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The Role of Renewable Energy and Human Capital in Reducing Environmental Degradation in Europe and Central Asia: Panel Quantile Regression and GMM Approach

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Abstract: Environmental sustainability concerns are growing worldwide. Reducing carbon dioxide (CO_2) emissions is crucial to combating global warming and reaching sustainable global economic development. Many recent studies have focused on key indicators of CO_2 emissions, but less consideration has been given to associated factors such as renewable energy and human capital. This article applies the two-step system FOD-GMM (Forward-Orthogonal Deviations-Generalized Method of Moments) to estimate the role of renewable energy and human capital in reducing environmental degradation in Europe and Central Asia. The results reveal that renewable energy consumption and human capital have a significant negative impact on CO_2 emissions in the EU and Central Asian countries, government efficiency has a positive effect on CO_2 emissions, and economic development has a neutral effect, confirming the strong role of renewable energy and human capital in reducing CO_2 emissions in EU and Central Asian countries. The role of human capital and renewable energy in promoting CO_2 reduction should be fully utilized. Policymakers should develop infrastructure for renewable energy and education to support the decrease in CO_2 emissions in Europe and Central Asia.

Keywords: renewable energy; human capital; government effectiveness; economic development; CO_2; Central Asia; Europe

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1. Introduction

Due to human activities, the concentration of carbon dioxide in the atmosphere has reached dangerous levels [1]; consequently, this increase contributes to the frequency and intensity of extreme events [2]. The Paris Agreement, a legally binding international agreement [3] on climate change adopted in 2016 by 196 countries to limit global warming to well below 2 °C or 1.5 °C, has been a key mitigation strategy [1,4]. In order to achieve this goal, it is important to focus on reducing environmental degradation, in particular reducing carbon emissions [2,3]. In the literature, economic growth, trade openness, industrialization, foreign direct investment, and emission taxes have mainly been studied as factors impacting on reducing environmental degradation [4–6]. However, despite its significance, little is understood about how environmental sustainability is attained and how human capital development helps to lessen environmental damage. Human development is relevant in the context of environmental sustainability, since any kind of mitigation measures need human comprehension of the environment, climate change, and its effects [7]. It is known that human development and a healthy lifestyle depends on education, which increases people's responsibility for environmental sustainability and teaches them how to protect their surroundings [8]. People with higher levels of education and skill are more likely to follow environmental legislation [9].

In the new millennium, the biggest threat to every nation on the planet is climate change. In order to truly address the global environmental challenge posed by the need to reduce global CO_2 output, there must be a global response; otherwise, the ongoing upward trend in CO_2 emissions will only worsen [10]. There are many different causes of excessive carbon emissions. According to research by the World Health Organization, aggravating outdoor air pollution results in around 4.2 million premature deaths year [11]. According to the International Energy Agency (IEA), worldwide CO_2 emissions from energy sources have stabilized at approximately 33 billion tons in 2019, nearly unchanged from the previous year [12], following a two-year rise. A one-year CO_2 emission freeze, however, does not signify that global emissions have peaked, given that the global GDP decreased during the COVID-19 epidemic shutdowns that impacted numerous economies. But it is an indication that the economies of the world can trust that reducing global warming would increase the likelihood that future economic output and human well-being will not reach catastrophic levels [13]. The rise in the use of green fuel sources for the production of electricity has contributed to a reduction in the global expansion of emissions. For instance, the IEA discovered that, compared to 2018, there was an approximately 200 Mt decrease in global CO_2 emissions due to a decrease in the use of coal to generate power globally in 2019.

Natural resources, economic growth, and their impact on Central Asia's environmental quality are all available in the literature. Few of them, nevertheless, looked at how human capital affected the Eurasian territory from the nexus viewpoint. This study aims to fill the gap in existing research by examining the relationship between human capital development and its impact on reducing environmental degradation, particularly in the context of CO_2 emissions. Environmental degradation has already become a global problem in the world both in developing and developed countries. There are several factors that have a relationship with CO_2, such as economic development, renewable and no-renewable energy, government effectiveness, human capital, and others. A few examples of the things that are at risk from climate change are the health of people and animals, the security of food and water, and the stability of the economy. Renewable energy has emerged as a crucial weapon in the fight against this global issue and is starting to take center stage in the transformation of energy systems. The need for energy consumption in all its forms has been seen as a necessary complement to other factor inputs, like labor and capital, in the economies' production processes [14]. According to the International Energy Report, if decisive actions are not implemented, energy-related CO_2 emissions would quadruple by 2050, and rising trends in oil demand will exacerbate the problems with energy security and postpone one of the most important SDGs (Sustainable Development Goal 13) [12]. It is significant to note that, despite the sector's remarkable growth, notably for solar and wind power, the share of REC in total energy consumption has increased very slightly in recent years. With a relative contribution of 54% for hydroelectricity and 26% for wind energy, respectively, the renewable portion of global power generation is anticipated to rise from 18% in 2007 to 23% in 2035, and it means that renewable energy consumption is believed to be one of the main factors of decreasing carbon dioxide emissions [15].

As the world is becoming more concerned about environmental sustainability, CO_2 emissions indicators have been the subject of numerous recent studies, but the connection with human capital has received less attention. The link between human capital and CO_2 emissions has been found to be negative at the microlevel through a number of routes. The innovative technologies and emission-reducing approaches in the manufacturing industry are introduced by more qualified and educated people [16]. As human capital and environmental degradation are more likely to be long-term oriented, more human capital-rich firms are better suited to promote sustainable development [17]. As a result, industrial firms typically have more stringent pollution controls and larger human capital reserves. Additionally, it is less probable that they will disregard outside environmental regulations. The contribution of human capital to environmental deterioration is substantial since education modifies people's attitudes towards the environment and enables them to make positive changes to it; highly educated households appreciate the environment significantly more than less educated or illiterate households [18]. Furthermore, households with higher levels of education are more likely to prefer energy-efficient home equipment [12,19] and minimize energy consumption overall [20]. However, because there are so many opposing ways that human capital could affect CO_2 releases, the macro-level relationship between it and CO_2 emissions is more complicated. It has been noted that there are three different ways that physical capital, wealth, and technology may all have an impact on environmental quality [21]. The link between human capital and CO_2 emissions may be mediated by economic development.

2. Literature Review

2.1. Renewable Energy and CO_2 Emissions

It is widely accepted that boosting the use of renewable energy is a useful strategy for encouraging the reduction of CO_2 emissions. Consuming energy from renewable sources has thus emerged as one of the most effective substitute tactics for sustainable growth [22]. Seven East African countries (EACs) have had their asymmetric relationship between CO_2 emissions and renewable energy, as well as their economic and population growth, examined at the regional and national levels. The results show that the consumption of renewable energy has a negative impact on CO_2 emissions [23]. In response, ref. [24] examined the asymmetric relationship between CO_2 emissions and solar energy consumption in the top ten solar-consuming nations, highlighting the need to integrate renewable energy sources for environmental quality and sustainable growth.

In the Portugal example, ref. [25] used wavelet analysis to support the idea that using renewable energy can reduce CO_2 emissions over the medium and long term in the nation. Additionally, ref. [22] uses the 3SLS model to perform an empirical investigation on the relationships between the BRICS countries' real output, consumption of renewable energy, and CO_2 emissions (apart from Russia). Notably, ref. [26] uses the Dumitrescu–Hurlin test for the next 11 countries to find a bidirectional causal relationship between CO_2 emissions and renewable energy. Similarly, in the 39 developing countries that were chosen, ref. [27] demonstrated through the use of the Environmental Kuznets curve (EKC) hypothesis that the use of renewable energy sources significantly lowers emissions over time. Accordingly, ref. [28] studied this relationship in Uzbekistan, as the country's economy highly depends on non-renewable energy (97.3%). Ref. [29] raised the unidirectional causal effect between the consumption of hydropower (renewable) energy and CO_2 emissions per capita, recommending to lower CO_2 emissions through the implementation of effective carbon price laws and the participation of the private sector in renewable energy projects.

2.2. Human Capital and CO_2 Emissions

Increasing education is essential to halting environmental deterioration and maintaining the viability of economic growth. Ref. [30] makes the case that human capital levels influence how economic development affects CO_2 emissions. Ref. [31] investigated the possibility that increases in human capital are linked to better environmental quality through lower CO_2 emissions. However, ref. [32] pointed out that human capital can inversely regulate the impact of CO_2 emissions and that internet usage is one of the key drivers of the development of a low-carbon economy.

Ref. [33] investigates the relationship between human capital and CO_2 emissions in the economies of Brazil, Russia, India, China, and South Africa (BRICS). It finds that improvements in education have a long-term beneficial effect on CO_2 emissions, while long-term negative changes in education have an adverse effect. Similarly, ref. [34] demonstrated that in the BRICS nations, renewable energy lowers emissions and restores environmental sustainability. According to [35], the Belt and Road countries stand to benefit greatly from technology transfer, the use of renewable energy sources, and human capital as means of reducing carbon dioxide emissions. Ref. [36] found that creative human capital reduces environmental degradation in China, suggesting that if China keeps building its creative human capital, its economic growth will eventually support environmental sustainability. In fact, ref. [37] brought up that technology greatly reduces CO_2 emissions, the impact of wealth on CO_2 emissions shows an inverted U-shape trend, and the population growth exacerbates CO_2 emissions. Furthermore, ref. [38] examines the relationship in Central Asian states between natural resources, economic growth, human capital, and CO_2 and demonstrates that, both short- and long-term, human capital has a significant and opposite association with CO_2.

2.3. Government Effectiveness and CO_2 Emissions

The interaction between institutional factors and the environment is essential to secure sustainable development. Ref. [39] raised that political stability, government effectiveness, democracy, and the control of corruption influence CO_2 emissions negatively. Ref. [40] investigates the connection between carbon dioxide (CO_2) emissions and five aspects of good governance—political stability, government efficacy, regulatory quality, rule of law, and corruption—in a sample of 99 developing nations. The findings confirm that, in the case of developing nations, these five factors have a negative and statistically significant correlation with CO_2 emissions per capita.

In the case of South Asian countries (India, Pakistan, Sri Lanka, and Bangladesh), according to [41], a 1% increase in governance results in a 7.68% decrease in carbon emissions. As for BRICS countries, ref. [42] discovered that long-term increases in government stability, law and order, and corruption have a negative effect on carbon emissions. Through an analysis of 44 sub-Saharan African nations, ref. [43] explores the role that governance dynamics such as political stability, voice and accountability, government effectiveness, regulation quality, rule of law, and corruption-control play in moderating environmental degradation. Ref. [44] evaluated 93 emerging and developing nations, noting that those with highly effective governments saw statistically significant drops in CO_2 emissions. However, as [45] point out, there can be both positive and negative effects of government effectiveness in reducing carbon emissions in both developed and developing nations.

2.4. Economic Development and CO_2 Emissions

Environmental degradation has become one of the most worrying problems in the global setting over the last few decades. Economic development has also been the main goal of all countries since it leads to increasing the quality of living conditions, but is likewise considered as the main reason for rising CO_2 emissions, which is the main factor of environmental degradation [46]. Numerous studies have examined the relationship between environmental degradation and economic development, with varying degrees of success. Ref. [47] examined the connections between CO_2, renewable and non-renewable energy sources, and economic growth using data from 28 developed and developing nations. They discovered that while there is a two-way causal relationship between the consumption of renewable and nonrenewable energy in developed countries, there is no significant correlation between economic growth and energy consumption in developing countries. Research has demonstrated that in Pakistan, long-term economic growth is slowed down by positive shocks to carbon dioxide emissions, while short- and long-term growth is accelerated by negative shocks [48]. A study on the long-term cointegration relationship between China's economic growth and CO_2 emissions notes that the country's economic growth has a strong predictive ability for CO_2 emissions. In [49,50], the authors investigated the relationship between economic growth and environmental degradation in the context of Turkey, discovering that financial development and energy consumption have long-term positive and statistically significant effects on CO_2 emissions, and economic expansion has a statistically significant negative impact on CO_2 emissions. Ref. [51] examined the relationship between economic development and environmental degradation in Central Asian nations, finding that while trade openness and the value added of agriculture had negative and statistically significant effects on CO_2 emissions in the countries under consideration, economic growth had positive long-term effects on CO_2 emissions.

3. Methodology

To empirically explore the relation among CO_2 emissions, renewable energy consumption, human capital, government effectiveness, and economic development, an unbalanced panel dataset is built containing 27 European Union and 5 Central Asian countries, spanning the period 1996–2021. The wide geographic coverage and 25-year time span ensures the novelty of the research. In the study, CO_2 emissions (measured in metric tons per capita) are the dependent variable, whereas renewable energy consumption (measured in the percentage of total energy consumption) and the human development index (proxy for human capital, measured in index) are used as the independent variables. Government effectiveness (measured as index) and GDP per capita (measured in constant 2015 USD) are employed as the control variables. The data of CO_2 emissions, renewable energy consumption, government effectiveness, and GDP per capita are obtained from World Development Indicators, while the human development index is downloaded from the United Nations Development Program. Table 1 provides a definition and sources of the employed variables.

Table 1. Definition and sources of the variables.

Variable Type	Notation	Name	Definition	Source
Dependent variable	CO_2	CO_2 emissions	CO_2 emissions in metric tons per capita	World Development Indicators
Independent variable	REN	Renewable energy	Renewable energy consumption, % of total final energy consumption	World Development Indicators
	HC	Human Capital	Human development index	United Nations Development Program
	GEF	Government effectiveness	Index of Government Effectiveness: Estimate	World Development Indicators
	PGDP	Economic development stage	GDP per capita (constant 2015 US$)	World Development Indicators

According to the descriptive statistics of the variables given in Table 2, an average of 7.30 metric ton CO_2 emissions per capita is emitted in European Union and Central Asian countries during the period 1996–2021. The consumption of renewable energy is 19.62% in the total energy consumption on average. The Human Development Index counts as 0.83 on average. The index of government effectiveness is averagely 0.80. The GDP per capita is 24,391.38 USD on average. The standard deviations of CO_2 (3.81) and renewable energy consumption (19.00) are high, whereas the standard deviation of per capita GDP is huge, and is counted as 20,965.41. The standard deviations of the Human Development Index (0.08) and government effectiveness index (0.93) are nearly around the mean. In order to estimate the impact of renewable energy, human capital, government effectiveness, and economic development on CO_2 emissions in EU and CA countries, the baseline model can be used as (1):

$$CO_{2i,t} = a_0 + a_1 REN_{i,t} + a_2 HC_{i,t} + a_3 X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where CO_2 represents carbon dioxide emissions; REN is renewable energy consumption; and HC is human capital. X is a vector of control variables including government effectiveness (GEF) and economic development (PGDP); i is cross-sections; t is time period; and ε is an error term.

Table 2. Descriptive statistics of the studied variables.

	CO_2	REN	HC	GEF	PGDP
Mean	7.30	19.62	0.83	0.80	24,391.38
Standard deviation	3.81	19.00	0.08	0.93	20,965.41
Minimum	0.32	0	0.50	−1.64	371.83
Maximum	25.60	0.82	0.94	2.35	112,417.9
Observations	768	768	819	768	830

In the economic system, fluctuations are affected by factors such as financial crises, natural disasters, and political conflicts, which are unexpected and often cause the economic data to be heterogeneous. Employing the OLS estimator for heterogeneous data may give a misleading guide since the OLS estimator takes average associations into consideration between variables. For this reason, the study applies panel versions of the two-step system FOD-GMM (Forward-Orthogonal Deviations- Generalized Method of Moments) Arellano and Bover [52] and quantile regression [53] models for heterogeneous data to investigate the linear impact of renewable energy, human capital, government effectiveness (GEF), and economic development (PGDP) on CO_2 emissions in EU and CA countries.

The two-step system FOD-GMM estimator manages to control the joint endogeneity of explanatory variables by using internal instruments. For model selection, the presence of autocorrelation is checked following Arellano and Bond (1991) [54], and instrument overidentification is carried out by the Sargan–Hansen test. This estimator is effective when working with an unbalanced panel dataset, and the number of cross-sections are higher than the number of observations (N > T). Regarding the panel quantile regression model, it allows us to test the possible heterogeneity and asymmetry of the explanatory variables at different positions in the conditional distribution of the explained variables. Both methods do not have to obey the assumptions of OLS such as the zero mean, equal variance, and normal distribution.

A two-step version of the GMM estimator can be described as follows (Equations (2) and (3)):

$$CO_{2i,t} = \sigma_0 + \sigma_1 CO_{2i,t-\tau} + \sigma_2 REN_{i,t} + \sigma_3 HC_{i,t} + \sum_{h=1}^{k} \gamma_h X_{h,i,t-\tau} + v_{i,t} \tag{2}$$

$$CO_{2i,t} - CO_{2i,t-\tau} = \sigma_1 (CO_{2i,t-\tau} - CO_{2i,t-2\tau}) + \sigma_2 (REN_{i,t} - REN_{i,t-\tau}) + \sigma_3 (HC_{i,t} - HC_{i,t-\tau}) + \sum_{h=1}^{k} \delta_h (X_{h,i,t-\tau} - X_{h,i,t-2\tau}) + (v_{i,t} - v_{i,t-\tau}) \tag{3}$$

where σ are the coefficients to be estimated, X is the vector of control variables (GEF, PGDP), τ is a lag order, and v is the two-way disturbance term.

The panel quantile regression model can be prescribed in Equation (4).

$$Q_{CO_{2i,t}}(\tau | x_{i,t}) = \beta_0 + \beta_1 REN_{i,t} + \beta_2 HC_{i,t} + \beta_4 X_{i,t} + \varepsilon_{i,t} \tag{4}$$

where $Q_{logCO_{2i,t}}(\tau | x_{i,t})$ is the quantile distribution of $CO_{2i,t}$ (explained variable), which is constrained by the position of the explanatory and control variables, and τ represents the quantile of each section (i).

An important aspect for the consideration to employ the GMM estimator and panel quantile regression model is to test for heteroskedasticity. For the heteroskedasticity test, we use White's test [54,55].

4. Results

Firstly, we run a test for the multicollinearity (Table 3) between CO_2 emissions (CO_2), renewable energy consumption (REN), human capital (HC), government effectiveness (GEF), and per capita GDP (PGDP). Since the values of VIF (Variance Inflation Factor) for all studied variables are lower than 10, we consider that there is no multicollinearity between the explained (CO_2) and explanatory variables (REN, HC, GEF, PGDP).

Table 3. The results of multicollinearity test.

Variable	VIF	1/VIF
REN	1.05	0.95
HC	3.85	0.25
GEF	4.40	0.22
PGDP	2.25	0.44
Mean VIF	2.89	

For the multicollinearity test, we report VIF values. The assumption of no-multicollinearity is verified if the VIF value is lower than 10.

As a next step, a test for heteroskedasticity is conducted. To this end, we apply White's test [55], whose results are given in Table 4. According to the results, there is a presence of heteroskedasticity in the data.

Table 4. The results of White's test for heteroskedasticity.

White's Test	
Ho: homoskedasticity	chi2 (35) = 129.59
against Ha: unrestricted heteroskedasticity	Prob > chi2 = 0.00

For White's test for heteroskedasticity, we report the p-value of chi-square. The null hypothesis is that the data are homoscedastic, whereas the alternative hypothesis means that the data are heteroskedastic. The null hypothesis is rejected if the *p*-value is lower than 0.05.

The existence of heteroskedasticity allows us to develop the two-step system FOD-GMM estimator and quantile regression model. In the estimations, we complete estimations with a common sample of both EU and CA countries, and divide the sample by the group of EU and CA countries. To run the estimations by the group of EU and CA countries, we introduce a dummy as 1 if it is a CA country, and 0 if otherwise. In this case, the coefficients integrated with a dummy refer to the results for CA countries, whereas the baseline coefficients denote the results for EU countries.

According to the results of Model 1 (Table 5) obtained by a two-step version of the FOD-GMM estimator, both renewable energy (REN) and human capital (HC) have a significant and negative impact on CO_2 emissions (CO_2) in the common sample of EU and CA countries, whereas government effectiveness (GEF) positively impacts on CO_2 emissions (CO_2). Economic development (PGDP) has a neutral effect on CO_2 emissions (CO_2), which validates the strong role of renewable energy (REN) and human capital (HC) in reducing CO_2 emissions (CO_2) in EU and CA countries.

Model 2 shows that renewable energy (REN) has no impact on CO_2 emissions (CO_2) when the estimation is run dividing the sample of EU and CA countries with dummies. Moreover, the incoherence appears also for the effect of human capital (HC) on CO_2 emissions (CO_2), and the association is negative in EU countries whereas it is positive in CA countries. Government effectiveness (GEF) positively influences on CO_2 emissions (CO_2) in EU countries, while there is no effect in CA countries. Economic development (PGDP) has no impact on the CO_2 emissions (CO_2) in both economies.

Table 5. The estimation results of the two-step system FOD-GMM estimator in EU and CA countries.

Dependent Variable CO_2 Emissions (CO_2)		
Independent Variables	**Model 1**	**Model 2**
	Coefficients	
$CO_2(-1)$	0.93 ***	0.85 ***
REN	−0.01 ***	−0.01
HC	−5.60 ***	−7.59 **
GEF	0.72 ***	1.16 **
PGDP	0.00 ***	0.00 *
REN × CA		0.02
HC × CA		13.65 ***
GEF × CA		−0.56
PGDP × CA		−0.00 **
constant	3.90 ***	4.26 ***
AR(1)	0.00	0.00
AR(2)	0.16	0.16
Sargan–Hansen test	0.12	0.25
Number of groups > linear moment conditions	32 > 26	32 > 29

Notes: ***, **, and * denote statistically significant coefficients at the 1%, 5%, and 10% levels, respectively. The coefficients of variables, non-interacted with dummies in Model 2, refer to EU economies. CA refers to the corresponding dummies. Lines AR(1) and AR(2) include the p-value of the Arellano–Bond test for residual correlation, with the expectation of rejecting the null at lag 1, but not at lag 2. We also report the p-value of the Sargan–Hansen overidentification test, which shows no overidentifying restrictions.

5. Discussion

Although the results gained by the means of the two-step version of the FOD-GMM estimator consider heteroskedasticity, the incoherence motivates us to run the estimations by employing the panel quantile regression model.

Table 6 represents the results of the common sample for EU and CA countries with the panel quantile regression model. According to the estimated coefficients, renewable energy (REN) has a significant and negative impact on CO_2 emissions (CO_2) across all quantiles, and in POLS results as well. The human capital (HC) significantly and positively impacts on CO_2 emissions (CO_2) in quantile 15% and 65%. There is no effect between CO_2 emissions (CO_2) and human capital (HC) in other quantiles or the POLS model. The association between CO_2 emissions (CO_2) and government effectiveness (GEF) varies across quantiles. More specifically, the relationship is negative in quantiles 5%, 65%, 75%, and 85%, whereas it is positive in quantiles in 25% and 35%. The association is marginally significant and negative due to the POLS model. Regarding the economic development (PGDP), the relation is highly significant, but it shows a neutral effect on CO_2 emissions (CO_2) across all quantiles and the POLS method since it is equal to 0.

According to the results provided in Table 7 with the panel quantile regression model, renewable energy (REN) significantly and negatively impacts on CO_2 emissions (CO2) in the case of EU countries across all quantiles and the POLS method. The association of the CA case shows that renewable energy (REN) has a significant and negative effect with CO_2 emissions (CO_2) in quantile 5% and the POLS method. The relation between CO_2 emissions (CO_2) and human capital (HC) is significant and negative in quantiles 5%, 25%, 35%, 45%, 95%, and the POLS method in EU countries, whereas the association is always significant and negative in all quantiles and the POLS method in CA countries. The relation between CO_2 emissions (CO_2) and government effectiveness (GEF) is positive in quantiles 5%, 35%, 55%, and 95%, and there is no effect according to the POLS method in EU. In CA, all quantiles and the POLS method show that the association is significant and negative. In both EU and CA, economic development (PGDP) has a significant and neutral effect on CO_2 emissions (CO_2) across all quantiles and in the POLS method.

Table 6. The estimated coefficients by the means of quantile regression in the common sample of EU and CA countries.

Dependent Variable CO_2 Emissions (CO_2)											
	QR										POLS
	Percentile										
Independent Variables	5%	15%	25%	35%	45%	55%	65%	75%	85%	95%	
REN	−0.05 ***	−0.05 ***	−0.06 ***	−0.06 ***	−0.06 ***	−0.06 ***	−0.07 ***	−0.08 ***	−0.05 **	−0.03 **	−0.07 ***
HC	−0.42	6.86 **	−0.06	0.35	0.18	2.62	8.30 **	8.02	9.36	−4.18	2.08
GEF	−0.50 **	0.47	0.48 **	0.32 **	0.30 *	0.05	−0.94 ***	−1.53 ***	−2.23 **	−0.82	−0.46 *
PGDP	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
Constant	3.18 **	−1.31	4.15 **	4.19 ***	4.65 ***	3.28	−0.54	0.78	1.23	14.57 **	4.28 **
N	664	664	664	664	664	664	664	664	664	664	664
R^2	0.39	0.30	0.29	0.29	0.28	0.26	0.22	0.21	0.20	0.33	0.46

Note: The asterisks *, **, *** show statistical significance at 10%, 5%, and 1% level, respectively.

Table 7. The estimated coefficients by means of quantile regression separately by the groups of EU and CA countries.

Dependent Variable CO_2 Emissions (CO_2)											
	QR										POLS
	Percentile										
	5%	15%	25%	35%	45%	55%	65%	75%	85%	95%	
REN	−0.03 ***	−0.04 ***	−0.05 ***	−0.05 ***	−0.05 ***	−0.05 ***	−0.05 ***	−0.04 ***	−0.03 **	−0.04 **	−0.04 ***
HC	−14.36 ***	−5.17	−8.46 ***	−7.46 ***	−5.86 ***	−3.25	−5.37	−8.22 *	−8.04	−28.04 ***	−12.22 ***
GEF	0.79 ***	0.14	0.23	0.52 ***	0.35 *	0.49 **	0.43	0.25	1.09 *	2.68 ***	0.60 **
PGDP	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
REN × CA	−0.05 ***	−0.01	−0.00 ***	−0.12	−0.12	−0.02	−0.01	−0.04	−0.05	−0.07	−0.03 **
HC × CA	−10.69 ***	−10.77 ***	−11.30 ***	−10.49 ***	−10.64 ***	−10.75 ***	−11.76 ***	−11.22 ***	−11.52 ***	−16.94 ***	−12.73 ***
GEF × CA	−3.98 ***	−3.79 ***	−4.00 ***	−4.28 ***	−4.35 ***	−5.15 ***	−5.02 ***	−4.40 ***	−5.21 ***	−6.36 **	−4.86 ***
PGDP × CA	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
Constant	14.41 ***	8.44 ***	10.92 ***	10.12 ***	9.05 ***	7.35 ***	9.84 ***	12.28 ***	12.72	31.38 ***	14.86
N	664	664	664	664	664	664	664	664	664	664	664
R^2	0.47	0.39	0.39	0.39	0.39	0.38	0.36	0.36	0.36	0.44	0.60

Note: The asterisks *, **, *** show significance at 10%, 5%, and 1% level, respectively. The coefficients of variables, non-interacted with dummies, refer to EU economies. CA refers to the corresponding dummies.

A limitation of the research could be the omitted variable problem. However, to the best knowledge of the authors, including additional variables into the estimations can affect the degree of freedom. On this occasion, the remaining potentially useful variables would be involved in future research works.

6. Conclusions

In this study, the influence of renewable energy consumption and human capital variables on CO_2 emissions was studied in the case of the European Union and Central Asian countries. According to the two-step system FOD-GMM results, renewable energy consumption and human capital have a significant negative impact on CO_2 emissions in the EU and Central Asian countries as a whole, government efficiency has a positive effect on CO_2 emissions, and economic development has a neutral effect, confirming the strong role of renewable energy and human capital in reducing CO_2 emissions in EU and Central Asian countries. When authors analyzed the assessment results separately for EU and Central Asian countries, it became evident that renewable energy has no effect on CO_2 emissions. To compare, the impact of human capital on CO_2 emissions is negative in EU countries while it is positive in Central Asian countries. Government efficiency has a positive effect on CO_2 emissions in EU countries, but no effect in Central Asian countries. The economic development control variable has no significant effect on CO_2 emissions in both economies.

In general, according to the results of primary calculations with the panel quantile regression model and the POLS method for the EU and Central Asian countries, renewable energy consumption has a significant and negative effect on CO_2 emissions in all quantiles and POLS results. Human capital has a significant and positive effect on CO_2 emissions in some quantiles, but no effect in other quantiles and in the POLS model. The relationship between CO_2 emissions and government efficiency is negative in the higher quantiles and positive in the lower quantiles, while it is significant and negative in the POLS model. As for economic development, this relationship is highly statistically significant, but it has a neutral effect on CO_2 emissions across all quantiles and the POLS method. Renewable energy consumption has a significant and negative impact on CO_2 emissions in EU countries across all quantiles and the POLS method. It shows that renewable energy has a significant and negative impact on CO_2 emissions in Central Asian countries at the 5% quantile and by the POLS method.

The relationship between CO_2 emissions and human capital is significant and negative in EU countries at 5%, 25%, 35%, 45%, 95%, and POLS, and is always significant and negative in all quantiles and POLS in Central Asian countries. In EU countries, the correlation between CO_2 emissions and government efficiency is positive in the higher quantiles, while there is no effect according to the POLS method. It shows that it is significant and negative in Central Asian countries according to all quantiles and the POLS method. In addition, economic development in the European Union and Central Asian countries has a significant and neutral effect on CO_2 emissions in all quantiles and in the POLS method. Policymakers should prioritize countries' CO_2 emissions reductions, primarily by increasing human capital and renewable energy consumption, as these factors are important factors in reducing CO_2 emissions for both economies.

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