energies

*Article*

# Does Renewable Energy Sector Affect Industrialization-$CO_2$ Emissions Nexus in Europe and Central Asia?

**Grzegorz Mentel [1], Waldemar Tarczyński [2], Marek Dylewski [3] and Raufhon Salahodjaev [4,5,*]**

1 Department of Quantitative Methods, Faculty of Management, Rzeszow University of Technology, 35-959 Rzeszow, Poland
2 Department of Sustainable Finance and Capital Markets, Institute of Economics and Finance, University of Szczecin, 71-101 Szczecin, Poland
3 Institute of Economics and Finance, WSB University in Poznan, Powstańców Wielkopolskich 5, 61-895 Poznan, Poland
4 School of Business, Akfa University, 264, Milliy Bog Street, Kibray District, Tashkent 111221, Uzbekistan
5 ERGO Analytics, 18/1 Oybek Street, Tashkent 100000, Uzbekistan
* Correspondence: salahodjaev@gmail.com

**Abstract:** Current research assesses the impact of industrialization and the renewable energy sector on greenhouse gas emissions, proxied by $CO_2$ emissions in Europe and Central Asia. We rely on a two-step system GMM estimator on a sample of 48 countries over the period 2000–2018. Empirical results show that industrialization has a positive effect on $CO_2$ emissions: a 10% increase in industry value added as % of GDP leads to an increase of 2.6% in $CO_2$ emissions. In contrast, renewable energy mitigates $CO_2$ emissions. Ten percentage points increase in renewable energy consumption reduces $CO_2$ emissions per capita by 2.2%. The interaction term between renewable energy and industry value added is negative, suggesting that renewable energy consumption compensates for the negative effect of industrialization on environmental quality. Our main results also confirm the U-shaped inverted relationship between GDP per capita and $CO_2$ emissions. Our study has a number of policy implications and avenues for future research.

**Keywords:** industrialization; renewable energy; $CO_2$ emissions; Europe and Central Asia

check for updates

**Citation:** Mentel, G.; Tarczyński, W.; Dylewski, M.; Salahodjaev, R. Does Renewable Energy Sector Affect Industrialization-$CO_2$ Emissions Nexus in Europe and Central Asia? *Energies* **2022**, *15*, 5877. https://doi.org/10.3390/en15165877

Academic Editor: Nuno Carlos Leitão

Received: 30 June 2022
Accepted: 11 August 2022
Published: 13 August 2022



## 1. Introduction

As a result of socio-economic transformations such as urbanization, industrialization, and global integration, a significant increase in $CO_2$ emissions has been recorded across different regions [1,2]. Consequently, there has been growing academic interest in understanding the economic drivers of $CO_2$ emissions [3]. It is crucial to explore these topics and make essential policy implications to develop sustainable development frameworks for developing countries. Previous research shows that economic indicators and $CO_2$ emissions are significantly interrelated both across regions and single countries [4,5]. Policy makers use various policies such as structural transformation or promoting industrial policies to foster economic growth, which inevitably can lead to environmental degradation [6]. Intensity of energy and industrial energy use in countries are also linked to higher $CO_2$ emissions [7,8], while sustainable energy consumption, on the contrary, can mitigate $CO_2$ emissions [9]. The fossil fuel energy consumption driven by international trade, industrialization, and FDI leads to a rise in GDP growth, but impacts environmental sustainability. However, scholars argue that economic growth can have an opposing effect on $CO_2$ emissions depending on the level of economic development, the so-called Environmental Kuznets curve (EKC). The EKC posits that "economic growth can improve environmental degradation after an economy has reached an adequate level of economic growth" [10] (p. 1393). The EKC has been validated for OPEC countries [11], Turkey [12], OECD members [13], and BRICS [14]. At the same time, empirical studies show that renewable energy consumption can reduce environmental damage from industrialization and significant dependence on the exploitation of natural resources [1,15].

The moderating effect of renewable energy can arise for a number of reasons. First, while electricity and industrialization are considered contributing factors to $CO_2$ emissions [16], renewable energy can generate electricity with little CO2 release into the atmosphere. In comparison, coal releases up to 1.6 kg of $CO_2$ per kWh and solar emits only 0.09 kg of $CO_2$ per kWh (https://www.ucsusa.org/resources/benefits-renewable-energy-use, accessed on 10 July 2022). Promoting a rapid shift toward renewable energy sources can act as a substitute for carbon-heavy energy production and substantially mitigate $CO_2$ emissions. Second, there is evidence that renewable energy can promote sustainable economic growth and create additional jobs in industries that have a small carbon footprint. For example, the causal effect of renewable energy on GDP growth is documented for Brazil [17], the EU [18] and the Balkan countries [19].

Previous studies have separately explored the effect of renewable energy on $CO_2$ emissions [20] and the effect of industrialization on $CO_2$ emissions [21]. In this sense, we believe that it is essential to explore whether a shift to renewable energy consumption can act as an important factor in the industrialization and $CO_2$ emissions relationship. Therefore, this study attempts to fill the gap in existing literature by exploring the relationship between industrialization, renewable energy, and $CO_2$ emissions in Europe and Central Asia over the period 2000–2018. The motivation of this study is explained by a number of reasons. First, some of the ECA countries are among the top countries that have increased the share of industry in GDP during the period 2000–2018. Moreover, the average level of industrialization in the ECA region over this period (24%) was below that in MENA (44%), Upper middle-income countries (35%), East Asia and Pacific (35%), and Latin America and the Caribbean (29%) (World Bank Development Indicators database). This implies that our study can help assess whether a potential increase in the contribution of industry to GDP in the aftermath of Industry 4.0 trends can be combined with renewable energy consumption to meet the demands of sustainable development goals. At the same time, there is a significant gap in the empirical literature on this topic. To the best of our knowledge, only two studies include renewable energy and industrialization in $CO_2$ emissions modeling for Sub-Saharan Africa [1] and global data [22] but do not consider the interaction between renewable energy and industrialization. Using a two-step GMM estimator, we find that industrialization has a significant effect on increasing $CO_2$ emissions. On the contrary, renewable energy mitigates $CO_2$ emissions and can offset the negative effect of industrialization on environmental quality. The innovation of this study is that we test the joint effect of renewable energy and industrialization on $CO_2$ emissions in the ECA region, which consists of a large set of countries with heterogeneous levels of economic performance. The remainder of the study is structured as follows. Section 2 reviews the most recent empirical literature. Section 3 presents the methodology, and Section 4 offers empirical results. Second 5 concludes the study.

## 2. Review of Recent Empirical Evidence

### *2.1. Renewable Energy and $CO_2$ Emissions*

A large group of studies explores the relationship between renewable energy and $CO_2$ emissions. Abbasi et al. [23] explore the relationship between renewable energy and $CO_2$ emissions in Thailand using data over the period 1980–2018. The study uses the ARDL regression method and shows that renewable energy reduces $CO_2$ emissions both in the short and long run. These results are in line with an earlier study by Chunark [24] in which authors show that shifting toward renewable energy consumption can help policymakers in Thailand reach the long-term $CO_2$ emission targets.

Rahman et al. [25] explore the effect of renewable energy on $CO_2$ emissions in 22 countries that have observed a decrease in greenhouse gas emissions over the years 1990–2018. Using NARD and PMG econometric methods, the study shows that renewable energy is one of the variables that predict a decrease in $CO_2$ emissions. Furthermore, the study highlights the importance of innovation and export sophistication in reducing greenhouse gas emissions. Inal et al. [26] attempt to unbundle the relationship between renewable energy and $CO_2$ emissions in a sample of major oil-producing economies in Africa for the period 1990–2014. AMG regression estimates show that renewable energy reduces $CO_2$ emissions, but has no significant effect on economic growth. Therefore, the study recommends that countries should opt for a mix of energy consumption from renewable and non-renewable energy sources. Saidi and Omri [27] use FMOLS and VECM regression methods to explore the effects of renewable and nuclear energy on $CO_2$ emissions in OECD countries. At the same time, Chiu and Chang [28] show that in the case of OECD member states, the share of renewable energy consumption should reach a critical level of 8.4% to begin mitigating $CO_2$ emissions. Moreover, the negative effect of renewable energy on $CO_2$ emissions was confirmed by Zaghdoudi [29] even after accounting for the role of oil prices among OECD countries during the period 1990–2015.

The results indicate that both energy sources can reduce $CO_2$ emissions and are complementary. Azam et al. [30] explore the relationship between renewable energy, economic growth, ICT, and $CO_2$ emissions across 10 countries with the highest levels of $CO_2$ emissions. The panel data causality tests show that renewable energy use, GDP growth, and ICT are causal to $CO_2$ emissions. Yu et al. [31] explore the effect of renewable energy from solar energy on $CO_2$ emissions in the 10 largest solar energy generating countries, using the quantile-on-quantile regression method. Econometric estimates suggest that overall solar energy consumption reduces $CO_2$ emissions in 9 out of 10 countries. Furthermore, the effect is stronger for countries with higher levels of $CO_2$ emissions. Namahoro et al. [32] explore the relationship between energy intensity, renewable energy, and $CO_2$ emissions in a sample of African economies over the years 1990–2018. The authors using panel cointegration methods show that renewable energy consumption decreases $CO_2$ emissions, however, energy intensity leads to environmental degradation. Moreover, renewable energy significantly mitigated $CO_2$ emissions during the last 10 years of analysis. de Souza Mendonca et al. [33] use the hierarchical regression method on a sample of 50 countries with the highest GDP to explore the relationship between renewable energy and $CO_2$ emissions. Empirical results show that GDP and population are positively related to $CO_2$ emissions, while renewable energy consumption has a negative impact on $CO_2$ emissions.

### 2.2. Industrialization and $CO_2$ Emissions

A small but growing number of papers explore the relationship between industrialization and $CO_2$ emissions. Li and Lin [34] use the STRIPAT model on a sample of 73 countries over the period 1971–2010 and show that industrialization has a positive influence on $CO_2$ emissions in low- and middle-income countries. At the same time, industrialization is insignificantly related to $CO_2$ emissions in high-income countries. Liu and Bae [35] use an ARDL regression estimator to examine the long-term relationship between industrialization and $CO_2$ emissions in China. The study documents that urbanization and industrialization have a positive effect on $CO_2$ emissions, while the use of renewable energy mitigates $CO_2$ emissions. The study highlights the importance of innovation and energy efficiency to achieve environmental sustainability. In a different study for China, Xu and Lin [36] used an ARDL estimator to document the bidirectional causality between industrialization and $CO_2$ emissions. In addition, urbanization, energy use, and GDP increase $CO_2$ emissions in the long run. Mahmood et al. [37] test the effect of industrialization on $CO_2$ emissions controlling urbanization over the period 1968–2014. The results show that an increase in the contribution of industry to GDP has a significant positive impact on $CO_2$ emissions, and urbanization is also detrimental to environmental quality. In a similar vein, Musa et al. [38] examine the relationship between urbanization, industrialization, and $CO_2$ emissions in Nigeria over the period 1982–2018. The results from the Toda and Yamamoto causality tests suggest that urbanization has bidirectional causality with economic growth and urbanization leads to an increase in industrialization. Therefore, it is important to adopt sustainable industrial and demographic policies to improve environmental quality in the long run.

Appiah et al. [39] using various dynamic panel data methods show that non-renewable energy use and industrialization have positive effects on $CO_2$ emissions in Sub-Saharan African countries. Moreover, the causality tests show that there is bidirectional causality between these variables and $CO_2$ emissions. In a different study, Mentel et al. [1] used a two-step GMM estimator for a sample of 44 Sub-Saharan African economies to show that industrialization is a significant positive determinant of $CO_2$ emissions. Furthermore, renewable energy has been shown to reduce the harmful effect of industrialization on $CO_2$ emissions.

Taking into account the review of empirical literature mentioned above, we will test the following hypotheses.

**Hypothesis 1 (H1).** *Renewable energy has significant negative effect on $CO_2$ emissions in ECA region.*

**Hypothesis 2 (H2).** *Industrialization has significant positive effect on $CO_2$ emissions in ECA region.*

**Hypothesis 3 (H3).** *Renewable energy can offset the positive effect of industrialization on $CO_2$ emissions in ECA region.*

## 3. Methodology

This study follows earlier research on $CO_2$ emissions and uses panel data methods for a sample of 48 countries over the period 2000–2018 to model the relationship between renewable energy, industrialization, and $CO_2$ emissions. We use this time frame because Eastern Europe and Central Asia countries have undergone economic transition reforms with the collapse of the Soviet Union and experienced substantial economic shocks in the 1990s. Our empirical model is based on the EKC framework. The environmental Kuznets curve posits that there is a quadratic relationship (inverted U-shaped) relationship between GDP per capita and $CO_2$ emissions (Figure 1).

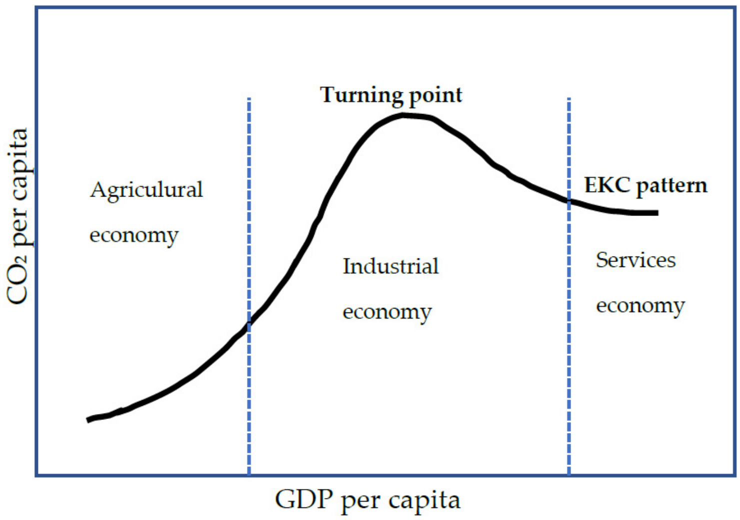


**Figure 1.** The EKC theoretical framework.

Figure 1 shows the relationship between GDP and $CO_2$ emissions. According to the theoretical considerations [10] at low levels of economic development shift from a rural economy to an industrial economy is followed by a sharped increase in $CO_2$ emissions. However, once GDP per capita reaches a certain level, which varies for different countries and regions, further increase in GDP and transition to a services economy leads to a reduction in $CO_2$ emission. In our study, we augmented the EKC with additional control variables in line with related empirical studies. For example, international trade leads to an increase in GDP per capita, but also promotes a shift of pollution-intensive production in less developed countries (pollution haven hypothesis). As a result, trade can have both negative and positive effects on $CO_2$ emissions. Apart from those demographic transitions such as rapid urbanization and population growth followed by industrialization and an increase in off-farm employment opportunities increases carbon footprint. As a result of structural changes such as a shift from ag-economy towards industrial economy while promoting economic progress may have an impact on environmental degradation.

First, as suggested by the above-mentioned studies, we include a share of the urban population from the World Bank. We also include population growth and trade openness following Martínez-Zarzoso et al. [40] and Munksgaard et al. [41]. The proposed econometric model can be expressed as:

$$CO_{2i,t} = a_0 + a_1 CO_{2,i,t-1} + a_2 IND_{i,t} + a_3 RE_{i,t} + a_4 RE * IND_{i,t} + \beta X^k_{i,t} + e_{i,t} \quad (1)$$

where $CO_2$ stands for $CO_2$ emissions per capita; IND represents industry value added as % of GDP, RE denotes renewable energy consumption as % total energy use, and *X* is a vector of control variables (GDP, GDP squared, trade, urbanization, and population growth), *i* denotes a country, *t* denotes time, and *e* is an error term of the regression. Summary statistics and description of variables are reported in Table 1.

**Table 1.** Summary statistics.

| Variable | Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| $CO_2$ | t$CO_2$ emissions per capita | 6.91 | 3.86 | 0 | 26.44 |
| GDP | GDP per capita, adjusted for PPP, international dollars per person | 30,389.71 | 21,180.69 | 1252.46 | 115,415.4 |
| TO | Trade as % of GDP | 100.81 | 48.55 | 22.49 | 408.36 |
| UR | Urbanization rate, % | 66.22 | 18.49 | 14.303 | 100 |
| PG | Population growth, % | 0.37 | 0.90 | −3.85 | 4.37 |
| IND | Industry value added as % of GDP | 25.25 | 8.07 | 7.43 | 66.58 |
| ICT | Internet users as % of the population | 52.28 | 28.74 | 0.05 | 99.01 |
| FDI | FDI net inflows as % of GDP | 16.86 | 87.01 | −58.32 | 1282.63 |
| EXP | Exports as % of GDP | 48.86 | 26.83 | 8.78 | 205.48 |
| TEXP | Tourism receipts as % of exports | 12.16 | 12.77 | 0.62 | 73.74 |
| RE | Renewable energy consumption, % | 18.33 | 16.65 | 0 | 78.2135 |

Equation (1) can be estimated using various panel data methods, such as pooled OLS regression, fixed effects regression, generalized least squares, panel-corrected standard errors, and others. However, recent studies on the drivers of $CO_2$ emissions suggest that the two-step system generalized method of moments (GMM) is advantageous for several arguments [1,2,42,43]. For example, two-step GMM can take into account the problems of endogeneity and omit variable bias, and produces more efficient estimates in the cases when the number of panels (nations) is above the number of time units (years). We do not use methods such as VECM, ARDL, or co-integration tools as we have a large set of countries and shorter time spans, and we also include interaction terms between industrialization and renewable energy consumption. The technical discussion of the two-step GMM estimator can be found in Arellano and Bover [44]. We also report the conventional tests for autocorrelations by AR(1) and AR(2) and the Hansen *p*-value to show the econometric credibility of estimated models. The two-step GMM estimator is superior to the instrumental variable two-stage least approach (IV 2SLS) approach as it can take into account the presence of more than one endogenous variable in the model. With the aid of a two-step GMM estimator, we can also confirm the existence of the EKC framework: if the coefficient for GDP per capita ($\beta_1$) > 0 and the coefficient for GDP per capita squared

$(\beta_1) < 0$. This would confirm the existence of an inverted U-shaped relationship between economic development and environmental degradation.

We use the following specifications in the level (2) and 1st difference (3) forms:

$$CO2_{i,t} = \sigma_0 + \sigma_1 CO2_{i,t-\tau} + \sigma_2 RE_{i,t} + \sigma_3 IND_{i,t} + \sigma_4 IND * RE_{i,t} + \sum_{h=1}^{k} \delta_h W_{h,i,t-\tau} + v_{i,t} \quad (2)$$

$$\begin{aligned} CO2_{i,t} - CO2_{i,t-\tau} = \sigma_1(CO2_{i,t-\tau} - CO2_{i,t-2\tau}) + \sigma_2(RE_{i,t} - RE_{i,t-\tau}) + \sigma_3(IND_{i,t} - IND_{i,t-\tau}) + \\ \sigma_3(IND * RE_{i,t} - IND * RE_{i,t-\tau}) + \sum_{h=1}^{k} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) - (v_{i,t} - v_{i,t-\tau}) \end{aligned} \quad (3)$$

where $\sigma_0$ constant; $\sigma$ and $\delta$ are parameters to be estimated; W is a set of control variables; $\tau$ denotes the parameter of auto-regression; v is the disturbance term. The results of the multicollinearity test in Table 2 show that multicollinearity was not the problem in our case, as the VIF for single variables has not exceeded the threshold value of 10.

**Table 2.** Multicollinearity test results.

| Variable | VIF |
|---|---|
| Lagged $CO_2$ | 3.68 |
| GDP | 4.11 |
| TO | 1.15 |
| UR | 2.98 |
| PG | 1.04 |
| IND | 1.33 |
| RE | 1.39 |
| OVERALL | 2.03 |

## 4. Results

The core empirical findings are presented in Table 3. Column 1 estimates only the direct effects of renewable energy and industrialization on $CO_2$ emissions. According to the above-mentioned survey of the literature, renewable energy mitigates $CO_2$ emissions while industrialization deteriorates environmental quality. For example, a 10% increase in renewable energy consumption reduces $CO_2$ emissions per capita by 2.2%. On the contrary, a 10% increase in industry value added to an increase of 2.6% in $CO_2$ emissions. For example, Alam [45] finds that a 10 % increase in industry value added leads to a 1.5% increase in per capita $CO_2$ emissions in India. Therefore, our results show that the renewable energy sector is instrumental in curbing $CO_2$ emissions in the ECA region. Indeed, Isaeva et al. [46] posit that rising energy consumption degrades environmental quality in post-Communist states (a region that is part of the ECA sample), therefore substituting non-renewable energy with renewable energy consumption can improve environmental quality without harming economic growth.

The AR(2) tests and Hansen *p*-value show that our two-step GMM estimators are reliable and efficient. In column 2, we now introduce the interaction term between industrialization and $CO_2$ emissions. The coefficient of the interaction term is negative and significant, suggesting that renewable energy consumption offsets the negative effect of industrial policies on environmental quality. This is the core finding of our study suggesting that the increasing penetration of the renewable energy sector has the potential to mitigate the overall level of $CO_2$ emissions in the ECA region. Furthermore, the renewable energy sector can have an effect on local industries and generate additional employment, which has an effect on overall GDP [47].

**Table 3.** Main results.

| | I | II |
|---|---|---|
| $CO_{2t-1}$ | 0.8735 | 0.8196 |
| | (32.08) *** | (37.65) *** |
| GDP | 0.4394 | 0.5193 |
| | (2.25) ** | (2.24) ** |
| $GDP^2$ | −0.0200 | −0.0221 |
| | (1.99) * | (1.82) * |
| TO | 0.0001 | 0.0000 |
| | (1.32) | (0.16) |
| UR | 0.0016 | 0.0016 |
| | (2.23) ** | (2.21) ** |
| PG | 0.0118 | 0.0090 |
| | (2.56) ** | (1.80) * |
| IND | 0.0026 | 0.0036 |
| | (2.40) ** | (3.75) *** |
| RE | −0.0022 | −0.0021 |
| | (3.96) *** | (4.62) *** |
| IND * RE | | −0.0001 |
| | | (3.40) *** |
| Constant | −2.3152 | −2.8460 |
| | (2.46) ** | (2.55) ** |
| AR (1) | 0.001 | 0.001 |
| AR (2) | 0.946 | 0.932 |
| Hansen *p*-value | 0.145 | 0.176 |
| Fisher *p*-value | 0.00 | 0.00 |
| Number of countries | 48 | 48 |
| *N* | 849 | 849 |

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; We logged GDP per capita.

We also find that GDP per capita has a quadratic relationship with $CO_2$ emissions, which confirms the existence of the EKC for the ECA region. The U-shaped inverted relationship between GDP per capita and $CO_2$ emissions for ECA countries is also confirmed by Salahodjaev et al. [48] and Bibi and Jamil [49]. However, the estimated turning point is approximately 125,000 international dollars, which is considerably above of that in our sample. In our data, the highest GDP per capita is reported for Luxemburg in 2007 at the level of approximately 115,000 international dollars. Therefore, our results suggest that ECA countries have not reached the turning point yet, and further economic growth exerts carbon footprint on the environment. Turning points above existing levels of economic development are common in related studies. For example, Pata [50] tests the presence of the EKC framework for Turkey durring the period 1971–2014. The results confirmed an inverted U-shaped relationship between GDP per capita and $CO_2$ emissions. However, the estimated vertex is outside the data period.

In Table 4 we test the robustness of our core results by adding additional control variables. In column 1, we include the Internet penetration rate as there is evidence that ICT is linked to $CO_2$ emissions. Furthermore, World Bank data suggest that the share of Internet users increased from 13% in 2000 to 84% in 2020 (https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=Z7, accessed on 10 July 2022). The results suggest that a 10% increase in Internet users leads to a 0.6% increase in $CO_2$ emissions. Indeed, in the case of OECD member states, Salahuddin et al. [51] also find that Internet penetration has a marginal impact on $CO_2$ emissions. Taking into account the low level of significant and small parameters, we believe that ICT penetration should be viewed as a substantial environmental threat in the ECA region.

**Table 4.** Robustness test.

| | I | II | III | IV |
|---|---|---|---|---|
| IND | 0.0022 | 0.0032 | 0.0033 | 0.0061 |
| | (1.69) * | (2.86) *** | (3.36) *** | (4.14) *** |
| RE | −0.0033 | −0.0030 | −0.0027 | −0.0057 |
| | (5.96) *** | (3.98) *** | (2.58) ** | (4.34) *** |
| IND * RE | −0.0003 | −0.0002 | −0.0001 | −0.0002 |
| | (6.80) *** | (4.27) *** | (2.82) *** | (2.99) *** |
| ICT | 0.0006 | | | |
| | (1.83) * | | | |
| FDI | | 0.0001 | 0.0001 | |
| | | (2.99) *** | (2.14) ** | |
| EXP | | | 0.0002 | −0.0009 |
| | | | (0.71) | (1.81) * |
| TEXP | | | | −0.0037 |
| | | | | (3.97) *** |
| Constant | −0.2783 | −2.4640 | −2.4015 | −4.3507 |
| | (0.30) | (1.51) | (1.32) | (1.55) |
| AR (1) | 0.001 | 0.001 | 0.001 | 0.001 |
| AR (2) | 0.916 | 0.604 | 0.433 | 0.908 |
| Hansen $p$-value | 0.389 | 0.462 | 0.386 | 0.865 |
| Fisher $p$-value | 0.000 | 0.00 | 0.000 | 0.000 |
| Number of countries | 48 | 48 | 48 | 45 |
| $N$ | 833 | 836 | 835 | 685 |

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Baseline controls are included but not reported.

Column 2 adds FDI as % of GDP to capture the relationship between foreign capital and environmental degradation. FDI trends in ECA exhibited significant volatility over the period 2000-2018, peaking at nearly 9% of GDP in 2007 (https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS?most_recent_value_desc=false&locations=Z7, accessed on 10 July 2022). For example, Salahodjaev and Isaeva [52], using data from post-Communist countries, find that FDI has a positive effect on $CO_2$ emissions. Our results are in line with Salahodjaev and Isaeva [52] and Blanco et al. [53]. In column 3, we use exports as % of GDP as an alternative proxy for trade openness. Exports are insignificantly related to $CO_2$ emissions, while our main results are not affected. Apart from exports, studies show that the tourism sector is linked to environmental degradation across various groups of countries. For instance, a significant link between tourism and exports is observed for Cyprus [54], South-East Asia [55], Turkey [56], and EU member states [57]. Tourism can increase $CO_2$ emissions via expansion of the transportation and services sector and increase in demand for food consumption. Thus, following the abovementioned studies and Paramati et al. [58], we take into account the effect of tourism on $CO_2$ emissions. We include tourism receipts as % of exports and find that tourism has a negative and significant effect on $CO_2$ emissions. The results in Table 4 show that renewable energy retains its negative effect on $CO_2$ emissions. Therefore, our main results remain robust.

## 5. Conclusions

Environmental degradation as expressed by rising GHG emissions has become one of the widely explored scholarly topics in the field of social sciences. In particular, scholars in the discipline of energy economics are particularly interested in examining the role that renewable energy can play in mitigating $CO_2$ emissions in different groups of countries. This study aims to empirically contribute to this ongoing research by exploring the moderating effect of renewable energy consumption in the relationship between industrialization and $CO_2$ emissions. More specifically, this study uses data from 48 countries in Europe and the Central Asia region over the period 2000–2018. Our study employs a two-step system GMM estimator as adopted by a number of the above-mentioned papers. Empirical results show that industrialization increases $CO_2$ emissions, while renewable energy has a significant negative impact on $CO_2$ emissions. Furthermore, our findings suggest that a shift to renewable energy consumption can offset the damaging effect of industrial policies on the environment. We also statistically confirm the existence of the EKC hypothesis in the ECA region, which suggests that the majority of countries have not reached the turning point yet. This study makes an essential contribution to related research as it (1) adds additional evidence to the research strand exploring the presence of the EKC hypothesis in countries and regions; (2) we statistically show that renewable energy can mitigate $CO_2$ emissions; and (3) we document that it can offset the negative effect of industrialization on environmental quality. Studies that were previously reviewed in our study mainly focus on the direct effects of renewable energy on $CO_2$ emissions.

Our study offers the following policy implications for governments in the ECA region. First, it is important to increase environmental awareness and improve perceptions of the use of renewable energy by households. For example, Central Asian countries have substantial potential to use solar and wind energy sources to power economic growth in remote rural areas. This may have significant spillover effects in other sectors such as tourism, services, health, and education. Second, to promote the shift to renewable energy use, it is important to create various legal and monetary incentives for the population and households. For example, tax rebates or zero-interest loans may be offered to the private sector to promote the rapid penetration of sustainable energy consumption in different industries. In addition, policymakers can use grants and subsidies which can help communities adopt renewable energy technologies.

The adoption of renewable energy technologies cannot be achieved without an increase in R&D spending. For example, greater public funds can be channeled to academic institutions via grants to conduct research on the socio-economic benefits of renewable energy consumption. In addition, companies engaged in environmental R&D should be also subject to tax cuts and low-interest loans.

This study has a number of limitations. First, we focused on the general effect of renewable energy and industrialization on $CO_2$ emissions in the ECA countries. Prospective studies should extend our main results by looking at separate countries in this sample. For example, countries in the ECA region have different renewable energy potentials. Therefore, the relationship between renewable energy consumption and $CO_2$ emissions may vary between countries. Second, future studies should consider the spillover effects that may exist, as suggested by published studies [59]. Finally, it is important to examine whether renewable energy can affect the relationship between other economic variables such as FDI, trade, or government spending, and $CO_2$ emissions. Prospective studies can extend our work in a number of ways. For example, several countries in the ECA region have a high level of personal remittances received. Therefore, it may be vital to test the link between remittances, renewable energy, and $CO_2$ emissions for these countries, as previous research shows that remittances may be another important determinant of $CO_2$ emissions [60]. Considering that we observe that renewable energy is important in mitigating $CO_2$ emissions, it may be important to explore the drivers of $CO_2$ emissions in the ECA region. Finally, our method does not allow us to assess the effect of renewable energy and industrialization on $CO_2$ separately for each country in the ECA region. Therefore, this remains an avenue for future research.

**Author Contributions:** Conceptualization, G.M., R.S., W.T. and M.D.; methodology, R.S. and G.M.; software, R.S.; validation, G.M., R.S., W.T. and M.D.; formal analysis, R.S.; writing—original draft preparation, G.M., R.S., W.T. and M.D.; writing—review and editing, G.M., R.S., W.T. and M.D. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The data are available from sources cited in the study.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations

Augmented mean group (AMG)
Autoregressive Distributed Lag (ARDL)
Brazil, Russia, India, China and South Africa (BRICS)
Carbon dioxide ($CO_2$)
Organization for Economic Co-operation and Development (OECD)
Environmental Kuznets curve (EKC)
European Union (EU)
Foreign direct investment (FDI)
Fully Modified OLS (FMOLS)
Gross domestic product (GDP)
Generalized method of moments (GMM)
Information and communication technologies (ICT)
Middle East and North Africa (MENA)
Non-linear autoregressive distributed lag (NARDL)
Organization of the Petroleum Exporting Countries (OPEC)
Pooled mean group (PMG)
Vector error correction model approach (VECM).

## References

1. Mentel, U.; Wolanin, E.; Eshov, M.; Salahodjaev, R. Industrialization and $CO_2$ Emissions in Sub-Saharan Africa: The Mitigating Role of Renewable Electricity. *Energies* **2022**, *15*, 946. [CrossRef]
2. Kuldasheva, Z.; Salahodjaev, R. Renewable Energy and $CO_2$ Emissions: Evidence from Rapidly Urbanizing Countries. *J. Knowl. Econ.* **2022**, 1–19. [CrossRef]
3. Shahbaz, M.; Bhattacharya, M.; Ahmed, K. $CO_2$ emissions in Australia: Economic and non-economic drivers in the long-run. *Appl. Econ.* **2017**, *49*, 1273–1286. [CrossRef]
4. Arouri, M.E.H.; Youssef, A.B.; M'Henni, H.; Rault, C. Energy consumption, economic growth and $CO_2$ emissions in Middle East and North African countries. *Energy Policy* **2012**, *45*, 342–349. [CrossRef]
5. Saboori, B.; Sulaiman, J.; Mohd, S. Economic growth and $CO_2$ emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve. *Energy Policy* **2012**, *51*, 184–191. [CrossRef]
6. Cherniwchan, J. Economic growth, industrialization, and the environment. *Resour. Energy Econ.* **2012**, *34*, 442–467. [CrossRef]
7. Shahbaz, M.; Solarin, S.A.; Sbia, R.; Bibi, S. Does energy intensity contribute to $CO_2$ emissions? A trivariate analysis in selected African countries. *Ecol. Indic.* **2015**, *50*, 215–224. [CrossRef]
8. Zhou, S.; Kyle, G.P.; Yu, S.; Clarke, L.E.; Eom, J.; Luckow, P.; Chaturvedi, V.; Zhang, X.; Edmonds, J.A. Energy use and $CO_2$ emissions of China's industrial sector from a global perspective. *Energy Policy* **2013**, *58*, 284–294. [CrossRef]
9. Zoundi, Z. $CO_2$ emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1067–1075. [CrossRef]
10. Kaika, D.; Zervas, E. The Environmental Kuznets Curve (EKC) theory—Part A: Concept, causes and the $CO_2$ emissions case. *Energy Policy* **2013**, *62*, 1392–1402. [CrossRef]
11. Murshed, M.; Nurmakhanova, M.; Elheddad, M.; Ahmed, R. Value addition in the services sector and its heterogeneous impacts on CO2 emissions: Revisiting the EKC hypothesis for the OPEC using panel spatial estimation techniques. *Environ. Sci. Pollut. Res.* **2020**, *27*, 38951–38973. [CrossRef] [PubMed]
12. Pata, U.K. Renewable energy consumption, urbanization, financial development, income and $CO_2$ emissions in Turkey: Testing EKC hypothesis with structural breaks. *J. Clean. Prod.* **2018**, *187*, 770–779. [CrossRef]
13. Iwata, H.; Okada, K.; Samreth, S. Empirical study on the determinants of $CO_2$ emissions: Evidence from OECD countries. *Appl. Econ.* **2012**, *44*, 3513–3519. [CrossRef]
14. Haseeb, A.; Xia, E.; Baloch, M.A.; Abbas, K. Financial development, globalization, and $CO_2$ emission in the presence of EKC: Evidence from BRICS countries. *Environ. Sci. Pollut. Res.* **2018**, *25*, 31283–31296. [CrossRef] [PubMed]
15. Szetela, B.; Majewska, A.; Jamroz, P.; Djalilov, B.; Salahodjaev, R. Renewable Energy and $CO_2$ Emissions in Top Natural Resource Rents Depending Countries: The Role of Governance. *Front. Energy Res.* **2022**, *10*, 242. [CrossRef]
16. Shahbaz, M.; Uddin, G.S.; Rehman, I.U.; Imran, K. Industrialization, electricity consumption and $CO_2$ emissions in Bangladesh. *Renew. Sustain. Energy Rev.* **2014**, *31*, 575–586. [CrossRef]
17. Pao, H.-T.; Fu, H.-C. Renewable energy, non-renewable energy and economic growth in Brazil. *Renew. Sustain. Energy Rev.* **2013**, *25*, 381–392. [CrossRef]
18. Ntanos, S.; Skordoulis, M.; Kyriakopoulos, G.; Arabatzis, G.; Chalikias, M.; Galatsidas, S.; Batzios, A.; Katsarou, A. Renewable Energy and Economic Growth: Evidence from European Countries. *Sustainability* **2018**, *10*, 2626. [CrossRef]
19. Koçak, E.; Şarkgüneşi, A. The renewable energy and economic growth nexus in Black Sea and Balkan countries. *Energy Policy* **2017**, *100*, 51–57. [CrossRef]

20. Sadorsky, P. Renewable energy consumption, $CO_2$ emissions and oil prices in the G7 countries. *Energy Econ.* **2009**, *31*, 456–462. [CrossRef]
21. Li, K.; Lin, B. Impacts of urbanization and industrialization on energy consumption/$CO_2$ emissions: Does the level of development matter? *Renew. Sustain. Energy Rev.* **2015**, *52*, 1107–1122. [CrossRef]
22. Amri, F. Renewable and non-renewable categories of energy consumption and trade: Do the development degree and the industrialization degree matter? *Energy* **2019**, *173*, 374–383. [CrossRef]
23. Abbasi, K.R.; Adedoyin, F.F.; Abbas, J.; Hussain, K. The impact of energy depletion and renewable energy on $CO_2$ emissions in Thailand: Fresh evidence from the novel dynamic ARDL simulation. *Renew. Energy* **2021**, *180*, 1439–1450. [CrossRef]
24. Chunark, P.; Limmeechokchai, B.; Fujimori, S.; Masui, T. Renewable energy achievements in $CO_2$ mitigation in Thailand's NDCs. *Renew. Energy* **2017**, *114*, 1294–1305. [CrossRef]
25. Rahman, M.M.; Alam, K.; Velayutham, E. Reduction of $CO_2$ emissions: The role of renewable energy, technological innovation and export quality. *Energy Rep.* **2022**, *8*, 2793–2805. [CrossRef]
26. İnal, V.; Addi, H.M.; Çakmak, E.E.; Torusdağ, M.; Çalışkan, M. The nexus between renewable energy, $CO_2$ emissions, and economic growth: Empirical evidence from African oil-producing countries. *Energy Rep.* **2022**, *8*, 1634–1643. [CrossRef]
27. Saidi, K.; Omri, A. Reducing $CO_2$ emissions in OECD countries: Do renewable and nuclear energy matter? *Prog. Nucl. Energy* **2020**, *126*, 103425. [CrossRef]
28. Chiu, C.-L.; Chang, T.-H. What proportion of renewable energy supplies is needed to initially mitigate $CO_2$ emissions in OECD member countries? *Renew. Sustain. Energy Rev.* **2009**, *13*, 1669–1674. [CrossRef]
29. Zaghdoudi, T. Oil prices, renewable energy, $CO_2$ emissions and economic growth in OECD countries. *Econ. Bull.* **2017**, *37*, 1844–1850.
30. Azam, A.; Rafiq, M.; Shafique, M.; Yuan, J. An empirical analysis of the non-linear effects of natural gas, nuclear energy, renewable energy and ICT-Trade in leading $CO_2$ emitter countries: Policy towards $CO_2$ mitigation and economic sustainability. *J. Environ. Manag.* **2021**, *286*, 112232. [CrossRef]
31. Yu, J.; Tang, Y.M.; Chau, K.Y.; Nazar, R.; Ali, S.; Iqbal, W. Role of solar-based renewable energy in mitigating $CO_2$ emissions: Evidence from quantile-on-quantile estimation. *Renew. Energy* **2022**, *182*, 216–226. [CrossRef]
32. Namahoro, J.; Wu, Q.; Zhou, N.; Xue, S. Impact of energy intensity, renewable energy, and economic growth on CO2 emissions: Evidence from Africa across regions and income levels. *Renew. Sustain. Energy Rev.* **2021**, *147*, 111233. [CrossRef]
33. De Souza Mendonça, A.K.; Barni, G.D.A.C.; Moro, M.F.; Bornia, A.C.; Kupek, E.; Fernandes, L. Hierarchical modeling of the 50 largest economies to verify the impact of GDP, population and renewable energy generation in $CO_2$ emissions. *Sustain. Prod. Consum.* **2020**, *22*, 58–67. [CrossRef]
34. Ding, Y.; Li, F. Examining the effects of urbanization and industrialization on carbon dioxide emission: Evidence from China's provincial regions. *Energy* **2017**, *125*, 533–542. [CrossRef]
35. Liu, X.; Bae, J. Urbanization and industrialization impact of $CO_2$ emissions in China. *J. Clean. Prod.* **2018**, *172*, 178–186. [CrossRef]
36. Xu, B.; Lin, B. How industrialization and urbanization process impacts on $CO_2$ emissions in China: Evidence from nonparametric additive regression models. *Energy Econ.* **2015**, *48*, 188–202. [CrossRef]
37. Mahmood, H.; Alkhateeb, T.T.Y.; Furqan, M. Industrialization, urbanization and $CO_2$ emissions in Saudi Arabia: Asymmetry analysis. *Energy Rep.* **2020**, *6*, 1553–1560. [CrossRef]
38. Musa, K.S.; Maijama'a, R.; Yakubu, M. The causality between urbanization, industrialization and $CO_2$ emissions in Nigeria: Evidence from Toda and Yamamoto Approach. *Energy Econ. Lett.* **2021**, *8*, 1–14. [CrossRef]
39. Appiah, M.; Li, F.; Korankye, B. Modeling the linkages among $CO_2$ emission, energy consumption, and industrialization in sub-Saharan African (SSA) countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 38506–38521. [CrossRef]
40. Martínez-Zarzoso, I.; Bengochea-Morancho, A.; Morales-Lage, R. The impact of population on $CO_2$ emissions: Evidence from European countries. *Environ. Resour. Econ.* **2007**, *38*, 497–512. [CrossRef]
41. Munksgaard, J.; Pade, L.L.; Minx, J.; Lenzen, M. Influence of trade on national $CO_2$ emissions. *Int. J. Glob. Energy Issues* **2005**, *23*, 324–336. [CrossRef]
42. Asongu, S.A.; Le Roux, S.; Biekpe, N. Enhancing ICT for environmental sustainability in sub-Saharan Africa. *Technol. Forecast. Soc. Change* **2018**, *127*, 209–216. [CrossRef]
43. Muhammad, B.; Khan, S. Understanding the relationship between natural resources, renewable energy consumption, economic factors, globalization and $CO_2$ emissions in developed and developing countries. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Oxford, UK, 2021; Volume 45, No. 2; pp. 138–156.
44. Arellano, M.; Bover, O. Another look at the instrumental variable estimation of error-components models. *J. Econ.* **1995**, *68*, 29–51. [CrossRef]
45. Alam, J. Impact of agriculture, industry and service sector's value added in the GDP on $CO_2$ emissions of selected South Asian countries. *World Rev. Bus. Res.* **2015**, *5*, 39–59.
46. Isaeva, A.; Salahodjaev, R.; Khachaturov, A.; Tosheva, S. The Impact of Tourism and Financial Development on Energy Consumption and Carbon Dioxide Emission: Evidence from Post-communist Countries. *J. Knowl. Econ.* **2022**, *13*, 773–786. [CrossRef]
47. Heinbach, K.; Aretz, A.; Hirschl, B.; Prahl, A.; Salecki, S. Renewable energies and their impact on local value added and employment. *Energy, Sustain. Soc.* **2014**, *4*, 1. [CrossRef]
48. Salahodjaev, R.; Sharipov, K.; Rakhmanov, N.; Khabirov, D. Tourism, renewable energy and $CO_2$ emissions: Evidence from Europe and Central Asia. *Environ. Dev. Sustain.* **2022**, 1–12. [CrossRef]

49. Bibi, F.; Jamil, M. Testing environment Kuznets curve (EKC) hypothesis in different regions. *Environ. Sci. Pollut. Res.* **2021**, *28*, 13581–13594. [CrossRef]
50. Pata, U.K. The influence of coal and noncarbohydrate energy consumption on $CO_2$ emissions: Revisiting the environmental Kuznets curve hypothesis for Turkey. *Energy* **2018**, *160*, 1115–1123. [CrossRef]
51. Salahuddin, M.; Alam, K.; Ozturk, I. The effects of Internet usage and economic growth on $CO_2$ emissions in OECD countries: A panel investigation. *Renew. Sustain. Energy Rev.* **2016**, *62*, 1226–1235. [CrossRef]
52. Salahodjaev, R.; Isaeva, A. Post-Soviet states and $CO_2$ emissions: The role of foreign direct investment. *Post-Communist Econ.* **2021**, 1–22. [CrossRef]
53. Blanco, L.; Gonzalez, F.; Ruiz, I. The impact of FDI on $CO_2$ emissions in Latin America. *Oxf. Dev. Stud.* **2013**, *41*, 104–121. [CrossRef]
54. Katircioglu, S.T.; Feridun, M.; Kilinc, C. Estimating tourism-induced energy consumption and $CO_2$ emissions: The case of Cyprus. *Renew. Sustain. Energy Rev.* **2014**, *29*, 634–640. [CrossRef]
55. Sherafatian-Jahromi, R.; Othman, M.S.; Law, S.H.; Ismail, N.W. Tourism and $CO_2$ emissions nexus in Southeast Asia: New evidence from panel estimation. *Environ. Dev. Sustain.* **2017**, *19*, 1407–1423. [CrossRef]
56. Eyuboglu, K.; Uzar, U. The impact of tourism on $CO_2$ emission in Turkey. *Curr. Issues Tour.* **2020**, *23*, 1631–1645. [CrossRef]
57. Paramati, S.R.; Alam, S.; Lau, C.K.M. The effect of tourism investment on tourism development and $CO_2$ emissions: Empirical evidence from the EU nations. *J. Sustain. Tour.* **2018**, *26*, 1587–1607. [CrossRef]
58. Paramati, S.R.; Alam, M.S.; Chen, C.-F. The Effects of Tourism on Economic Growth and $CO_2$ Emissions: A Comparison between Developed and Developing Economies. *J. Travel Res.* **2017**, *56*, 712–724. [CrossRef]
59. Shahnazi, R.; Shabani, Z.D. The effects of renewable energy, spatial spillover of $CO_2$ emissions and economic freedom on $CO_2$ emissions in the EU. *Renew. Energy* **2021**, *169*, 293–307. [CrossRef]
60. Khan, Z.U.; Ahmad, M.; Khan, A. On the remittances-environment led hypothesis: Empirical evidence from BRICS economies. *Environ. Sci. Pollut. Res.* **2020**, *27*, 16460–16471. [CrossRef]