-varying parameter estimation. In contrast to previous studies, this research shows that both renewable and non-renewable energy use has a positive link with CO_2 emissions. At the same time, the authors find that generating electricity from renewable sources results in lower CO_2 emissions compared to producing electricity from non-renewable sources. Pata (2018) investigates the relationship between GDP per capita, renewable energy, financial development and CO_2 emission in Turkey during 1974-2014. The empirical tests confirm cointegration among variables and existence of long-run relationships. The regression estimates show that GDP per capita, financial development and urbanization increase CO_2 emissions. In turn, renewable energy consumption has no statistically significant impact on environmental degradation in Turkey. Yurtkuran (2021)

5 https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS?most_recent_value_desc=true

examined the role of renewable energy on reducing CO_2 emission in Turkey in the context of agriculture, globalization and CO_2 emissions nexus. The study was based on the data spanning from 1970 to 2017 and relied on a set of time-series econometric methods such as ARDL, FMOLS and DOLS. The results show that the variables are cointegrated and in the long-run renewable energy leads to an increase in CO_2 emissions. In a more recent study Karaaslan and Çamkaya (2022) examined the long- and short-term effects of macroeconomic variables on CO_2 emissions in Turkey over the period 1980-2012. Using ARDL estimator the study finds that health expenditure and renewable energy consumption decreases CO_2 emissions, while GDP per capita is positively linked to environmental degradation. The causality tests revealed that there is unidirectional causality running from GDP, renewable energy and health expenditure to CO_2 emissions. Raihan and Tuspekova (2022), used DOLS to assess the dynamic effects of economic growth, renewable energy, tourism and CO_2 emissions in Turkey over the years 1990-2020. The study finds that economic growth, urbanization and tourism lead to a rise in CO_2 emission. On the other hand, 1% increase in renewable energy consumption leads to 0.43% decrease in per capita CO_2 emissions. The study concludes that Turkey could take steps to reduce the cost of renewable energy while limiting fossil fuel use in industries, businesses, and households.

Renewable energy-emissions nexus was also examined by scholars using data from Thailand and Malaysia. Abbasi et al. (2021) examine CO_2 emissions trends in the context of 2030 emissions reduction targets of Paris Agreements. The study, using ARDL estimators over the period 1980-2018, finds that renewable energy reduces CO_2 emissions in the short-run. Moreover, energy depletion and GDP have a positive effect on environmental degradation in the short- and long-run. Similarly, Raihan et al. (2023) rely on ARDL to model CO_2 emissions drivers in Thailand over the period 1990-2020. The estimates derived from FMOLS estimator show that economic growth, urbanization, industrialization and tourism increase CO_2 emissions, while renewable energy consumption and re-forestation leads to a decline in greenhouse gas emissions. Xuan et al. (2024), using data for Thailand over the years 2000-2022 examines the effect of population, FDI and renewable energy on CO_2 emissions. The VECM results suggest that population growth increases CO_2 emissions, and renewable energy leads to a decrease in CO_2 emissions.

Raihan (2024), Suki et al. (2022) and Aeknarajindawat et al. (2020) all document that renewable energy use is negatively and significantly related to CO_2 emissions in Malaysia, using different time periods. Apergis et al. (2023) evaluated the relationship between use of renewable and fossil fuel energy and CO_2 emissions in Uzbekistan for the years 1985-2020. Using ARDL estimator the authors show that in the short- and long-run renewable energy consumption leads to a decrease in CO_2 emissions. In contrast fossil fuel energy consumption is associated with an increase in greenhouse gas emissions.

Parmova et al. (2024) examine the effect of renewable energy and FDI on CO_2 emissions in a sample of 45 nations in Europe and Central Asia over the period 2000-2019. Using a two-step system GMM estimator the study finds that renewable energy decreases CO_2 emissions. Moreover, the study confirms the EKC framework with a turning point of 59,000 international dollars. These results carry important policy implications for regional governments and international organizations aiming to promote sustainable development across Europe and Central Asia.

Ozcan and Ozturk (2019) examine the link between renewable energy consumption and economic growth across 17 emerging economies from 1990 to 2016. Using a bootstrap panel causality test that accounts for cross-country dependencies and heterogeneity, the findings reveal that the neutrality hypothesis holds for all countries in the sample, except for Poland, which supports the growth hypothesis. Specifically, since no causality was found running from renewable energy consumption to economic growth, energy-saving (mitigation) policies are unlikely to negatively affect the growth rates of the 16 emerging countries.

3. DATA AND METHODOLOGY

This study focuses on the 12 selected countries that are on the path of economic transition towards entering the list of Upper Middle-Income countries. The sample includes Uzbekistan, Kazakhstan, Vietnam, Egypt, Morocco, Philippines, Sri Lanka, Indonesia, Turkey, Thailand, Malaysia, and Bulgaria. These countries were selected based on a combination of economic classification, growth potential, and regional representation. These countries are presently undergoing structural transformation. A number of developing middle income countries were included in the sample as they currently face turbulence in economic growth, rely heavily on oil and gas exports, which makes their transition to high-income less predictable or struggle with economic crises, inflation, or stagnation.

The data for this study is obtained from the World Bank. The main dependent variable is CO_2 emissions metric tons per capita. Overall CO_2 emissions range from 0.32 to 15.34. The average level of emissions in UMIT countries is 3.63 (Table 1). In order to account for the role of economic development we include GDP per capita adjusted for purchasing power parity (PPP) from the World Bank. In this study we do not take into consideration the EKC framework as countries in our sample are within the same narrow income bracket. The trends in economic growth rates in our sample are reported in Figure 1. We logged CO_2 per capita and GDP per

Figure 1: GDP per capita change relative to 1995, %

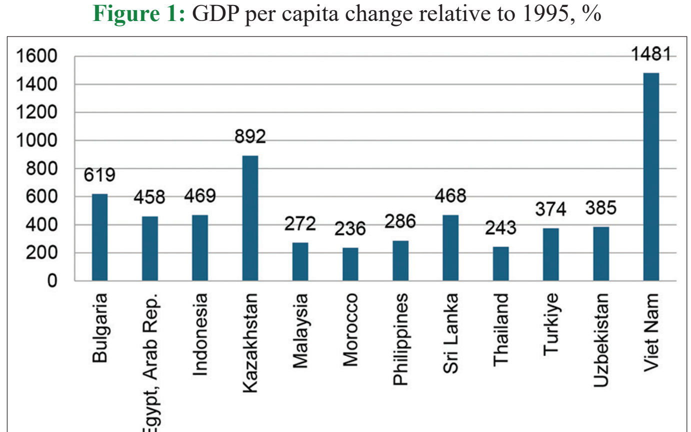

Table 1: Summary statistics

Variable	Description	Mean	Standard deviation	Min	Max
CO_2	CO_2 emissions per capita	3.63	3.08	0.32	15.34
GDP	GDP per capita	3928.31	3268.38	281.13	13974.45
RE	Renewable energy use, %	20.59	18.33	0.72	69.94
TRADE	Trade as % of GDP	84.70	41.55	29.19	220.41
POP	Population growth, %	1.14	0.96	−6.19	2.82

capita to account for skewed distribution of the data. Renewable energy is measured as the share of renewable energy from total energy consumption. Following related research, we control for the level of trade openness (Farhani et al., 2014; Akin, 2014) measured by international trade as % of GDP. International trade openness can lead to increased CO_2 emissions by stimulating industrial production, transportation, and energy use associated with the movement of goods across borders. However, it can also reduce emissions if it facilitates the diffusion of cleaner technologies and environmental standards through global integration. Finally, to account for demographic transitions we include population growth rate (%). Population growth can reduce CO_2 emissions if it is accompanied by greater investment in sustainable infrastructure, compact urban planning, and widespread adoption of low-carbon technologies. Additionally, in some contexts, a younger population may lead to lower per capita energy consumption compared to aging, high-consuming populations.

Taking into consideration the discussion above, the link between renewable energy and CO_2 emissions is examined using the following empirical framework:

$$CO_2 = f(RE, GDP, TRADE, POP) \quad (1)$$

Eq. (1) can be expressed in linear form as:

$$CO_2 = a_0 + a_1 * RE + a_2 * GDP + a_3 * TRADE + a_4 * POP + \varepsilon \quad (2)$$

Where CO_2 stands for CO_2 emissions, RE is renewable energy consumption, GDP represents GDP per capita, TRADE is trade openness, POP is population growth, e is an error term, respectively.

In line with Yuan et al. (2008), we utilize Pedroni's (1999) panel cointegration tests, the panel dynamic OLS (DOLS) estimation method, and the panel Granger causality test proposed by Dumitrescu and Hurlin (2012). Prior to conducting the panel DOLS estimation and causality analysis, we present the correlation matrix and unit root test results (Tables 2 and 3). According to Table 2 renewable energy and population growth are negatively correlated with CO_2 emission, while GDP and trade are positively linked to air pollution. Correlation across variables in Table 2 suggests that multicollinearity is not a problem for our study.

In line with related research on CO_2 emissions and renewable energy consumption (Apergis and Payne, 2010, Inglesi-Lotz, 2016), we rely on panel unit root test as suggested by Im et al. (2003). The empirical form of the unit root test can be specified as:

$$y_{i,t} = \rho_{i,t}\, y_{i(t-1)} + \sigma_t x_{i,t} + \varepsilon_{i,t} \quad (3)$$

Table 2: Correlation matrix

	CO_2	GDP	RE	TRADE	POP
CO_2	1.00				
GDP	0.60	1.00			
RE	−0.81	−0.44	1.00		
TRADE	0.27	0.19	−0.05	1.00	
POP	−0.27	−0.09	−0.04	−0.07	1.00

Table 3: Im-Pesaran-Shin unit-root test

Variables	Z-t-tilde-bar	Z-t-tilde-bar
	Level	First difference
CO_2 emissions per capita, log	0.5457	−8.9281***
GDP per capita, log	3.3939	−7.4823***
Renewable energy	0.0903	−8.8544***
Trade openness	0.8496	−8.1835***
Population growth	2.1796	−5.8157***

Source: Authors' computations; *** denote 1% significance

Table 4: Pedroni test for cointegration

Test type	Statistic	P-value
Modified Phillips-Perron t	1.2962	0.0975
Phillips-Perron t	−3.0453	0.0012
Augmented Dickey-Fuller t	−2.1966	0.0140

where x_{it} denotes the vector of independent variables; ρ_i represents the autoregressive elasticities, ε_{it} is the error term, i=1.,N is for nations and t=1...,T is yearly effects (Table 3).

4. RESULTS

We conduct Pedroni's (1999) cointegration test in Table 4. Modified Phillips-Perron t (1.2962, P = 0.0975). This statistic is not significant at the 5% level (P > 0.05) but is marginally significant at the 10% level. Suggesting, weak evidence of cointegration. Phillips-Perron t (−3.0453, P = 0.0012). This result is statistically significant at the 1% level (P < 0.01). Indicating strong evidence of cointegration based on this statistic. Augmented Dickey-Fuller (ADF) t (−2.1966, P = 0.0140). This result is statistically significant at the 5% level (P < 0.05). Indicating moderate to strong evidence of cointegration. Since at least two out of the three test statistics (Phillips-Perron and ADF t) are statistically significant at conventional levels (1% and 5%, respectively), there is robust evidence of cointegration among the panel variables. This suggests that a long-run equilibrium relationship exists.

Tables 5-7 report the findings of the panel cointegration regressions. Cointegration techniques, especially in panel data settings like Pedroni's test, allow researchers to detect long-run relationships across multiple cross-sectional units, offering more

Table 5: DOLS results

Variables	Coefficient	T-statistic
GDP per capita	0.15	10.85
Renewable energy	−0.06	−28.03
Trade openness	0.01	19.98
Population growth	−0.17	−3.51

Table 6: FMOLS

Variables	Coefficient	T-statistic
GDP per capita	0.16	26.99
Renewable energy	−0.05	−47.86
Trade openness	0.00	22.07
Population growth	−0.04	2.66

Table 7: CCR

Variables	Coefficient	T-statistic
GDP per capita	0.15	18.88
Renewable energy	−0.05	−37.16
Trade openness	0.00	15.53
Population growth	−0.03	−1.04

	OLS with year fixed effects		OLS with year and country fixed effects	
	Coefficient	T-stat		
GDP per capita	0.31	8.77	0.11	2.55
Renewable energy	−0.03	−27.78	−0.03	−15.46
Trade openness	0.00	9.39	0.00	3.72
Population growth	−0.25	−15.49	−0.03	−1.45
F-stat	78.76		602.54	
R-sq	0.84		0.98	

robust and generalizable results than time-series-based approaches like ARDL or VECM. Unlike ARDL, which is typically limited to small samples and individual country analysis, panel cointegration exploits both time-series and cross-sectional variation, enhancing statistical power. Our results show that renewable energy has a significant and negative effect on CO_2 emissions. The results of the DOLS, FMOLS, and CCR are robust. The negative effect of renewable energy on CO_2 emissions is in line with a number of recent studies (Salahodjaev and Sadikov, 2024; Kuldasheva et al., 2023). Moreover, we find that GDP per capita increases CO_2 emissions in the long run across all specifications (DOLS, FMOLS, CCR). Moreover, the results remain robust when use conventional OLS regression estimator with time and country fixed effects (Table 8).

After confirming the existence of a causal relationship, we determine its direction using the panel Granger non-causality test for heterogeneous panel data, as developed by Dumitrescu and Hurlin (2012). Table 9 presents the results of the Dumitrescu and Hurlin's panel Granger causality test results. We first test whether renewable energy does not Granger-cause CO_2 emissions. At the 1% significance level, we reject the null hypothesis. Moreover the P-value from Z-bar tilde suggests that there is unidirectional causality from renewable energy to CO_2 emissions in our sample.

Table 8: OLS regression with year and country fixed effects

Variables	OLS with year fixed effects		OLS with year and country fixed effects	
	Coefficient	T-statistic		
GDP per capita	0.31	8.77	0.11	2.55
Renewable energy	−0.03	−27.78	−0.03	−15.46
Trade openness	0	9.39	0	3.72
Population growth	−0.25	−15.49	−0.03	−1.45
F-statistic	78.76		602.54	
R-square		0.84		0.98

Table 9: Dumitrescu and Hurlin (2012) Granger non-causality test results

Statistics	P-values
Lag order: 1	
W-bar=2.0543	
Z-bar=2.5825	(P=0.0098)
Z-bar tilde=1.9674	(P=0.0491)

5. CONCLUSION

In conclusion, this study examines the relationship between renewable energy and CO_2 emissions across 12 upper middle income transition countries (Uzbekistan, Kazakhstan, Vietnam, Egypt, Morocco, Philippines, Sri Lanka, Indonesia, Turkey, Thailand, Malaysia, Bulgaria) over the period 2000-2020. The study makes a novel contribution to related research by focusing on a specific sample of countries that are the edge to make economic transition and structural transformation. Using various estimation methods such as cointegration, OLS and fixed effects the study robustly documents that renewable energy reduces CO_2 emissions. For example, 1% point increase in renewable energy consumption leads to nearly 6% decrease in per capita CO_2 emissions in the long run. Moreover, we find that GDP per capita and trade openness lead to a rise in CO_2 emissions. The findings suggest that as GDP per capita rises in upper-middle-income transition countries, increased economic activity leads to higher energy demand, which in turn raises CO_2 emissions. Additionally, greater trade openness often results in higher production and transportation activities, contributing to increased carbon emissions due to reliance on fossil fuels in trade-related sectors.

Our study offers a number of policy implications. Policymakers should actively promote investments in renewable energy infrastructure by offering incentives, subsidies, and creating a supportive regulatory framework. These measures can attract private sector investments, accelerating the shift towards clean energy. Additionally, governments should encourage foreign direct investment (FDI) in sectors focused on environmental sustainability. Supporting FDI in renewable energy projects and eco-friendly technologies presents a mutually beneficial opportunity, fostering economic growth while simultaneously reducing CO_2 emissions. Investment in research and development (R and D) of renewable energy technologies is also essential. Governments should allocate funding to research institutions and incentivize private innovation to improve the efficiency and affordability of renewable energy solutions (Parmova et al. (2024).

By adopting these policy measures, governments and international organizations can pave the way for a greener, more sustainable future in upper middle income countries, driving economic growth while safeguarding the environment for future generations.

Future studies can extend the results of this research in a number of ways. First, it is important to explore the effect of renewable energy sector development on other environmental indicators such as deforestation or vulnerability to climate change. Renewable energy may lower vulnerability to climate change by providing stable, low-emission energy sources that reduce greenhouse gas emissions and support climate-resilient infrastructure. In addition, due to the lack of longer time-series data, we were not able to examine the role of other variables in the renewable energy-emissions nexus. Therefore, prospective studies can extended UMIT sample by including other relevant countries and examine whether variables such as governance, human capital or innovation moderates the effect of renewable energy on CO_2 emissions (Salahodjaev and Sadikov, 2025; Nigmatullaeva et al., 2025). Finally, it is essential to examine the perceptions of renewable energy use in UMIT countries to understand which deep-rooted variables may explain variation in renewable energy deployment across countries.

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