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CO_2 Emissions, Remittances, Energy Intensity and Economic Development: The Evidence from Central Asia

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Abstract: Remittances are a crucial part of economic expansion, especially in Central Asia. Nevertheless, it is not possible to ignore its environmental damage. This paper is a pioneer in investigating the association among CO_2 emissions, remittances, energy consumption and economic development in Central Asian countries (Uzbekistan, Kazakhstan, Kyrgyzstan and Tajikistan) spanning the period of 1995–2022. As a methodology, the FMOLS estimator is applied to check linear impact and long-run association as well. Panel threshold regression model and 2SLS method are applied to examine potential non-linear relations among the studied variables. Hausman–Taylor and Amacurdy estimators are employed to control the endogeneity issue among the variables of interest. The results suggest the existence of a long-run relationship among the studied variables. Precisely, applying the FMOLS method, remittances negatively impact CO_2 emissions in the long run. The relationship between CO_2 emissions and remittances is distorted when the endogeneity issue is considered with the Panel threshold regression model, 2SLS method, and Hausman–Taylor and Amacurdy estimators. This distortion validates the linear impact of remittances on CO_2 emissions in CA. The Dumitrescu–Hurlin causality test shows that all independent variables have a causal effect on the dependent variable, validating the effect of the studied variables. Consequently, decision-makers should facilitate remittances towards more environmentally friendly and sustainable solutions to prevent the detrimental effects of remittance inflows on carbon emissions in Central Asia.

Keywords: environmental degradation; remittances; energy intensity; economic development; Central Asia; FMOLS; threshold; 2SLS; Hausman–Taylor; Amacurdy

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1. Introduction

In an era characterized by globalization and interconnected economies, the intricate relationship between human activities and the environment has garnered increasing attention (Horner 2020). The pressing need to understand the environmental consequences of economic processes has led scholars and policymakers to delve into the multifaceted dynamics that underlie the intricate web of factors influencing environmental degradation (Wang et al. 2020). Studying the impact of remittances, energy consumption and economic development on environmental degradation in Central Asia is crucial for several reasons. The region faces unique challenges and opportunities, and understanding these relationships can inform sustainable development strategies.

Remittances, as financial transfers from migrants to their home countries, constitute a significant source of income for numerous developing nations (Adams 2011). This inflow of funds has been widely acknowledged for its potential to alleviate poverty and stimulate economic growth in Central Asian countries (FAO 2020). Remittances, however, can also have a detrimental effect on an economy by increasing inflation (Apergis and Payne 2010), decreasing labor market participation and strengthening the real exchange rate (Heidari et al. 2015). While a large amount of research has examined the macroeconomic effects of foreign remittance inflows, relatively few studies have examined the environmental effects of remittances. The authors of (Zafar et al. 2021) studied the relationship between remittances, export diversification, education and CO_2 emissions in a panel of 22 top remittance-receiving countries from 1986 to 2017, controlling for economic growth and renewable energy. The results showed that remittances have a negative impact on emissions, which helps to reduce environmental degradation. The authors of (Li and Zhou 2015) reached the conclusion that the increase in migrant remittance can improve the environment in the short term but worsen the environment in the long run.

Moreover, the relationship between economic development and environmental degradation is a subject of ongoing debate (Mikayilov et al. 2018). While economic growth is often considered a prerequisite for improving living standards, the environmental cost of such development is increasingly evident. Concerns about climate change and global warming are being raised by the alarming rate at which environmental quality is declining (Kuziboev et al. 2023; Rahaman 2012). Understanding the reasons behind environmental degradation and how it relates to economic growth has thus grown in significance in recent years (Kasman and Duman 2015). In (Aye and Edoja 2017), the authors indicate that in low-growth regimes, economic growth has a negative impact on CO_2 emissions; in high-growth regimes, it has a positive effect with a higher marginal effect.

Energy is required to meet basic needs and achieve economic development objectives, but increasing energy intensity could harm the environment if energy production is reliant on fossil fuels (Shahbaz et al. 2015). In (Saidmamatov et al. 2023), the authors examine the impacts of economic growth, energy consumption, agriculture, irrigation water use, and agriculture productivity on environmental pollution in five Central Asian nations. The findings suggest that economic growth, water productivity, energy consumption and electricity production have a positive long-term effect on CO_2 emissions in Central Asia (Saidmamatov et al. 2023). Conversely, agriculture value added and trade openness exhibit a negative and statistically significant impact on CO_2 emissions.

The contribution of this research is that the study analyzes the complex interactions between remittances, energy consumption, economic development and their combined effects on environmental degradation. In Central Asia, there is a knowledge gap in this direction (as the region was part of the Soviet Union until the 1990s). This research aims to contribute by estimating the effect of remittances on environmental degradation in Central Asia for the first time. In comparison with other developing countries, there is a differential factor—the energy intensity variable is firstly applied in the investigation of CO_2 emissions-remittances-economic development.

2. Literature Review

2.1. The Impact of Personal Remittances on CO_2 Emissions

The effect of remittances has been the subject of much scholarly investigation, with researchers examining its correlation with a diverse range of independent variables. Among others, (Jamil et al. 2021) examined the connection between personal remittances and environmental degradation: findings indicate that remittances can significantly reduce CO_2 emissions. This implies that as remittances increase, CO_2 emissions also tend to rise. However, the study notes that trade openness does not significantly impact CO_2 emissions (Derindag et al. 2023; Zhang et al. 2023). While economic growth, value-added agriculture, and increased remittances can all aid in reducing carbon emissions, improvements to the financial system and industrial expansion typically lead to higher CO_2 emissions, according to another study (Wang et al. 2021).

The authors of (Ahmad et al. 2019) examined the impact of money transfers on greenhouse gas emissions in six Asian countries: Bangladesh, Sri Lanka, China, India, the Philippines, Pakistan, and the Philippines between 1982 and 2014. The results showed that, in both the short and long terms, CO_2 rises dramatically in all sample countries as energy use rises (Rahman et al. 2019). China, Sri Lanka and India's environmental conditions are significantly impacted by remittances. Using time series data from 1980 to 2014, (Ahmad et al. 2019) investigated any potential asymmetric transmissions between China's carbon dioxide emissions (CO_2) and remittances. The long-term asymmetric link between the inflow of remittances and carbon emissions is examined using the Non-linear NARDL approach (Rahman et al. 2019). The results demonstrate that although a negative remittance shock results in a drop in CO_2 emissions (Mirza and Kanwal 2017), a positive remittance shock produces an increase in CO_2 emissions (Ahmad et al. 2019; Ahmad et al. 2017). As shown in the literature, the remittance might affect CO_2 emissions both positively and negatively due to the country and region-specific characteristics. Our study further investigates such a relationship in the case of Central Asian countries.

2.2. The Impact of Energy Intensity on CO_2 Emissions

The literature indicates that energy intensity is generally considered an important factor influencing CO_2 emissions. According to (Radovanović et al. 2021), there are strong but inverse relationships between GDP per capita, CO_2 emissions per unit of GDP, and energy intensity per unit of GDP. These correlations indicate a methodological problem, implying that further detailed data or alternative techniques of analysis may be required to fully capture the connection between energy intensity and CO_2 emissions. The authors of (Zhang et al. 2023) used annual time-series data for Morocco from 1990 to 2020 to analyze the relationship with CO_2 emissions. The results showed that increasing energy intensity significantly increases carbon emissions.

Although the precise relationship between energy intensity and CO_2 emissions in Central Asian nations has not been well studied, carbon emissions accounting is acknowledged as a measurable indicator of how economic activity affects the environment. This suggests that energy intensity, an essential component of economic activity, is probably going to play a big part in CO_2 emissions, albeit the specifics of this relationship have not been outlined for Central Asia. A study conducted between 2010 and 2020 that examined the accounting of carbon emissions in Central Asian nations—Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan and Uzbekistan—showed that these nations' carbon emissions were rising (Zhao et al. 2023). Along with energy and carbon intensity, it also covered the variables influencing these emissions, like population growth and the economy. The findings show that population growth and the economy both increase emissions but that in some nations, energy intensity and carbon intensity are negative drivers (Wang et al. 2021; Zhao et al. 2023). The authors in (Apergis et al. 2023) examine a modified iteration of Okun's Law, which integrates energy consumption and temperature variables, within the context of five Central Asian countries. According to the study (Shum et al. 2021) on the primary drivers of carbon emissions in China, economic expansion and energy utilization were the main drivers of carbon emissions, followed by population density and industrialization. Although this study is not specific to Central Asia, it suggests that energy intensity, as a measure of energy consumption, can be a significant driver of carbon emissions. Studies have indicated that energy-efficiency initiatives can effectively reduce greenhouse gas emissions in certain nations (Saboori et al. 2012). In this context, energy intensity is viewed as a negative element, suggesting that increasing energy intensity will probably result in higher emissions (Tariq et al. 2022).

2.3. The Impact of Economic Development on CO_2 Emission

The correlation between economic growth and carbon dioxide emission has been extensively investigated in recent years. Economic development may have a negative influence on carbon dioxide emission through diverse aspects of environmental issues, specifically climate change, environmental pollution and loss of wildlife habitats (Phimphanthavong 2013). These main environmental issues are considered the main trouble in the economic development of many countries. The authors of (Kraft and Kraft 1978) analyzed the causal link between economic growth and energy utilization in the United States and affirmed the causal impact of economic development on energy consumption. The fast economic development has been accomplished by the overuse of energy, and consequently, carbon dioxide emissions have increased simultaneously.

A study (Aslanidis and Iranzo 2009) researched the connection between economic growth and CO_2 release in non-OECD countries between 1971 and 1997, using the smooth transition regression model with panel data. The research concluded that in low-income countries, economic growth gradually leads to an increase in CO_2 emissions. Furthermore, (Heidari et al. 2015) analyzed the relationship between economic development, CO_2 and energy use in ASEAN countries from 1980 to 2008. The analyses showed that in the first group countries where the GDP per capita is below 4686 USD, the economic growth caused an increase in the deterioration of the environment, whereas the second group countries (where GDP per capita is more than 4686 USD) were vice versa. The investigation also highlighted that energy consumption leads to growing carbon dioxide emissions in both country groups.

3. Data and Methodology

3.1. Data

To empirically examine the association among CO_2 emissions, remittances, energy intensity and economic development, a balanced panel dataset including four Central Asian countries—Uzbekistan, Kazakhstan, Kyrgyzstan and Tajikistan—is created due to data availability for the period of 1995–2022 using annual data (Apergis and Payne 2010; Kuziboev et al. 2023). CO_2 emissions, expressed in metric tons per capita, are the explained variables in the study, while remittances, expressed as a percentage of GDP, are the explanatory variables. Energy intensity, measured in primary energy and economic development, measured in gross domestic product per capita in USD, are applied as the control variables (Ahmad et al. 2019; Rahman et al. 2019). All data are obtained from World Bank Data. Table 1 provides the definition and sources of the studied variables.

Table 1. Definition and sources of the variables (The World Bank 2023).

Variable Types	Notation	Name	Definition	LOG Transformation
Explained variable	$CO2$	CO_2 emissions	Carbon dioxide emissions, metric tons per capita	$logCO2$
Core explanatory variable	REM	Remittances	Personal remittances received (% of GDP)	-
Control variables	$PGDP$	Economic development stage	GDP per capita, constant 2015 USD (United States Dollar)	$logPGDP$
	EI	Energy intensity	Energy intensity level[1] of primary energy (MJ/USD2017 PPP GDP)	$logEI$

Due to the descriptive statistics of the studied variables given in Table 2, an average of 4.34 metric tons per capita CO_2 emissions ($CO2$) are released in the Central Asian region during the period of 1995–2022. Remittances (REM) received as a percent of GDP is 11.71 on average. Gross domestic product per capita ($PGDP$) is average counted as 2340.84 USD. The energy intensity (EI) level is 9.80 USD on average in the region.

Table 2. Descriptive statistics of the studied variables.

	CO2	*REM*	*PGDP*	*EI*
Mean	4.34	11.71	2340.84	9.80
Standard deviation	4.46	14.59	3320.98	6.33
Minimum	0.32	0	137.18	4.33
Maximum	15.34	50.94	13,890.60	30.42
Observations	112	112	112	112

3.2. Methodology

3.2.1. Linear Model

The baseline model to explore the relationship among CO_2 emissions ($logCO2$), remittances (REM), economic development ($logPGDP$) and energy intensity ($logEI$) can be prescribed as the following (Equation (1)):

$$logCO2_{i,t} = a_0 + a_1 REM_{i,t} + a_2 logPGDP_{i,t} + a_3 logEI_{i,t} + \varepsilon_{i,t} \quad (1)$$

where a_0 is an intercept; $a_1,\ a_2,\ a_3$ are elasticity coefficients; ε is an error term; i is a country; and t is a time period.

Equation (1) is estimated by means of the FMOLS (Fully Modified Least Squares) method (Phillips and Hansen 1990). FMOLS method allows the identification of whether the long-run association among the employed variables exists or not since the FMOLS equation is considered a cointegrating equation.

3.2.2. Panel Threshold Regression Model

We also assume that the effect of economic development ($logPGDP$) on CO_2 emissions ($logCO2$) varies depending on the level of energy intensity ($logEI$) of Central Asian countries. This assumption leads us to apply a panel threshold regression model (Wang 2015) to estimate the threshold relation of economic development ($logPGDP$) on CO_2 emissions ($logCO2$). As a threshold variable, energy intensity ($logEI$) is used. The panel threshold regression model can be represented by Equation (2):

$$logCO2_{i,t} = c_0 + c_1 logPGDP_{i,t} * I\left(logEI_{i,t} \le \gamma\right) + c_2 logPGDP_{i,t} * I\left(logEI_{i,t} > \gamma\right) + c_3 logEI_{i,t} + c_4 REM_{i,t} + u_i + \varepsilon_{i,t} \quad (2)$$

where $I()$ expresses the indicator function. The threshold regression model explores the effect of economic development ($logPGDP$) on CO_2 emissions ($logCO2$) with the changes in energy intensity ($logEI$) regimes. c_0 is intercept, c_1, c_2, c_3 and c_4 are elasticity coefficients, u_i is the individual effect, and $\varepsilon_{i,t}$ is the disturbance.

3.2.3. Two-Step Least Square Method

Furthermore, we investigate the effect of economic development ($logPGDP$) instrumented by energy intensity ($logEI$) on CO_2 emissions ($logCO2$). More specifically, economic development is an endogenous variable affected by energy intensity. To this end, the 2SLS (two-stage least square) method is applied, whose specification can be described as the following:

$$logCO2_{i,t} = \beta_0 + \beta_1 REM_{i,t} + \beta_2 logPGDP_{i,t} + \varepsilon_{i,t} \quad (3)$$

$REM_{i,t}$ is an exogenous variable uncorrelated with $\varepsilon_{i,t}$, $logPGDP_{i,t}$ is endogenous variable potentially correlated with $\varepsilon_{i,t}$, β_0, β_1, β_3, which are unknown parameters, $logEI_{i,t}$ is instrumental variable.

3.2.4. Hausman–Taylor and Amacurdy Estimators

Moreover, we estimate Equation (1) by means of Hausman–Taylor and Amacurdy estimators to cope with the endogeneity issue further (Hausman and Taylor 1981).

3.2.5. Unit Root and Cointegration Tests

As complementary tests, we apply the cross-sectional independence test proposed by (Pesaran 2004) to check if cross-sectional dependence exists or not. Moreover, as unit root tests, we run IPS (Im et al. 2003) and the CIPS unit root tests (Pedroni 2004; Westerlund 2005). To identify the long-run relations among the studied variables, (Caporin et al. 2023) considered panel cointegration tests (Phillips and Hansen 1990). Similar studies covered this topic in the case of developing countries (Mitić et al. 2022; Tawiah et al. 2021; Hasanov et al. 2019).

4. Results and Discussions

First of all, we perform VAR (vector autoregressive) lag selection criteria. Table 3 shows the optimal lag orders given the following criteria: LR (likelihood ratio), FPE (final prediction error), AIC (Akaike's information criterion), SIC (Schwarz Information Criterion), and HQ (Hannan–Quinn). We choose optimal lag as 1 following AIC (Akaike information criterion).

Table 3. The results of lag selection criteria.

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	−543.3602	NA	2.969820	12.44001	12.55261	12.48537
1	17.78814	1058.530	1.24×10^{-5}	0.050269	0.613301 *	0.277101 *
2	39.66592	39.28056 *	1.08×10^{-5} *	−0.083316 *	0.930140	0.324980
3	45.61762	10.14494	1.37×10^{-5}	0.145054	1.608935	0.734815
4	52.92121	11.78535	1.69×10^{-5}	0.342700	2.257005	1.113925
5	57.97353	7.693304	2.20×10^{-5}	0.591511	2.956241	1.544201
6	66.48852	12.19191	2.68×10^{-5}	0.761625	3.576780	1.895780

* Represents the criterion selecting the lag order. LR = sequential modified LR statistic, FPE = final prediction error, AIC = Akaike information criterion, SIC = Schwarz information criterion, HQ = Hanan–Quinn information criterion.

Table 4 denotes the results of the cross-sectional dependence (CD) and (IPS, CIPS) unit root tests. The null hypothesis of the cross-section dependence (CD) test is no cross-section dependence. The null hypothesis of the (IPS, CIPS) unit root tests is the presence of unit root. The null hypothesis is rejected when the p-value is statistically significant at 1% and 5% levels. The results show that cross-sectional dependence exists for the $logCO2$, REM, and $logPGDP$ variables, whereas $logEI$ has no cross-sectional dependence. Regarding unit root tests, all variables are integrated at the first differences, $I(1)$.

Table 4. Results of cross-section dependence tests and panel unit-root tests.

Variables	CD Test	IPS Test		CIPS Test	
		Level	1st Difference	Level	1st Difference
$logCO2$	−1.69 ***	1.68	−3.53 ***	−1.23	−4.64 ***
REM	5.28 ***	0.21	−4.21 ***	−2.25 *	−3.89 ***
$logPGDP$	12.21 ***	1.35	−3.22 ***	−2.80 ***	−4.36 ***
$logEI$	10.88 ***	−0.71	−3.20 ***	−1.49	−4.30 ***

*** and * represent statistical significance at the levels of 1% and 10%, respectively. Lag length is selected as 1 based on AIC criterion.

As a next step, we apply both Pedroni and Westerlund cointegration tests. The null hypothesis for both cointegration tests is that there is no long-run relationship among the variables. When the p-value is less than 0.05 ($p < 0.05$), the null hypothesis is rejected, which is statistically significant.

The results of cointegration tests provided in Table 5 show that the long-run association exists among the studied variables, $logCO2$, REM, $logPGDP$, and $logEI$. Consequently, we might proceed with model estimations. We use the Dumitrescu–Hurlin causality test to examine the causal relationships between the variables in our panel prior to model estimation. The outcomes are shown in Table 6.

Table 5. Results of panel cointegration tests.

	Statistic	***p*-Value**
Pedroni test		
Modified Phillips–Perron t	1.77	0.03
Westerlund test		
Variance ratio	1.66	0.04

Table 6. Dumitrescu–Hurlin panel causality tests.

Null Hypothesis:	**W-Stat**
REM does not homogeneously cause $logCO2$	2.67 *
$logCO2$ does not homogeneously cause REM	1.13
$logPGDP$ does not homogeneously cause $logCO2$	3.42 ***
$logCO2$ does not homogeneously cause $logPGDP$	3.55 ***
$logEI$ does not homogeneously cause $logCO2$	4.26 ***
$logCO2$ does not homogeneously cause $logEI$	2.32
$logPGDP$ does not homogeneously cause REM	0.22
REM does not homogeneously cause $logPGDP$	9.06 ***
$logEI$ does not homogeneously cause REM	4.42 ***
REM does not homogeneously cause $logEI$	3.47 ***
$logEI$ does not homogeneously cause $logPGDP$	3.58 ***
$logPGDP$ does not homogeneously cause $logEI$	0.41

When focusing on the causality among the series, we observe that REM has a unidirectional causal effect on CO_2 emissions with marginal significance. Moreover, $logPGDP$ has a bidirectional causal relation with CO_2 emissions. Furthermore, there is a causality between energy intensity and CO_2 emission. All variables have a causal effect on CO_2 emissions, which is a relevant element in developing a model.

The results of the Dumitrescu–Hurlin panel causality test are displayed in the table as p-values. In the case of 1% and 10% levels of statistical significance, respectively, asterisks denote *** and *. By utilizing SIC, the ideal lag has been chosen.

The estimated coefficients of the cointegrating Equation (1) are shown in Table 7 for the three possible $PGDP$ impact options (linear, quadratic, and cubic). A long-term relationship between the variables is confirmed by the estimations in column 1, with the coefficients—particularly REM and $logEI$—being statistically significant. In addition, in all specifications, REM negatively impacts CO_2 emissions, whereas $logEI$ has a positive influence on CO_2 emissions. More specifically, an increase in remittances (REM) is associated with lower CO_2 emissions in the long run, while a rise in energy intensity enhances environmental degradation. If we narrow our focus to the linear impact alone, the $logPGDP$ coefficient is positive and significant. The related coefficients lose their statistical significance when higher-order impacts, such as the quadratic and cubic effects, are introduced. In this study, the invalidation of the EKC (Environmental Kuznets Curve) hypothesis is in line with the findings of (Caporin et al. 2023), who also do not find the justification for U- and/or

N-shaped EKC relation for Central Asia. On this occasion, we proceed with our estimations, biasing linear relations among remittances, energy intensity, economic development and environmental degradation.

Table 7. FMOLS estimation results of cointegration equation.

	Dependent Variable=*logCO2* (Carbon Dioxide Emissions)		
Variables	**Testing the Relation between *logCO2* and *PGDP***	**Testing U-Shaped Kuznets Curve**	**Testing N-Shaped Kuznets Curve**
REM	−0.008 ***	−0.008 ***	−0.006 **
$logEI$	1.077 ***	1.055 ***	1.054 ***
$logPGDP$	0.176 ***	0.163	−1.42
$logPGDP^2$		0.000	0.213
$logPGDP^3$			−0.009

FMOLS method is run with the consideration of linear trend. Asterisks represent statistical significance *** and ** for 1% and 5% levels, respectively.

Theoretically, the impact of economic development on environmental degradation happens due to energy use for economic activities. On this occasion, we employ the 2SLS (two-stage least square) method and threshold regression model to calculate the impact of economic development on the indirect relationship between energy intensity and CO_2 emissions. The results are provided in Table 8.

Table 8. The results obtained by 2SLS method and threshold regression model.

	Dependent Variable: *logCO2*		
	2SLS		**Threshold Regression**
	logPGDP* Instrumented by *logEI		
	1st Stage	**2nd Stage**	
$logPGDP * I\ (logEI \leq 1.488)$			0.399 ***
$logPGDP * I\ (logEI > 1.488)$			0.281 ***
Independent variables			
$logREM$	−0.03 ***	−0.043 ***	0.003 *
$logEI$	−1.065 ***		0.512 ***
$logPGDP$		−0.042	
Constant	9.66 ***	1.640	−2.319 ***
Wald test F-value of instrument	19.01 ***		
Threshold effect test F-stat for single threshold value			164.91 ***

Asterisks stand for *** and *, respectively, statistical significance at the 1% and 10% levels.

According to Table 8, remittances have a negative and significant effect on CO_2 emissions in the 2SLS method when economic development is instrumented by energy intensity. However, economic development itself loses its significant impact on CO_2 emissions. In contrast, remittances positively influence CO_2 emissions in the threshold regression model, where energy intensity indirectly impacts economic development. Moreover, the effect of remittances is marginally significant in the threshold regression model.

This incoherence leads us to further check the endogeneity issue. To this end, we apply Hausman–Taylor and Amacurdy estimators for error-components models. The results are provided in Table 9.

Table 9. The results of the Hausman–Taylor and Amacurdy estimators.

	Dependent Variable: $logCO2$					
Independent Variables	**Model 1 Hausman–Taylor**	**Model 2 Amacurdy**	**Model 3 Hausman–Taylor**	**Model 4 Amacurdy**	**Model 5 Hausman–Taylor**	**Model 6 Amacurdy**
Time-varying exogenous						
REM			0.004 **	0.004 **	0.004 **	0.004 **
$logEI$	0.447 ***	0.447 ***			0.447 ***	0.447 ***
$logPGDP$	0.285 ***	0.285 ***	0.285 ***	0.285 ***		
Time-varying endogenous						
REM	0.004 **	0.004 **				
$logEI$			0.447 ***	0.447 ***		
$logPGDP$					0.285 ***	0.285 ***
Time-invariant exogenous						
id	−0.349	−0.349	−0.349	−0.349	−0.349	−0.349
Constant	−1.315	−1.315	−1.315	−1.315	−1.315	−1.315
N	112	112	112	112	112	112

*** and ** represent the significance at the 1% and 5% levels, respectively.

The results estimated by Hausman–Taylor and Amacurdy estimators (Table 9) show that all variables suffer from endogeneity issues. All employed variables, REM, $logPGDP$, and $logEI$, have significant and positive impacts on $logCO2$. The results are quite different from the ones estimated by the FMOLS method (Table 7). However, it should be noted that FMOLS results refer to the long-run association among the variables. It can be inferred that remittances and CO_2 emissions are positively correlated when the endogeneity is counted, whereas, in the long run, the association becomes negative.

5. Conclusions

This study examines for the first time the connection between Central Asian economic development, energy intensity, remittances, and CO_2 emissions between 1995 and 2022. FMOLS, Panel threshold regression model, 2SLS method, Hausman–Taylor, and Amacurdy estimators are applied to do this. The results indicate that there is a long-term relationship between the variables under consideration. In light of the FMOLS approach, remittances have a negative influence on CO_2 emissions in the long run. The Dumitrescu–Hurlin causality test demonstrates that all independent factors have a causal effect on the dependent variable, hence verifying the effect of the variables tested.

It should be noted that a panel threshold regression, the two-step least square method, and Hausman–Taylor and Amacurdy estimators, which refer to the controlling endogeneity issue, show that the relationship between CO_2 emissions and remittances is distorted under endogeneity control. Therefore, we rely on FMOLS results to derive the policy implications which document a negative association between CO_2 emissions and remittances in Central Asia.

Due to the fact that remittances are such an important component of financial development and economic progress, their influence in harming the environment cannot be overlooked, especially in Central Asia, where most of the remittances inflow from neighboring countries (i.e., Russia) and Eastern European countries (i.e., Poland, Czech Republic), their environmental best practices can be replicated. This research has numerous significant policy implications for decision-makers in Central Asia. The key policy implications of this research are that economies should pursue different economic routes and that policymakers should consider these aspects since remittances can be used for financial development, which reduces CO_2 emissions.

Considering the fragile environmental situation in the Aral Sea region, urgent strategic actions are required to ensure environmental resilience and sustainability of ecological, social and economic development in Central Asia and beyond. Furthermore, to prevent the detrimental effects of remittance inflows on carbon emissions, the government should direct remittances towards useful purposes and, more importantly, should concentrate on environmentally friendly and sustainable financial expansion. It is, therefore, imperative that policymakers and governments disseminate a novel approach to renewable energy, incorporating both a carbon price and a renewable energy subsidy. In order to promote the adoption of cutting-edge environmental technologies, the government should also push the banking industry to offer better terms on domestic loans to investors, business owners, and industrialists.

The research also has limitations. More specifically, additional control variables such as technological development, literacy rate, life expectancy and digitalization could have been employed. However, the degree of freedom does not allow additional variables because of the principles of model building. However, this limitation might be served as a future research agenda that can be covered by collecting data on the country and province level in Central Asia.

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Note

[1] Energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used to produce one unit of economic output. Lower ratio indicates that less energy is used to produce one unit of output. (World Bank Data—https://databank.worldbank.org/metadataglossary/world-development-indicators/series/EG.EGY.PRIM.PP.KD#:~:text=Energy%20intensity%20is%20an%20indication,produce%20one%20unit%20of%20output (accessed on 5 December 2023)).

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