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Industrialization and CO_2 Emissions: Accounting for the role of Renewable Energy in OIC Member States

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ABSTRACT

The aim of this study is to assess the relationship between industrialization and CO_2 emissions in a sample of OIC member states over the period 1995-2020. The study adopts panel data methods such as two-step system GMM estimator to account for the problems of endogeneity and simultaneity. The empirical results suggest that industrializing has positive effect on CO_2 emissions. In contrast, renewable energy and financial development has pollution inhibiting impact on CO_2 emissions. Our results also show that GDP and ICT usage leads to a rise in CO_2 emissions. The policy implications of the study are discussed.

Keywords: Industrialization, Renewable Energy, CO_2 Emissions, Human Capital
JEL Classifications: Q50, Q40

1. INTRODUCTION

In recent decades, the world has witnessed significant changes in both global CO_2 emissions and urbanization patterns. These two trends are interconnected, as urban areas contribute significantly to greenhouse gas emissions. Analyzing these trends can provide valuable insights into the environmental challenges we face and the potential solutions for a sustainable future. Indeed, over the past century, human activities, primarily the burning of fossil fuels for energy production and transportation, have led to a substantial increase in carbon dioxide emissions. According to the International Energy Agency (2020), global energy-related CO_2 emissions reached a record high of 33.1 gigatonnes in 2019, representing a 2% increase compared to the previous year. When it comes to the distribution of CO_2 emissions, certain countries and regions stand out. Historically, developed nations have been the largest emitters. For example, in 2019, the top five CO_2 emitters were China (28% of global emissions), the United States (15%), the European Union (9%), India (7%), and Russia (5%). These figures, compiled by the Global Carbon Atlas, highlight the disproportionate contribution of these regions to global emissions.

However, emerging economies have witnessed a rapid increase in CO_2 emissions in recent years due to industrialization and urbanization. China, for instance, has experienced tremendous economic growth, resulting in a surge in energy demand. It surpassed the United States as the largest emitter in 2006 and accounted for 28% of global CO_2 emissions in 2019. India, another rapidly growing economy, witnessed a 2.9% increase in CO_2 emissions in 2019 alone, according to the IEA. Turning our attention to trends in urbanization, cities are expanding at an unprecedented rate. More than half of the world's population now lives in urban areas, and this figure is projected to reach 68% by 2050, according to the United Nations (2018; 2019). Rapid urbanization poses challenges in terms of CO_2 emissions and resource consumption. Urban areas are responsible for a significant share of CO_2 emissions due to high energy consumption. Buildings and transportation are major contributors, accounting for approximately 40% and 23% of global CO_2 emissions, respectively. As cities grow, so does the demand for infrastructure, housing, and transportation, leading to increased emissions. However, urbanization also presents opportunities for sustainable development. Compact and well-planned cities can optimize resource utilization and reduce per capita emissions. Many cities are implementing sustainable strategies to address environmental challenges. For example, cities like Copenhagen, Denmark, have set ambitious targets to become carbon neutral by 2025, relying on renewable energy and sustainable transportation systems. Thus, global trends in CO_2 emissions and trends in urbanization pose significant challenges for sustainable development. While CO_2 emissions continue to rise, efforts to transition to renewable energy sources and improve energy efficiency provide hope for reducing the environmental impact. Similarly, urbanization can be a driver of emissions but also an opportunity for sustainable transformation. By adopting environmentally friendly practices and embracing the concept of smart cities, urban areas can become part of the solution. Ultimately, global collaboration and innovative approaches are vital to address these trends and create a sustainable future for generations to come.

The goal of this study is to contribute to the ongoing research on the drivers of carbon dioxide emissions across the globe, by assessing the role of human capital and industrialization. There are number of reasons why these variables are important in this nexus. First, industrialization is associated with increased energy use and energy intensity, which has direct effect on CO_2 emissions (Ozturk et al., 2022). Second, a number of recent studies pinpoint that investment in human capital can mitigate climate change effects in developing countries and reduce environmental degradation (Khan, 2020; Azam et al., 2023). This is particularly important for the Organization of Islamic Cooperation (OIC) member states where the level of industrialization is approximately 30% of GDP. Moreover, a number of recent studies shed light on the antecedents of CO_2 emissions in OIC member states but overlook the role of industrialization and human capital (Farooq et al., 2020; Farooq et al., 2023; Ali et al., 2020). In this study we explore the industrialization, renewable energy, human capital and CO_2 emissions nexus for the same of OIC members over the period 1995-2020. Using fixed effects regressions and two-step system GMM estimator, we find that industrialization significantly increases environmental degradation. In contrast, rise in human capital accumulation leads to a decrease in CO_2 emissions.

The rest of the study is structured as follows. Section 2 provides overview of related studies. Section 3 presents data and methodology, while Section 4 discusses the main results. Section 5 concludes the study and offers policy implications.

2. REVIEW OF LITERATURE

2.1. Industrialization and CO_2 Emissions

Hossain (2011) examines the effects of energy consumption, economic growth, trade and urbanization in the context of newly industrialized economies over the period 1971-2007. The study finds that there is no long-run causal relationship between the variables, but in the short run the causality runs from trade and economic growth to CO_2 emissions. Moreover, energy consumption has significant impact on air pollution in industrialized countries. In turn, Dong et al. (2019) explore the peak carbon emissions in the context of developed countries, using panel threshold regression model. The empirical estimates suggest that GDP and urbanization exert double-threshold impact on environmental degradation. In addition, industrialization leads to a rise in CO_2 emissions, however, this effect decreases as GDP per capita increases in developed countries.

Zheng et al. (2021) contributes to this debate by exploring the role that energy service companies play in reducing CO_2 emissions in China. Using data from 29 provinces in China, the authors test the moderating effects of energy service companies. The empirical results show that urbanization decreases CO_2 emissions, while industrialization leads to environmental degradation. The authors conclude that energy service companies have stronger effect on CO_2 emissions in regions with lower levels of industrialization.

Mahmood et al. (2020) examine the effects of urbanization and industrialization on CO_2 emissions in Saudi Arabia over the period 1968-2014. The results show that both urban population increase and rise of industrial sector leads to an increase in CO_2 emissions. The authors suggest implementing more stringent urbanization and industrialization policies to mitigate climate change effects.

Shahbaz et al. (2014) explores the link between industrialization, energy consumption and CO_2 emissions in Bangladesh for the years 1975-2010. The authors use ARDL bounds estimator and innovative accounting approach to assess cointegrating relationships. The results indicate that financial development, trade and energy consumption lead to a rise in CO_2 emissions, while GDP per capita has U-shaped link with air pollution.

Liu and Bae (2018) explore the causal links between urbanization, GDP, industrialization, energy intensity and CO_2 emissions in China over the period 1970-2015. The authors using ARDL and VECM methods find energy intensity, economic growth, urbanization and industrialization increase CO_2 emissions. The authors offer the following policy suggestions: to implement policies aimed at sustainable urbanization; optimize industrial policies to reduce greenhouse gas emissions; and promote renewable energy sector development.

2.2. Urbanization and CO_2 Emissions

Martínez-Zarzoso and Maruotti (2011) investigated the impact of urbanization on CO_2 emissions in developing countries. Their study provided evidence of a positive relationship between urbanization and CO_2 emissions, suggesting that urban growth leads to increased energy consumption and associated emissions. Zhang and Lin (2012) conducted a regional analysis in China to estimate the relationship between urbanization, energy consumption, and CO_2 emissions. Their findings revealed a positive correlation between urbanization and CO_2 emissions at the regional level, emphasizing the importance of region-specific policies to manage urbanization and promote sustainable development. Balsalobre-Lorente et al. (2022) focused on the influence of growth, urbanization, and foreign direct investment (FDI) on CO_2 emissions in BRICS countries. Their study found that urbanization positively affects CO_2 emissions, but FDI plays a moderating role by reducing energy use. This highlights the potential of FDI in promoting cleaner and more sustainable urbanization.

Gierałtowska et al. (2022) conducted a global test to examine the relationship between renewable energy, urbanization, and CO_2 emissions. Their study demonstrated the positive impact of renewable energy sources on reducing CO_2 emissions, with urbanization acting as a catalyst for adopting renewable energy technologies. Mignamissi and Djeufack (2022) investigated the relationship between urbanization and CO_2 emissions intensity in Africa. Their study revealed that urbanization contributes to increased CO_2 emissions intensity in African countries, emphasizing the need for sustainable urban planning and policies that consider the unique challenges and opportunities in the African context. Yao et al. (2021) examined the impact of multiple dimensions of urbanization on CO_2 emissions in China's prefecture-level cities. Their spatial and threshold analysis of panel data highlighted the nonlinear relationship between urbanization and CO_2 emissions, suggesting the presence of an optimal level of urbanization that minimizes emissions. Lee et al. (2023) focused on China and explored the impact of urbanization on CO_2 emissions, with a specific emphasis on the key role of foreign direct investment. Their study revealed the significance of foreign direct investment in mitigating the positive effect of urbanization on CO_2 emissions in China. Khoshnevis Yazdi and Shakouri (2018) examined the effect of renewable energy and urbanization on CO_2 emissions using panel data. Their study indicated the potential of renewable energy sources in reducing CO_2 emissions, alongside the influence of urbanization on emissions.

2.3. Renewable Energy and CO_2 Emissions

Numerous empirical studies conducted after 2020 have examined the relationship between renewable energy and CO_2 emissions. These studies have employed various methodologies to assess the impact of renewable energy on reducing greenhouse gas emissions. The following review provides an overview of some notable empirical studies in this field. Chen et al. (2021) conducted an empirical analysis using panel data from 74 countries. They found a significant negative relationship between renewable energy consumption and CO_2 emissions. The results indicated that a 1% increase in renewable energy consumption led to a 0.82% reduction in CO_2 emissions. The study used econometric techniques to control for confounding factors and established a robust relationship between renewable energy and CO_2 emissions reduction. In a life cycle assessment (LCA) study, Martinez et al. (2022) compared the environmental performance of solar and wind power generation with conventional fossil fuel-based electricity generation. Their findings revealed that solar and wind energy systems had significantly lower CO_2 emissions throughout their life cycle. The study considered various stages, including resource extraction, manufacturing, operation, and disposal, and concluded that renewable energy technologies have a substantially lower carbon footprint compared to fossil fuel-based alternatives. An empirical study by Li et al. (2020) focused on the impact of renewable energy expansion on CO_2 emissions in the United States. By employing a vector error correction model, the researchers found that increasing the share of renewable energy in the energy mix had a negative and statistically significant effect on CO_2 emissions. Their findings suggested that further deployment of renewable energy sources could contribute to a sustainable reduction in CO_2 emissions in the U.S. Using scenario modeling, Wang et al. (2021) explored the potential impact of renewable energy deployment on CO_2 emissions in the European Union. The study developed multiple scenarios based on different levels of renewable energy capacity expansion. The results indicated that aggressive deployment of renewable energy could lead to substantial reductions in CO_2 emissions, surpassing the targets set by the Paris Agreement. The findings underscored the importance of policy support and investment in renewable energy for achieving climate targets. This empirical study by Zhang et al. (2021) focuses on the relationship between renewable energy consumption and CO_2 emissions reduction in the BRICS countries (Brazil, Russia, India, China, and South Africa). The findings provide evidence of a negative correlation between renewable energy consumption and CO_2 emissions, suggesting that an increase in renewable energy use leads to a reduction in emissions.

Gokmenoglu and Taspinar (2021) explores the relationship between renewable energy consumption and CO_2 emissions in emerging economies. Using asymmetric causality analysis, the authors find evidence of a bidirectional causal relationship between renewable energy consumption and CO_2 emissions, indicating the potential for a feedback loop between renewable energy deployment and emissions reduction. Liu et al. (2020a) investigates the relationship between renewable energy consumption and CO_2 emissions in both developed and developing countries. The findings reveal a negative relationship between renewable energy consumption and CO_2 emissions in developed countries, while the relationship in developing countries is less conclusive. The study provides insights into the varying dynamics of renewable energy and emissions reduction across different country groups. Liu et al. (2020b) specifically focuses on China and examines the effectiveness of renewable energy consumption in reducing carbon dioxide emissions. The empirical analysis shows a significant negative relationship between renewable energy consumption and CO_2 emissions in China, highlighting the potential of renewable energy as an effective means to mitigate carbon emissions in the country.

2.4. Human Capital and CO_2 Emissions

This literature review synthesizes findings from various studies that examine the relationship between human capital and CO_2 emissions, with a focus on sustainable economic development and global perspectives. The studies selected for this review shed light on different dimensions of this relationship and contribute to our understanding of the complex interplay between human capital, economic growth, and CO_2 emissions. Yao et al. (2020) investigate the long-term relationship between human capital and CO_2 emissions. Their study reveals that higher levels of human capital, measured by educational attainment and health indicators, are associated with lower CO_2 emissions. They argue that investments in human capital development can contribute to sustainable economic growth while mitigating environmental degradation. Building on this line of inquiry, Khan (2020) explores the role of human capital in achieving sustainable economic development while addressing CO_2 emissions. The findings suggest that increased human capital, specifically in terms of educational attainment and skills development, can facilitate the transition to a low-carbon economy and promote sustainable development. The study by Wang and Xu (2021) takes a novel approach by examining the relationship between internet usage, human capital, and CO_2 emissions from a global perspective. They find that greater internet usage, as an indicator of technological advancement and knowledge diffusion, positively moderates the relationship between human capital and CO_2 emissions. This suggests that information and communication technologies can facilitate more sustainable practices and reduce environmental impact.

Shifting the focus to a specific country, Lin et al. (2021) investigate the link between innovative human capital, economic growth, and CO_2 emissions in Chinese provinces. Their study demonstrates that innovative human capital, characterized by research and development activities, is positively associated with economic growth and negatively related to CO_2 emissions. This suggests that fostering innovation and human capital development can lead to sustainable economic growth while reducing carbon emissions.

Examining the Central Asian States, Isiksal et al. (2022) explore the relationship between natural resources, human capital, and CO_2 emissions. The study reveals a complex relationship, highlighting the need for targeted policies that leverage natural resources and human capital to achieve sustainable development and mitigate CO_2 emissions in this region. Lastly, Rahman et al. (2021) analyze the impacts of human capital, exports, economic growth, and energy consumption on CO_2 emissions in newly industrialized countries. The study findings emphasize the importance of human capital development in conjunction with sustainable energy policies and economic diversification to effectively address CO_2 emissions.

Collectively, the studies reviewed here provide valuable insights into the relationship between human capital and CO_2 emissions, with implications for sustainable economic development. They underscore the significance of investing in human capital development, promoting innovation, and adopting sustainable practices to achieve a low-carbon and resilient future. These findings contribute to the growing body of knowledge and provide a basis for evidence-based policy formulation and decision-making at the local, regional, and global levels.

3. DATA AND METHODOLOGY

In this study we explore the relationship between industrialization, renewable energy and CO_2 emissions for a sample of 52 OIC member states over the period 1995-2020. The dependent variable in this study is CO_2 emissions per capita from the World Bank. Figure 1 plots the data for the top-10 countries based on their levels of CO_2 emissions in 2020. As it can be observer Qatar, Kuwait and Bahrain are among the countries with highest per capita rates of CO_2 emissions. Our main independent variables are industrialization and human capital. Industrialization is measured by industry value added as % of GDP from the World Bank. Figure 2 suggests that there is positive relationship between industry value added and per capita levels of CO_2 emissions in OIC region. Human capital is proxied by average years of schooling from the Barro-Lee Educational Attainment Data.

In order to mitigate the omitted variable bias we incorporate a set of control variables as suggested by previous scholars. First, we include change in urbanization rate. Urbanization can influence CO_2 emissions through various mechanisms. Firstly, urban areas tend to experience higher energy consumption levels due to increased residential, commercial, and industrial activities. However, urbanization also facilitates the implementation of sustainable practices. Data for urbanization rate comes from the World Bank. Next, we include trade openness. A number of studies suggest that trade openness is important predictor of environmental degradation (Salahuddin et al., 2016; Awan et al., 2022). Internet usage is from the World Bank. We also control for financial development, in line with environmental and energy economic studies (Shoaib et al., 2020). The description statistics are reported in Table 1.

Figure 1: CO_2 emissions per capita, 2019

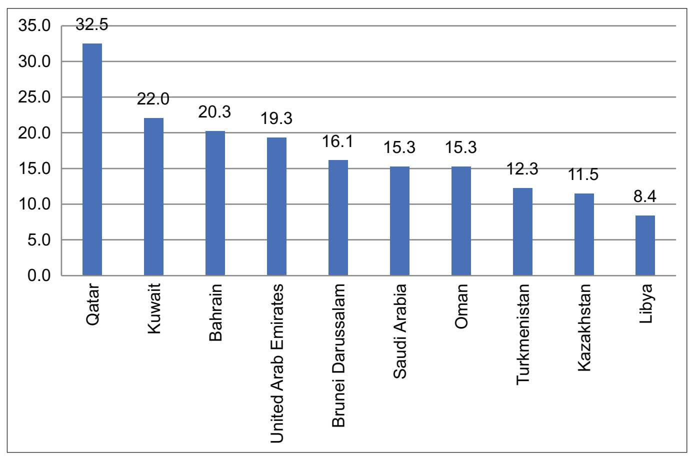

Figure 2: Scatter plot between industrialization and CO_2 emissions

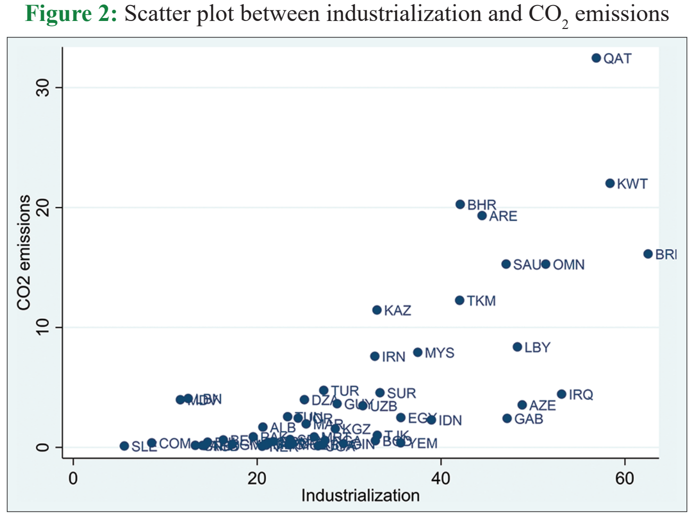

Table 1: Descriptive statistics

Variable	Description	Mean	SD	Min	Max
CO_2 emissions	CO_2 emissions per capita	4.620	7.857	0.000	50.954
GDP per capita	GDP per capita, constant USD prices	13.847	19.911	0.469	105.109
Urbanization	Urban population growth, %	3.184	1.908	−6.512	17.764
Internet	Internet usage, %	18.578	25.201	0	100
Financial development	Financial development index	0.160	0.160	0	0.743
Industrialization	Industry value added as % of GDP	30.507	15.358	4.556	86.670
Education	Average years of schooling	6.104	3.094	0.559	12.694
Renewable energy	Renewable energy consumption, %	35.706	34.422	0	98.138

To empirically estimate our statistical model, we utilize a two-step system GMM estimator. Previous studies have employed the fixed effects method for panel data in the empirical modeling of CO_2 emissions. However, this approach can be problematic due to the issue of endogeneity, as independent variables might be correlated with each other. Recent studies have addressed this concern by incorporating lagged CO_2e to account for environmental degradation inertia. When including lagged CO_2e in the analysis, the fixed effects regression produces biased parameters due to endogeneity. To overcome this endogeneity problem, we employ the two-step system GMM estimator proposed by Arellano and Bover (1995). This method offers several advantages for our study. Firstly, it effectively resolves the endogeneity problem by considering the existence of multiple endogenous factors, surpassing other methods like instrumental variable fixed effects regression. Secondly, it demonstrates particular efficiency in samples where the number of countries exceeds the total years of the period. Furthermore, the two-step system GMM outperforms the difference GMM method, which suffers from information loss and overlooks the level association among the model's factors and the links between the level and first differences. The consistency of the estimates computed by the system GMM estimator is confirmed by the Hansen test P-value and AR(1) and AR(2) tests. It is worth noting that the two-step system GMM estimator is widely used in related studies to model the relationship between socio-economic factors and environmental degradation.

4. RESULTS

The baseline results are presented in Table 2. The column 1 reports the findings obtained with the use of conventional OLS regression estimator adjusted for heteroskedasticity. We find that while there is inverted U-shaped pattern between GDP and CO_2 emissions, the GDP squared term is not statistically significant. Urban population growth leads to a decrease in CO_2 emissions. One plausibly explanation is that urbanization leads to more concentrated supply of services which decreases transportation effect on CO_2 emissions. Apart from that urbanization is also associated with increased energy efficiency, which has also instrumental effect on climate change. Internet usage and financial development are not significant predictors of CO_2 emissions when we use OLS regression estimator. Industrialization as a source of energy intensity in line with related studies have positive effect on CO_2 emissions (Shahbaz et al., 2015; Mentel et al., 2022). For example, 10% increase in energy intensity leads to nearly 0.05 tons per capita rise in CO_2 emissions in OIC countries (Model 1). In model 2, we account for the effect of human capital in mitigating CO_2 emissions. However, the results show that schooling is not significant predictor of CO_2 emissions. However, OLS regression estimates only show the association between our variables of interest and CO_2 emissions. OLS estimates suffer from the problem of endogeneity and efficiency. Thus, we report two-step GMM estimates in Table 3.

Table 2: Baseline results

Variable	Model 1		Model 2	
	Coefficient	P-value	Coefficient	P-value
CO_2, lagged	0.962	0.000	0.966	0.000
GDP per capita	0.013	0.046	0.015	0.028
GDP per capita squared	−0.000	0.319	−0.000	0.140
Urbanization	−0.027	0.078	−0.033	0.039
Internet	−0.001	0.226	−0.002	0.196
Industrialization	0.004	0.045	0.004	0.082
Financial development	−0.162	0.296	−0.088	0.576
Renewable energy	−0.001	0.074		
Human capital			0.001	0.888
Constant	0.095	0.171	0.035	0.648
R-sq	0.99		0.99	
F-test	10331.61		8648.61	

Table 3: Two-step system GMM results

Variable	Model 1		Model 2	
	Coefficient	P-value	Coefficient	P-value
CO_2, lagged	0.829	0.000	0.826	0.000
GDP per capita	0.039	0.000	0.055	0.000
GDP per capita squared	0.000	0.031	−0.000	0.402
Urbanization	−0.083	0.000	−0.096	0.000
Internet	0.005	0.008	0.002	0.013
Industrialization	0.009	0.001	0.009	0.001
Financial development	−1.462	0.033	−0.704	0.125
Renewable energy	−0.004	0.034		
Human capital			−0.011	0.676
Constant	0.342	0.017	0.141	0.319
AR (1)	0.033		0.041	
AR (2)	0.567		0.493	
Hansen P-value	0.169		0.353	

Table 3 reports two-step system GMM estimator. As expected, lagged CO_2 emissions are positive and significant, reinforcing the evidence of inertia in environmental degradation processes. Once, we account for the issue of endogeneity we again fail find that GDP per capita has significant inverted U-shaped relationship with carbon emissions. The findings suggest that overall economic growth is positively linked to CO_2 emissions in the region. Again, urbanization is negative and significant: 10% increase in urbanization growth rates leads to 0.83% decrease in CO_2 emissions. ICT usage and industrialization retain its significant effect on CO_2 emissions. Financial development is now negative and significant. Studies from Malaysia (Shahbaz et al., 2013) and 88 developing countries (Khan and Ozturk, 2021) also confirm pollution inhibiting role of financial development. If causal, one standard deviation increase in average years of schooling leads to 0.25 tons per capita decline in CO_2 emissions. Noteworthy, we find that human capital has not significant impact on CO_2 emissions. Overall, the results show that industrialization has positive effect on CO_2 emissions, while investing in human capital mitigates climate change effects. Moreover, our results reinforce the conclusion that renewable energy can alleviate the effect of industrialization on CO_2 emissions in developing countries. AR(1), AR(2) tests and Hansen P-value confirm the credibility of the two-step system GMM estimator results.

5. CONCLUSION

This research study explored the relationship between urbanization, human capital, industrialization, energy intensity, and CO_2 emissions in 52 OIC countries over the period of 1995-2020. The findings indicate that urbanization and human capital contribute to a decrease in CO_2 emissions, while industrialization and energy intensity are associated with an increase in CO_2 emissions. These findings shed light on the complex dynamics between socioeconomic factors and environmental sustainability.

Our study offers a number of policy implications that policymakers in developing countries can use to improve the prospects of sustainable economic growth. First is to enhance sustainable urban planning. The research highlights the potential of urbanization in reducing CO_2 emissions. Policymakers should focus on promoting compact city designs, efficient transportation systems, and access to green spaces in urban areas to support sustainable urban development. Second, increase investment in human capital and education. The study underscores the importance of investing in education and human capital development. Policies that prioritize education, vocational training, and skill development can empower individuals to adopt environmentally friendly practices and contribute to the reduction of CO_2 emissions. Third, promote environmental regulations for industrialization. Given the link between industrialization and environmental degradation, policymakers should implement stringent environmental regulations and incentives to encourage industries to adopt cleaner technologies, reduce emissions, and promote sustainable production practices.

Our study also provides avenue for future research:
- Further investigation is needed to assess the long-term effects of urbanization on CO_2 emissions. Studying the dynamics of urbanization over extended periods can provide insights into the sustainability of urban development and the effectiveness of mitigation strategies.
- Future research could examine the interplay between socioeconomic factors, environmental policies, and CO_2 emissions. Understanding how policy interventions interact with urbanization, human capital, industrialization, and energy intensity can inform the design and implementation of effective environmental policies.
- Researchers can delve deeper into the relationship between industrialization and environmental degradation by conducting sector-specific analyses. Exploring the environmental impact of different industries and identifying sector-specific mitigation strategies can contribute to more targeted and impactful policies.

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