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Renewable Energy, Private Sector Development, and CO_2 Emissions: Evidence from Early Demographic Dividend Countries

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ABSTRACT

The aim of this study is to examine the relationship between renewable energy and CO_2 emissions across 48 early demographic dividend countries over the period 2000-2020. The contribution of this study is many-fold. First, ours is the first study to assess the effect of RES on CO_2e while controlling for conventional predictors of environmental degradation. Second, we also examine the role of new business density on CO_2 emissions. Using various panel data estimation techniques such as Ordinary Least Squares (OLS), OLS with time fixed effects, Fixed Effects (FE) estimation, Panel-Corrected Standard Errors (PCSE), Generalized Least Squares (GLS), two-step system GMM estimator we find that renewable energy and private sector development mitigate CO_2 emissions. For instance, one standard deviation increase in renewable energy consumption is associated with 1.4% decrease in per capita CO_2 emissions. Governments should implement policies that encourage investment in renewable energy, such as tax incentives, subsidies, and public-private partnerships, to accelerate the decarbonization process. Second, promoting entrepreneurship and private sector growth through regulatory reforms and access to finance can contribute to environmental sustainability by fostering innovation in green technologies and resource-efficient business practices.

Keywords: Renewable Energy, Private Sector, CO_2 Emissions, Demographic Dividend, Climate Change
JEL Classification: O3

1. INTRODUCTION

Global carbon dioxide (CO_2) emissions have reached alarming levels, posing significant environmental and economic challenges. Global energy-related CO_2 emissions surged to an all-time high of 37.4 billion tonnes (Gt), with coal combustion contributing over 65% of the rise[1]. The Paris Agreement, adopted in 2015, set ambitious targets to limit global warming to well below 2°C above pre-industrial levels, urging nations to transition toward sustainable energy solutions. The social costs of CO_2 emissions are substantial, encompassing climate change-related natural disasters, declining agricultural yields, and adverse health effects due to air pollution (Liang et al., 2020; Apergis and Majeed, 2021). Studies estimate that air pollution caused by CO_2 and associated greenhouse gases contributes to approximately 8.7 million premature deaths annually, underscoring the urgent need for decarbonization policies.

Considering the negative effects of climate change, researchers have extensively explored various socio-economic predictors of

1 https://www.iea.org/reports/co2-emissions-in-2023/executive-summary

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CO_2 emissions across countries and regions (Ozturk et al., 2022; Salahuddin et al., 2016; Türkyılmaz and Öztürk, 2024; Ozturk et al., 2016; Aller et al., 2021; Iwata et al., 2012). Much of this research is rooted in the Environmental Kuznets Curve (EKC) theory, which posits an inverted U-shaped relationship between economic growth and environmental degradation. According to the EKC hypothesis, CO_2 emissions initially rise with economic development but eventually decline as countries reach higher income levels and adopt cleaner technologies and stringent environmental regulations. In recent years, numerous studies have tested a wide range of variables influencing CO_2 emissions, including urbanization, international trade, globalization, foreign direct investment (FDI), and information and communication technology (ICT) (Salahuddin et al., 2019; Shahbaz et al., 2013).

One particular strand of research on the determinants of CO_2 emissions focuses on the role of renewable energy sources in mitigating climate change. Renewable energy offers a sustainable alternative to fossil fuels, which remain the dominant energy source in many developing countries. Unlike coal, oil, and natural gas, which release large amounts of CO_2 and other pollutants, renewable energy sources produce little to no emissions, reducing air pollution and its associated health risks. For example, solar energy produces only 40-50 g CO_2 equivalent per kWh compared to 820 g CO_2 for coal and 490 g CO_2 for burning natural gas[2]. While the relationship between renewable energy and CO_2 emissions was extensively research across regions such as OECD (Chiu and Chang, 2009), MENA (Omri and Saidi, 2022), Central America (Apergis and Payne, 2014), Asia (Batool et al., 2022), Africa (Jebli and Youssef, 2017), BRICS (Sebri and Ben-Salha, 2014) and BRI countries (Wang et al., 2021). Moreover, renewable energy-emissions nexus was explored for particular samples of countries, for example, developing countries (Jie and Rabnawaz, 2024), major energy consuming countries (Huang et al., 2021), carbon intense countries (Mirziyoyeva and Salahodjaev, 2022), rapidly urbanizing countries (Kuldasheva and Salahodjaev, 2023), resource rent dependent countries (Szetela et al., 2022), tourism-oriented countries (Kuldasheva et al., 2023). However, no study has examined the relationship between renewable energy sources and CO_2 emissions among demographic dividend countries. This may be particularly important for a number of reasons. First, renewables enhance energy security by reducing dependence on imported fossil fuels, lowering long-term energy costs, and promoting job creation in the green economy. Moreover, demographic dividend countries are often characterized by rapid economic growth and increasing population, which in turn drives higher energy consumption in both industrial and residential sectors over the long term. This growing demand for energy makes it particularly important to foster the renewable energy sector to reduce environmental degradation without compromising economic progress. Encouraging investment in clean energy infrastructure can help these economies sustain their growth while mitigating the adverse effects of climate change.

The aim of this study is to examine the relationship between renewable energy and CO_2 emissions across 48 early demographic dividend countries over the period 2000-2020. The contribution of this study is many-fold. First, ours is the first study to assess the effect of RES on CO_2e while controlling for conventional predictors of environmental degradation. Second, we also examine the role of new business density on CO_2 emissions. In demographic dividend countries, the private sector is rapidly expanding, driven by government policies that stimulate entrepreneurship, investment, and industrialization. Many governments actively promote private sector development through regulatory reforms, financial incentives, and infrastructure investments to sustain economic growth and job creation. For example, in Uzbekistan new business registration has increased by nearly five-fold since 2006. Small business contributes more than 50% of GDP[3]. The "Uzbekistan - 2030" strategy approved by the President of the Republic of Uzbekistan, outlines a comprehensive plan to enhance private sector participation in the national economy, aiming to increase its share to 85%. Additionally, the policy framework emphasizes expanding opportunities for small and medium-sized enterprises (SMEs) in international markets, improving access to microfinance, and promoting innovation and start-up development. In this vein, the development of the private sector can also play a crucial role in reducing CO_2 emissions. Empirical research suggests that businesses, particularly in competitive markets, are incentivized to adopt energy-efficient technologies to reduce operational costs and enhance productivity (Talukdar and Meisner, 2001). Furthermore, increased private sector participation in renewable energy projects, such as solar and wind power generation, helps diversify energy sources and reduce dependence on fossil fuels. As firms invest in sustainable business models and green innovations, they contribute to lowering emissions while maintaining economic growth, making private sector engagement a key component of climate change mitigation strategies. Third, we use a number of panel data estimation methods to examine relationships between renewable energy and CO_2 emissions while accounting for endogeneity, heteroskedasticity and auto-correlation across panels.

The rest of the study is structured as follows. Section 2 provides a review of related literature on CO_2 emissions. Section 3 presents data and methodology, while Section 4 discusses main results. Section 5 concludes the study and offers policy implications.

2. LITERATURE REVIEW

Recently, a variety of researches have been held to decrease the level of CO_2 emissions and to increase the significance of renewable energy for each economic sector. For instance, Almulhim et al. (2025) explored the relationships between renewable energy usage, institutional quality, economic growth, and consumption-based CO_2 emissions in BRICS nations. This research contributes to the existing literature by investigating the dynamic links between institutional quality and CO_2 emissions using the innovative method of moments quantile regression (MMQR). Furthermore, Pata et al. (2025) examined the RKC and EKC hypotheses for the USA. To account for both abrupt and

2 https://world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity

3 https://www.uzdaily.uz/ru/kakaia-dolia-malogo-predprinimatelstva-biznesa-v-vvp-vrp/

gradual breaks, the study used the Fourier approximation in time series analyses. The findings illustrated that the turning point of the RKC model occurred before the turning point of the EKC model and that both the RKC and EKC hypotheses are valid for the USA.

Shabani (2024) investigated the impact of RE on CO_2 emissions by analyzing data from 67 countries, which were divided into developed and developing countries, over the period from 1999 to 2019. Furthermore, it was observed that population density had an effect on CO_2 emissions in the entire sample and in developing countries.

Zoungrana et al. (2025) analyzed, via transmission channels, the effects of energy efficiency and renewable energy consumption on carbon dioxide (CO_2) emissions in sub-Saharan Africa (SSA) over the period 2002-2020. Notably, it is necessary to promote the implementation of green technologies that reduce energy consumption and improve energy efficiency by facilitating access to the internet for 25 sub-Saharan African countries.

Renewable energy and CO_2 emissions have also been shown to play a dual role in environmental sustainability. Bennaceur et al. (2025) examined the impact of renewable energy consumption (REC), information and communication technology (ICT), and gross domestic product (GDP) on CO_2 emissions in Saudi Arabia over the period 1990-2020. The findings emphasize the importance of expanding renewable energy infrastructure and fostering sustainable technological innovation to mitigate emissions while sustaining economic growth in Saudi Arabia.

Saribayevich et al. (2024) explored the influence of various factors on CO_2 emissions in Uzbekistan during the period 1992-2020. The research provides a comprehensive analysis of factors affecting CO_2 emissions in Uzbekistan and highlights the multifaceted nature of impacts, ranging from the positive effects of increased forest cover to the challenges associated with rapid urbanization and industrial growth. Sustainable urbanization practices, together with the transition to renewable energy sources, are emerging as important strategies to limit CO_2 emissions. Akbulaev (2023) examined the correlation between the use of renewable energy sources, FDI, CO_2 emissions from energy sources, and GDP growth in France, Germany, and Italy from 1971 to 2021.

Borsha et al. (2024) investigated the importance of renewable energy and CO_2 emissions on GDP growth of the country. The research explores the presence of the Environmental Kuznets Curve (EKC) in Bangladesh, delving into the intricate relationships among GDP, industrialization, renewable energy utilization, and CO_2 emissions. Utilizing the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model, the investigation spans the years 1992-2021.

Khezri and Mamkhezri (2024) investigated the spillover effects of research and development and renewable energy on CO_2 emissions. The lack of consensus on the impact of renewable energy (RE) and research and development (R&D) expenditure on CO_2 emissions made them deeply research this field. Their research has confirmed the presence of both the intensity and scale effects of R&D, with the intensity effect being the dominant one. The key overwhelming evidence is that global R&D investment led to an overall (direct plus spillover) reduction of CO_2 emissions, driven by its spillover effect, through two channels: RE and economic growth. Finally, this research found that RE installations assist with reducing CO_2 emissions internationally, though RE composition and state of R&D can lead to different findings.

Borgi et al. (2024) explored the effect of eco-innovation and renewable energy on carbon dioxide emissions (CDE) for G7 countries. They conducted analysis to examine whether Hofstede national culture dimensions moderate the nexus of "eco-innovation-carbon emission" and "renewable energy-carbon emission" for G7 countries. They explored the impact of renewable energy and eco-innovation on carbon dioxide emissions in G7 countries; for them, this field is an understudied and unique context. The research covers the 2000-2019 period. The key findings of this research can encourage policymakers and regulators to promote investment in environmental quality by spending on the development of energy-based technologies and ECI and to provide infrastructure and markets for RE to make them accessible to users.

If nations want to attain sustainable development with the exponential growth of information and communication technology (ICT) around the world, they must understand the connection between ICT and carbon emissions. You et al. (2024) used panel data from 64 Belt and Road Initiative economies between 2000 and 2021 while finding the impact of ICT, renewable energy consumption (REC), human capital (HC), and economic growth (EG) on CO_2 emissions has been analyzed. Key findings reveal that human capital is all cause-and-effect linkages that affect CO_2 emissions in both directions. In order to reduce energy utilization and boost economic growth, the findings stress the importance of implementing cutting-edge ICT and REC in the industrial sector.

Mirziyoyeva and Salahodjaev (2023) analyzed the GDP-energy-CO_2 emissions nexus for the top 50 highly globalized countries. They explored the multidimensional relationship between economic growth, renewable energy, globalization, and climate change, using CO_2 emissions as a proxy for air pollution and focusing on the most globalized countries. The results suggest that renewable energy significantly contributes to the reduction of carbon emissions while GDP per capita has an inverted U-shaped link with CO_2 emissions. Thus, they confirmed the presence of the EKC hypothesis for highly globalized countries.

Yesbolova et al. (2024) analyzed the importance of renewable energy to decrease the CO_2 emissions in central Asian countries. This study aims to analyze the impact of energy consumption and industrial production on CO_2 emissions in the Turkic Republics using the panel data method for the period 2000-2020. Findings revealed that as renewable energy consumption increases, CO_2 emissions decrease. But renewable energy resources are the kind of resources that need high financial support. But, to reduce CO_2 emissions and gain a better understanding of the impact of renewable energy consumption on CO_2 emissions, they support the idea of investing money in renewable energy resources.

Mendoza-Rivera et al. (2023) examined the impact of the consumption of non-renewable energies (gasoline and gas), as well as the consumption of renewable energies (solar and wind) and CO_2 emissions (one of the main pollutants), on economic growth (EG) in North America. A vector autoregressive model is estimated to analyze the relationships between the studied variables from 1966 to 2020. The study concluded that economic growth is influenced by renewable and non-renewable energy consumption, though the impact varies between developed and developing countries in North America. Additionally, reducing CO_2 emissions is crucial for ecological sustainability, with sustainable development depending on significant emission reductions, environmental awareness, and the affordability of renewable technologies.

Farooq et al. (2024) discussed non-renewable energy, green technological innovation, and CO_2 emissions in South Asia. Employing the Autoregressive Distributed Lag (ARDL) model and NARDL, the study examined data spanning from 1985 to 2021. The findings indicate that an increase in non-renewable energy consumption leads to higher CO_2 emissions across all five studied countries, while a decrease in non-renewable energy consumption helped reduce CO_2 emissions.

Ahmat et al. (2025) determined the level and the pattern of the relationship between dependent and independent variables investigating the CO_2 emissions in Malaysia. Also, this study examined the long-term and short-term impacts of energy consumption, economic growth, and non-renewable energy on CO_2 emissions in Malaysia. The study suggested that energy consumption, economic growth, and non-renewable energy positively impact CO_2 emissions. The results through dynamic ARDL indicate that energy consumption, economic growth, and non-renewable energy positively impact Malaysia's CO_2 emissions in the short run and long run.

These investigations reveal the significance of renewable energy to decrease the level of CO_2 emissions in the entire world. There are many types of renewable energy, but nowadays the importance of these resources in every single economic sector is increasing. But every single economic sector has its drawbacks, like CO_2 emissions. So, there is an inverse relationship between CO_2 emissions and renewable energy. If we want to increase the economy in the mean of sustainability, we should decrease the CO_2 emissions and increase the significance of the pure energies.

Apergis et al. (2023) utilized the ARDL approach to investigate how renewable and non-renewable energy consumption influenced CO_2 emissions in Uzbekistan over the period 1985-2020. The study found that hydropower effectively lowers pollution levels both in the short term and over the long run. Conversely, the use of oil and gas is linked to increased emissions, while coal shows inconsistent effects. Supporting evidence from Thailand, as presented by Abbasi et al. (2021), indicates that renewable energy reduces emissions by 0.37% in the short run, whereas non-renewable sources drive emission growth. The findings collectively suggest that fossil fuels continue to play a central role in shaping national economic and energy strategies.

3. DATA AND METHODOLOGY

3.1. Sample

The selection of countries is obtained from the World Bank classification of early demographic dividend countries. Thus, we rely on the sample which includes the following countries: Argentina, Bangladesh, Bahrain, Belize, Bhutan, Botswana, Cabo Verde, Djibouti, Dominican Republic, Algeria, Ecuador, Egypt, Ethiopia, Micronesia, Gabon, Ghana, Grenada, Guatemala, Honduras, Haiti, Indonesia, India, Iran, Israel, Jordan, Cambodia, Kiribati, Lao PDR, Libya, Lesotho, Maldives, Mexico, Myanmar, Namibia, Nicaragua, Nepal, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Paraguay, West Bank and Gaza, Rwanda, Saudi Arabia, Solomon Islands, El Salvador, Suriname, Eswatini, Syrian Arab Republic, Tajikistan, Turkmenistan, Tonga, Turkiye, Uzbekistan, Venezuela, Vanuatu, Samoa, Yemen and South Africa.

3.2. Dependent Variable

The dependent variable in this study is CO_2 emissions (metric tons per capita) from the World Bank. Figure 1 plots the dynamics of CO_2 emissions for selected regions, including EDD countries. According to the data, CO_2 emissions in EDD countries increased from Mt 2825 in 1990 to Mt 8390 in 2023. However, these figures are lower than in upper middle income countries and East Asia and Pacific, for example.

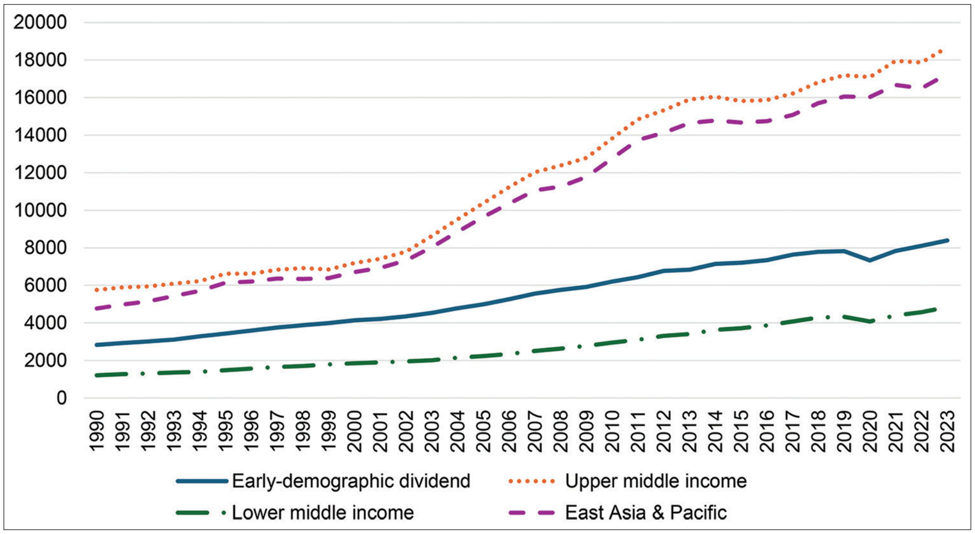
3.3. Independent Variables

In this study we use two main independent variables. First is renewable energy consumption (%) from the World Bank. Second is new business density (new registrations per 1,000 people ages 15-64) from the World Bank. Figure 2 plots top 10 countries by new business density per 1,000 adults. As it can be seen South Africa has the highest rate of new business density and countries such as Uzbekistan and Bahrain are also among top performing nations in the EDD sample. Figure 3 plots renewable energy consumption for the year 2020 across the regions. For example, renewable energy consumption in EDD is above that in EU member states or globally, while it is behind compared to lower middle-income countries.

3.4. Control Variables

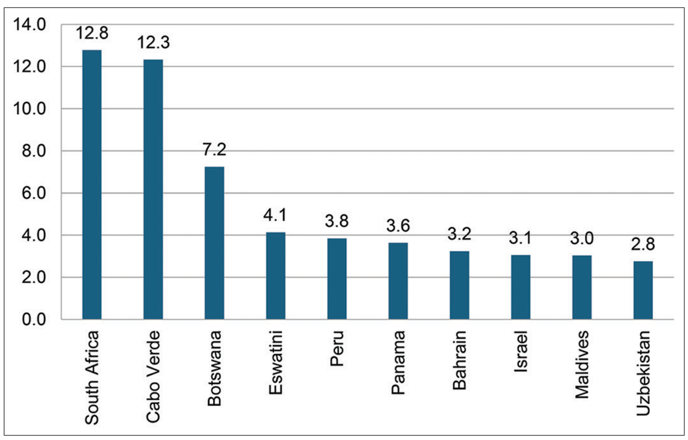
Following cross-country empirical studies, we include a set of variables to reduce omitted variable bias. First, we include GDP per capita from the World Bank as a catch all variable. Economic growth is a key driver of CO_2 emissions, as higher income levels are often associated with increased industrial activity, energy consumption, and transportation demand. Including GDP per capita allows us to control for the scale of economic development, which influences emission levels across countries. Considering that EDD countries have not reached high-income status, we expect a positive link between GDP per capita and CO_2 emissions. We also include urban population growth to account for demographic transition across countries. Rapid urbanization can lead to higher CO_2 emissions due to increased energy demand, transportation needs, and infrastructure expansion. By including urban population growth, we account for demographic shifts that influence a country's carbon footprint and energy consumption patterns. The data on urban population growth (%) is from the World Bank.

Figure 1: CO_2 emissions



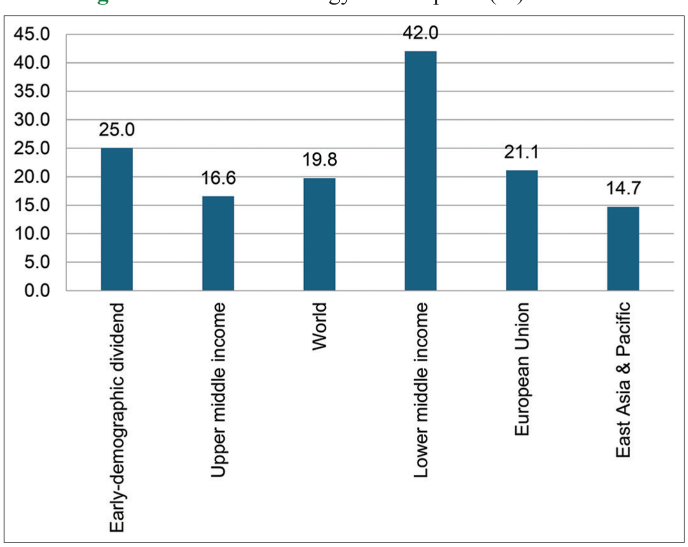
Source: World Bank

Figure 2: New registrations per 1,000 people ages 15-64 for 2020



Source: World Bank

Figure 3: Renewable energy consumption (%) for 2020



Source: World Bank

Finally, to account for the international dependencies we include trade openness which is measured by trade as % of GDP. The data comes from the World Bank. Greater trade integration can impact CO_2 emissions through both the scale effect (higher production and energy use) and the composition effect (shifts in industry structure due to trade specialization). Controlling for trade openness helps capture the environmental consequences of globalization and international trade dynamics.

3.5. Estimation Methods

To examine the relationship between renewable energy and CO_2 emissions for demographic dividend countries, we employ multiple econometric techniques to ensure robustness and address various econometric concerns. These methods include Ordinary Least Squares (OLS), OLS with time fixed effects, Fixed Effects (FE) estimation, Panel-Corrected Standard Errors (PCSE), and Generalized Least Squares (GLS). Each method offers unique advantages in addressing potential biases and improving the reliability of our results.

OLS provides an initial unbiased benchmark for comparison which is easy to interpret and useful for identifying general trends. To control for time-specific shocks that may influence CO_2 emissions across all countries, we extend the OLS model by including time fixed effects. However, these methods suffer from omitted variable bias if country-specific heterogeneity is not addressed. In order to account for time-invariant country-specific characteristics, we use a fixed effects (FE) estimator. FE controls for unobserved heterogeneity across countries, ensuring that estimates are not biased by omitted variables that do not change over time (e.g., geography, long-term institutional differences). However, it does not correct for heteroskedasticity or autocorrelation, which could affect standard errors. Given potential heteroskedasticity and cross-sectional dependence, we employ Panel-corrected standard errors (PCSE), which relaxes OLS assumptions and provides robust standard errors. Finally, we use GLS estimation to correct for potential heteroskedasticity and serial correlation in panel data. The descriptive statistics are reported in Table 1.

4. RESULTS

Baseline results are reported in Table 2. Column 1 presents the estimates from the OLS regression estimator. As expected renewable energy is negatively and significantly linked with CO_2 emissions. For example, one standard deviation increase in renewable energy consumption is associated with 1.4% decrease in per capita CO_2 emissions. Trade openness and GDP per capita have a positive relationship with CO_2 emissions. A positive link between trade openness and CO_2 emissions is also documented for Africa (Dauda et al., 2021) and top emitters (Ertugrul et al., 2016). Growth in urban population is not significant across models. New business density enters negative and significant across all specifications. This implies that CO_2 emissions decrease in countries where there is documented growth in the private sector. RE and NBG remain negative and significant after accounting for time fixed effects (column 2), cross sectional dependence (column 3) and autocorrelation (column 4). Thus, the results imply that renewable energy and new business density significantly correlated with reduction in greenhouse gas emissions.

Table 3 reports the findings from the two-step system GMM estimator. Again, GDP per capita and trade openness have a positive effect on CO_2 emissions: 1% increase in GDP per capita leads to 0.2% increase in CO_2 emissions per capita. Turning to renewable energy we document that renewable energy mitigates climate change: 1% point increase in renewable energy consumption leads to 1.2% decrease in CO_2 emissions. In a similar vein, new business density is an important determinant in reducing air pollution in EDD countries. For example, 10% increase in new business density leads to 0.6% in CO_2 emissions. In column 2, we check whether renewable energy influences the effect of the private sector on CO_2 emissions. We do so by including interaction terms between renewable energy and new business density. The interaction term is positive and significant, suggesting that these variables are substitutes in CO_2 emissions modeling. The positive interaction term between renewable energy and new business density can be explained by infrastructure limitations, fossil fuel dependency, or rebound effects. For example, greater renewable energy use might lower energy costs, encouraging businesses to increase overall energy consumption, some of which may still come from fossil fuels. AR(2) test results confirm that there is no second-order serial correlation, meaning that the moment conditions used in the GMM estimator are valid. Hansen P-value suggests that the instruments are neither overly weak (which would make them ineffective) nor invalid (which would introduce bias).

We tested the robustness of our main results in Table 4. We included a set of additional variables that are associated with CO_2 emissions and can potentially influence our main results. Empirical research demonstrates fintech's significant potential to mitigate CO_2 emissions through multiple mechanisms. Muganyi et al. (2021) reveal, using a semi-parametric difference-in-differences (SDID) model and city-level panel data (2011-2018), how China's fintech ecosystem enhanced green finance effectiveness, reducing industrial emissions through optimized environmental investments. Similarly, Wu's (2024) county-level analysis show significant carbon intensity reductions in Chinese regions with advanced Fintech adoption. Cross-border evidence from Tao et al. (2022) confirms these patterns across 65 nations using 2SLS and GMM estimations, examining the relationship between Fintech development, measured by a global Fintech index, and greenhouse gas (GHG) emissions. The Middle Eastern context examined by Ibrahim et al. (2024) further illustrates how digital financial innovations accelerate renewable energy deployment while improving energy efficiency, applying a panel regression framework (Fixed Effects and GMM estimators) on a dataset covering 2013-2023. Therefore, in column 1, following a large strand of empirical papers we added ICT development which is instrumental for fintech development proxied by Internet users as % of population from the World Bank (Wang et al., 2023; Işık et al., 2024). There are two competing arguments on the effects of the

Table 1: Descriptive statistics

Variable	Description	Mean	Standard deviation	Min	Max
CO_2	CO_2 emissions per capita, log	0.32	1.19	−2.94	3.14
GDP	GDP per capita, log	8.88	0.86	6.56	10.86
URB	Urban population growth (%)	2.50	1.46	−8.83	12.77
RE	Renewable energy consumption, %	33.71	28.14	0.00	95.55
TO	Trade as % of GDP	76.55	36.54	21.46	348.00
BUS	New business density per 1000 adults	1.71	2.77	0.01	23.01

Table 2: Baseline results

Variables	I	II	III	IV
CO_2, lag	0.942 (91.33)***	0.948 (93.69)***	0.942 (98.74)***	0.952 (146.58)***
GDP	0.047 (4.19)***	0.042 (3.78)***	0.047 (4.34)***	0.039 (5.44)***
URB	0.001 (0.36)	−0.001 (0.23)	0.001 (0.35)	0.002 (1.00)
RE	−0.001 (2.07)**	−0.000 (1.70)*	−0.001 (2.24)**	−0.001 (3.44)***
TO	0.000 (2.57)**	0.000 (2.50)**	0.000 (2.51)**	0.000 (3.24)***
BUS	−0.008 (2.28)**	−0.007 (2.04)**	−0.008 (2.16)**	−0.007 (3.11)***
Constant	−0.398 (3.97)***	−0.367 (3.65)***	−0.398 (4.08)***	−0.327 (5.19)***
R^2	0.99	0.99	0.99	
N	586	586	586	586
Method	OLS	OLS with year fixed effects	PCSE	GLS

*P<0.1; **P<0.05; ***P<0.01

Table 3: Two-step system GMM estimator results

Variables	I	II
CO_2, lag	0.621 (6.59)***	0.599 (8.35)***
GDP	0.223 (1.95)*	0.287 (2.87)***
URB	−0.010 (1.36)	−0.007 (1.67)
RE	−0.012 (5.18)***	−0.010 (4.97)***
TO	0.004 (5.69)***	0.004 (5.49)***
BUS	−0.061 (2.82)***	−0.129 (3.72)***
RE*BUS		0.001 (2.28)**
Constant	−1.669 (1.75)*	−2.301 (2.60)**
AR (1)	0.002	0.001
AR (2)	0.279	0.262
Hansen *P* value	0.319	0.211
N	586	586

*P<0.1; **P<0.05; ***P<0.01

Table 4: Robustness test: Additional controls

Variables	I	II	III
CO_2, lag	0.568 (8.11)***	0.530 (6.10)***	0.821 (12.58)***
GDP	0.301 (3.14)***	0.339 (3.40)***	0.093 (1.26)
URB	−0.006 (1.02)	−0.007 (1.43)	−0.010 (2.75)***
RE	−0.012 (7.28)***	−0.014 (5.89)***	−0.005 (3.12)***
TO	0.003 (5.18)***	0.003 (4.61)***	0.002 (5.17)***
BUS	−0.057 (2.67)**	−0.053 (2.76)***	−0.047 (2.95)***
ICT	−0.001 (1.31)		
RoL		0.032 (0.75)	
IND			0.001 (0.73)
Constant	−2.305 (2.85)***	−2.572 (3.14)***	−0.692 (1.16)
N	583	586	586

*P<0.1; **P<0.05; ***P<0.01

Internet on CO_2 emissions. Greater internet penetration can reduce CO_2 emissions by enabling digitalization and remote work, which decreases the need for transportation and energy-intensive office spaces. However, increased internet usage can also contribute to higher emissions through the growing energy demand of data centers and digital infrastructure. Our results suggest that while ICT is not significant, renewable energy and new business density retain its negative effect on CO_2 emissions. In column 2, we added the Rule of Law (RoL) index from the World Bank as a strong rule of law that can reduce CO_2 emissions by ensuring the enforcement of environmental regulations, promoting accountability for polluters, and encouraging sustainable business practices. Our main results remain unchanged. Finally, in column 3 we add industrialization rate as it may capture structural transformation in the EDD economies. Again, across all models we report that renewable energy mitigates CO_2 emissions in EDD countries.

5. CONCLUSION

This study empirically examines the relationship between new business density, renewable energy consumption, and CO_2 emissions in demographic dividend countries from 2000 to 2020, employing robust panel data methods, including two-step system GMM. The findings suggest that both renewable energy adoption and private sector development play a significant role in reducing CO_2 emissions. Specifically, a one standard deviation increase in renewable energy consumption is associated with a 1.4% decrease in per capita CO_2 emissions. These results highlight the importance of fostering a business-friendly environment and accelerating the transition to clean energy to mitigate climate change in rapidly growing economies. Our results extend previous research on developing countries that report that renewable energy sources mitigate CO_2 emissions (Haldar and Sethi, 2021; Bi et al., 2024).

From a policy perspective, the findings suggest several key implications. First, governments should implement policies that encourage investment in renewable energy, such as tax incentives, subsidies, and public-private partnerships, to accelerate the decarbonization process. Second, promoting entrepreneurship and private sector growth through regulatory reforms and access to finance can contribute to environmental sustainability by fostering innovation in green technologies and resource-efficient business practices. Third, integrating environmental regulations with industrial and energy policies can help ensure that economic growth in demographic dividend countries is sustainable and aligned with global climate goals.

Despite its contributions, this study has certain limitations. First, while the two-step system GMM approach helps address endogeneity concerns, potential bi-directional causality may existing in our study. Second, the study primarily relies on aggregate national-level data, which may not fully capture regional disparities in renewable energy adoption and private sector dynamics. Third, the analysis focuses on demographic dividend countries as a group, but differences in institutional quality, policy frameworks, and energy infrastructure across countries might influence the magnitude of the observed effects.

Future research can build on these findings in several ways. First, more analyses using sub-national data can provide deeper insights into the mechanisms through which business development and renewable energy adoption affect CO_2 emissions. Second, exploring the role of financial markets and green finance in accelerating the transition to low-carbon economies could offer additional policy recommendations. Third, investigating the long-term dynamic effects of renewable energy expansion and private sector growth on environmental sustainability through nonlinear or threshold models could further enhance understanding. Lastly, incorporating additional environmental indicators, such as air pollution and biodiversity loss, could provide a more comprehensive assessment of the broader ecological impacts of economic development strategies.

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