

Foreign Direct Investment and Renewable Energy Consumption in European and Central Asia Nations: The Moderating Role of Government Expenditure

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Abstract

Our study contributes to the growing literature on the 7th and 8th Sustainable Development Goals because it examines the moderating role of government spending in developing renewable energy consumption by attracting higher net FDI inflows. We use a dynamic system Generalized Method of Moments to analyze unbalanced panel data with 939 annual observations from 45 European and Central Asia countries from 2000 to 2019. While increasing the net FDI inflows discourages renewable energy consumption, higher government spending positively empowers renewable energy consumption. Moreover, the results find that government spending moderates the nexus between net FDI inflows and renewable energy consumption in European and Central Asian countries. The findings support the pollution haven hypothesis, public economics, and institutional theories. Finally, the findings support policymakers

in Europe, Central Asia, and other emerging nations to encourage sustainable renewable energy utilization.

Keywords: renewable energy consumption, foreign direct investment, government expenditure, GMM, moderation.

1. Introduction

This research investigates the impact of government spending and Foreign Direct Investment (FDI) on renewable energy utilization in Europe and Central Asia from 2000 to 2019. Renewable energy, including solar, wind, biomass, geothermal, hydroelectric, and tidal power, is critical for reducing carbon emissions and decreasing reliance on fossil fuels, which are increasingly insufficient to meet global demand (Tran et al., 2023). Renewable energy supports economic growth, enhances rural living standards, and aligns with the Sustainable Development Goals (SDGs). However, high financial constraints and technological requirements necessitate substantial capital and government support for renewable energy projects.

This study is conducted in European and Central Asian nations for the following reasons. These regions present unique challenges because Europe faces limited conventional energy resources, making renewable energy vital for energy security. Despite the high potential for producing renewable energies, Central Asia struggles with an underdeveloped renewable infrastructure (Akadiri et al., 2019; Shadrina, 2020). Both regions have shown commitment to environmental sustainability through policies like the Paris Agreement (Thieffry, 2016; Meyer et al., 2021), yet face distinct obstacles in transitioning to cleaner energy sources. Secondly, renewable energy growth in Central Asia is critical to fulfilling the rising local energy demand and avoiding significant environmental pollution. Shadrina (2020) comprehensively assesses renewable energy in Central Asia, focusing on renewable energy deployment and energy system preparation for regenerative dissemination. While the potential for renewable energy is sizable, the scale of deployment is underestimated in Central Asia (Laldjebaev et al., 2021).

Secondly, both regions are committed to developing sustainable energies but encounter distinct obstacles in transitioning to renewable energy sources. For Central Asia, addressing infrastructure deficits and securing investment is critical to meet the growing energy demands while minimizing environmental pollution. Shadrina (2020) emphasizes the need for comprehensive renewable energy assessments in Central Asia, focusing on deployment and preparing energy systems for sustainable development. Unfortunately, this region's scale of renewable energy deployment remains underestimated despite its potential to play a substantial role in local energy security and environmental protections (Laldjebaev et al., 2021).

This study implements a dynamic system Generalized Method of Moments (GMM) to analyze an unbalanced sample of 45 European and Central Asian countries from 2000 to 2019. Duong et al. (2022) and Le et al. (2024) demonstrated that Ordinary Least Squares (OLS), Fixed Effects Models (FEM), and Random Effects Models (REM) often violate asymptotic efficiency and fail to address heterogeneity issues. In contrast, the GMM approach is suitable for large cross-sectional datasets with short time dimensions (Arellano & Bond, 1991; Le et al., 2024).

This study contributes to the growing body of literature on the 7th and 8th SDGs for the following reasons. First, while existing research has explored renewable energy development in regions such as China (Vaccarini et al., 2017), Thailand (Premashthira, 2024), and G-11 nations (Sun et al., 2022), these studies often neglect the interaction between FDI and government spending in promoting renewable energy growth, particularly within Europe and Central Asia. Addressing this gap is crucial, as Europe and Central Asia provide a unique and underexplored context with distinct challenges and opportunities for renewable energy development. Secondly, prior studies have focused exclusively on either the impact of FDI inflows (Mahbub et al., 2022; Khan et

al., 2021) or government spending (Wu et al., 2020; Yu et al., 2016; Hussain et al., 2022) on renewable energy development. This research extends the literature by investigating whether government expenditure (GE) moderates or mediates the nexus between FDI and renewable energy utilization. Furthermore, this study also corroborates and extends Premashthira (2024) by demonstrating that the benefits of FDI for renewable-energy consumption are contingent upon domestic government spending. By concentrating on the Europe and Central Asia regions, this study offers a nuanced perspective on how FDI and government spending interact to influence renewable energy utilization. These regions' contrasting yet complementary challenges provide fertile ground for understanding the interplay between foreign investments and public policy. Therefore, this study addresses a significant gap in the existing literature and provides policymakers with valuable insights into leveraging FDI and GE to accelerate renewable energy consumption in these regions.

This study has the following structure. Section 1 is the introduction. Section 2 serves as an exposition of the theoretical background. Section 3 focuses on the data and methodology. Section 4 presents the findings. Section 5 discusses the empirical findings. Finally, Section 6 concludes the study.

2. Literature Review

2.1 Theories

Renewable energy is crucial for reducing environmental issues and decreasing reliance on energy imports such as natural gas and oil. However, investing in renewable energy is costly and uncertain, and transitioning from conventional to renewable energy requires significant financial resources (Zhang et al., 2019). FDI inflows are critical

capital sources, bringing technological support and innovation to renewable energy (Doytch & Narayan, 2016). FDI firms examine economic and business environments and incentives before investing in renewable energy projects because foreign investors expect good business performance and lower risk (Hanni et al., 2011).

Nevertheless, FDI flows can adversely affect renewable energy consumption from an environmental perspective, particularly in regions with weak environmental regulations. The pollution haven effect occurs when foreign firms maximize short-term profits by exploiting non-renewable energy sources to minimize production costs. This trend undermines the growth of the renewable energy sector, as investments are diverted away from green energy projects. FDI firms in such environments might prioritize fossil-fuel-based industries, leading to an overreliance on polluting energy sources rather than renewable energies. As a result, the production and consumption of renewable energy fall below the expected threshold. Although FDI corporations have an environmentally friendly obligation to meet the demands of local corporate social responsibility, their core industrial activities continue to create significant environmental pollution. Moreover, the high upfront costs of renewable energy infrastructure and a lack of stringent environmental enforcement often allow inefficiently motivated FDI firms to develop renewable energy utilization (Laldjebaev et al., 2021). Studies by Tan and Uprasen (2022), Rej et al. (2023), and Khan et al. (2021) report unfavorable associations between FDI and renewable energy in India, the UAE, and BRICS nations, partly due to the high financing costs and FDI's tendency to prioritize less sustainable energy sources.

Government expenditure (GE) constitutes a fundamental mechanism for promoting renewable energy consumption by addressing market failures and reinforcing institutional capacities. Within the framework of public economics theory,

state intervention is warranted to correct for the underallocation of resources to renewable energy, a symptom of externalities associated with conventional energy production and the high upfront capital requirements that deter private investment (Brown, 2001). Targeted subsidies, tax credits, and direct capital injections into renewable energy infrastructure effectively lower the private cost of generation and consumption, aligning private incentives with the broader social welfare objective of emissions reduction. Simultaneously, institutional theory suggests that the efficacy of such fiscal measures is contingent upon the quality of governing structures, regulatory coherence, and policy stability. Well-functioning institutions, characterized by clear mandates, transparent decision-making processes, and robust enforcement mechanisms, enhance the credibility of government spending and reduce uncertainty for market participants, ultimately leading to greater adoption rates of renewable technologies (Johnstone et al., 2010). Consequently, when executed through sound institutional channels, increasing GE mitigates the financing barriers inherent to the renewable energy sector. It fosters sustained consumption by embedding supportive policies within reliable governance frameworks.

2.2 The Relationship Between FDI and Renewable Energy

Previous studies indicated that FDI inflows positively improve renewable energy utilization in host countries (Doytch & Narayan, 2016). Through technology transfer and spillovers, FDI may favorably impact the technological advancement of companies in host nations. At the same time, renewable energy developments require huge capital and technology improvements (Doytch & Narayan, 2016). Therefore, FDI firms have a strong demand for energy to achieve economies of scale in production. As conventional energies become limited and overexploited, renewable energy becomes the solution for energy security and increasing demand

from host countries. Doytch and Narayan (2016) report that FDI firms reduce non-renewable energy consumption and positively develop renewable energy utilization. Shahbaz et al. (2022) show a positive relationship between FDI and renewable energy consumption and suggest that FDI is the primary source of promoting renewable energy development. The abundant renewable energy potential also attracts FDI inflows.

However, several studies suggest that FDI may negatively affect renewable energy consumption under certain conditions. Kilicarslan (2019) analyzed Turkey, where FDI inflows concentrated on industries with high energy demands but limited focus on renewable energy development. Using a time-series regression model, the author concluded that the capital-intensive nature of these industries led to an increased reliance on non-renewable energy sources, limiting the expansion of renewable energy. Similarly, Khan et al. (2021) explored the relationship between FDI and renewable energy in BRICS nations through a panel data approach from 1990 to 2018. Their findings highlighted that foreign firms often invest in sectors prioritizing cost-efficiency over environmental sustainability in countries with weak environmental regulations, resulting in a preference for cheaper, non-renewable energy. The methodology used in both studies includes regression analyses to assess FDI inflows' sectoral distribution and energy consumption patterns, revealing that FDI in energy-intensive industries can hinder renewable energy adoption when not adequately regulated. These studies demonstrate that while FDI firms can bring technological advancements, they also prioritize non-renewable energy sources if host countries do not implement stringent environmental protection policies.

Liu et al. (2016) employed factor analysis, data envelope analysis, and a panel data regression model on the performance of the Chinese energy industry from 2005

to 2011 to analyze the implications of the expansion of renewable energy technology, which directly relates to FDIs. They determined that the growth of renewable energy technologies that rely on FDI projects increases China's energy sector performance. Hanni et al. (2011) examined FDI in renewable energy generating and related equipment manufacturing and found that it increased dramatically between 2003 and 2010. According to their results, FDI projects are attracted by three factors, i.e., market-seeking, resource-seeking, and efficiency-seeking. Market-seeking drive is the most appropriate motivator for governments to increase their investments in renewable energy sources. The similarities between these studies are that FDI through investment in modern equipment to exploit renewable energy sources will increase renewable energy consumption.

FDI projects can also transfer production processes that contribute to increased environmental pollution in host countries, which is consistent with the pollution haven hypothesis. In countries with weak environmental standards, this leads to a significant rise in pollution as FDI prioritizes cost efficiency over environmental sustainability. As a result, the environmental consequences of foreign investments can undermine the benefits of renewable energy development. Host countries must implement strict and sensible rules to mitigate the harmful effects of FDI. Moreover, attracting FDI in renewable energy projects will contribute to national economic development while reducing environmental pollution. While some studies suggest that FDI promotes renewable energy consumption, a negative relationship may exist between FDI and renewable energy consumption in countries with weak environmental regulations or where FDI primarily flows into energy-intensive, non-renewable sectors. We propose the following hypothesis, as prior studies document the mixed findings between FDI and renewable energy consumption.

H1: FDI significantly impacts renewable energy consumption in European and Central Asian nations.

2.3 The Relationship Between Government Expenditure and Renewable Energy

Renewable energy production has limitations due to high upfront costs, unpredictability, and significant delays in economic returns. Thus, renewable energy projects necessitate heavy reliance on government incentives (Zhao et al., 2013). The complexity of policy instruments available globally has prompted research into the policy combinations that impact renewable energy development (Johnstone et al., 2010).

Prior studies showed a positive effect between government spending and renewable energy (Feng et al., 2022; Aguirre & Ibikunle, 2014). If the government liberalizes the energy marketplace, the energy strategy will phase out non-fossil fuel power production. Nosheen et al. (2021) assessed the effect of governmental investments on renewable energy sources in the European Union. They found that the frequency of gas and fossil fuel utilization is affected by government spending, which subsidizes renewable energy utilization. Johnstone et al. (2010) observed data from 25 countries from 1978 to 2003. Their results show that public policy substantially impacts the development of new renewable energy technology. Adopting the Kyoto Protocol has had a favorable and significant influence on wind and solar energy patent activity and renewable energy patents in general. Furthermore, public research and development (R&D) funding has a favorable and considerable influence on wind and solar-related innovation in all models, as well as geothermal and ocean resources. Chang and Wang (2017) emphasized the importance of financial regulation and management systems. They argue that the lack of sufficient support from the

government has slowed China's marine energy industry. Therefore, we propose the following hypothesis:

H2: Government expenditure significantly impacts renewable energy consumption in European and Central Asian nations.

2.4 The Moderating Role of Government Expenditure on Renewable Energy Consumption

Governments play a critical role in fostering renewable energy development by providing financial incentives and supportive policies that attract FDI and promote renewable energy consumption. Government spending can boost the impact of FDI on renewable energy utilization by lowering investment risks, offering financial incentives, and enhancing regulatory frameworks. Public investment in infrastructure, such as smart grids and renewable energy plants, lowers financial and technological risks, making projects more appealing to foreign investors (Dossou et al., 2025). Subsidies, tax breaks, and support for R&D help lessen entry barriers for FDI projects in renewable energy sectors. Investments in institutional capacity and policy enforcement also help to establish a predictable and investor-friendly climate, enhancing the benefits of FDI on renewable energy consumption (Dube & Horvey, 2023; Dossou et al., 2025). Conversely, GE may impede FDI's efficacy in fostering renewable energy consumption if resource misallocation, regulatory inefficiencies, or market distortions occur. Corrupt practices or poor governmental expenditures might redirect funding to non-productive projects, decreasing the GE's intended influence on renewable energy programs (Khan et al., 2021). Weak governance might result in uneven policy execution, inhibiting long-term FDI commitments and causing investor anxiety (Zeng et al., 2017). Thus, the significance of GE in regulating the link between FDI and

renewable energy utilization depends significantly on the level of governance and institutional effectiveness.

The moderating influence of GE is explained from two main theoretical perspectives, such as institutional theory and public economics theory. According to institutional theory, strong institutions, supported by effective government spending, create an environment where FDI may contribute positively to economic and environmental goals (North, 1990). In countries with strong renewable energy incentives, foreign investment is more effectively channeled into green infrastructure, amplifying renewable energy use (Viglioni et al., 2025). However, the moderating role of GE is not universally positive. Misallocation of public resources, regulatory inefficiencies, and corruption can distort markets and diminish the productivity of FDI (Khan et al., 2021; Zeng et al., 2017). Poor quality government spending may redirect resources toward non-productive or rent-seeking activities, undermining the intended impact of FDI on renewable energy goals. Therefore, the effectiveness of GE as a moderator depends critically on governance quality and institutional effectiveness. Countries with strong institutions and transparent fiscal management systems are more likely to experience a synergistic relationship between FDI and GE, accelerating progress in renewable energy consumption.

The second theory, public economics theory, explains the moderating role of GE on the nexus between FDI and renewable energy consumption. This theory suggests that government actions such as subsidies, tax incentives, and infrastructure investments assist in internalizing the positive externalities associated with renewable energy (Stiglitz & Rosengard, 2015) and implies that FDI's effect on renewable uptake is more potent in countries with more effective government policy, highlighting an

interactive role of public sector capacity and foreign investment in boosting renewables (Dossou et al., 2025)

While previous research has investigated the relationship between FDI and other economic factors, such as labor quality and political stability, little has been done to precisely evaluate the interaction between FDI and GE in the context of renewable energy. Tran et al. (2023) investigated how FDI affects environmental sustainability, but did not specifically address the moderating function of government spending. Dossou et al. (2025) examined the relationship between governance effectiveness and FDI regarding renewable energy consumption. Our analysis fills this gap by introducing GE as a moderating factor and experimentally examining its impact on the nexus between FDI and renewable energy consumption in European and Central Asian countries. Therefore, we propose the following hypothesis:

H3: Government spending has a moderating role in attracting FDI and increasing renewable energy consumption in European and Central Asian nations.

3. Methodology

3.1 Data

We gathered data from the World Bank database for 45 European and Central Asian countries. The sampling period is from 2000 to 2019. We follow Le et al. (2024) to eliminate data with inadequate information to estimate the needed variables. Our final sample is an unbalanced panel comprising 939 annual observations from 2000 to 2019. The country list is reported in Appendix A.

3.2 Variable Definitions

We follow Akadiri et al. (2019) to calculate renewable energy consumption as the ratio of renewable energy consumption to total final energy consumption. This ratio includes energy derived from wind, solar, hydro, and bioenergy sources. This measure provides a comprehensive indicator of a country's commitment to sustainable energy development by capturing the share of renewable energy within its overall energy use. It reflects the progress made by nations toward integrating cleaner energy sources into their energy mix, aligning with global sustainability goals and addressing climate change challenges.

FDI is another critical variable in our study. Following the approaches by Duong et al. (2022) and Le et al. (2024), we define FDI as the net FDI inflows relative to the host country's GDP. The net FDI inflow indicates the economic significance of foreign capital invested in the country. It also highlights the potential role FDI plays in fostering renewable energy development by providing capital, advanced technology, and expertise. Including this variable allows us to examine how much FDI contributes to renewable energy utilization and the economic mechanisms that drive this relationship.

Government spending is estimated using the methodology outlined by Nguyen and Su (2022). This variable is proxied by the total final government consumption expenditure, including current expenditures for goods and services and most national defense and public security expenses. However, it excludes military expenditures, focusing instead on the operational and developmental aspects of government spending. This proxy captures the scale of government involvement in the economy, emphasizing its potential role in shaping infrastructure and policies conducive to renewable energy development. The government can create favorable incentives for investments in renewable energy projects by investing in infrastructure, research, and incentives.

Other control variables, such as access to clean fuels and technologies for cooking (ATC), CO₂ emissions (LNCO₂), energy intensity (LNEPE), and GDP (GDP_GROWTH), are also included in our analysis to account for factors influencing renewable energy consumption. Detailed definitions and descriptions of these control variables are provided in Appendix B to ensure clarity and transparency.

3.3 Model Construction

To estimate the relationship between FDI and government expenditure on renewable consumption, we followed Khan et al. (2021) to construct Models 1, 2, and 3.

$$REC_{i,t} = \beta_0 + \beta_1 FDI_{i,t} + \beta_2 ATC_{i,t} + \beta_3 LNCO_{2,i,t} + \beta_4 LNEPE_{i,t} + \beta_5 GDP_GROWTH_{i,t} + \alpha_i + \alpha_t + \mu_t \quad (1)$$

$$REC_{i,t} = \beta_0 + \beta_1 GE_{i,t} + \beta_2 ATC_{i,t} + \beta_3 LNCO_{2,i,t} + \beta_4 LNEPE_{i,t} + \beta_5 GDP_GROWTH_{i,t} + \alpha_i + \alpha_t + \mu_t \quad (2)$$

$$REC_{i,t} = \beta_0 + \beta_1 FDI_{i,t} + \beta_2 GE_{i,t} + \beta_3 ATC_{i,t} + \beta_4 LNCO_{2,i,t} + \beta_5 LNEPE_{i,t} + \beta_6 GDP_GROWTH_{i,t} + \alpha_i + \alpha_t + \mu_t \quad (3)$$

Where REC is renewable energy consumption (% of total final energy consumption), FDI is Foreign Direct Investment, estimated by the net inflows (% of GDP), GE is general government final consumption expenditure (% of GDP), ATC is access to clean fuels and technologies for cooking (% of the population), LNCO₂ is the natural logarithm of CO₂ emissions, LNEPE is the natural logarithm of energy intensity level of primary energy, GDP_GROWTH is the annual GDP growth rate. α_i and α_t are the country-fixed effect and year-fixed effect. μ represents the residual. Appendix B has a comprehensive list of variable definitions.

In Model 4, we follow the methods from Dossou et al. (2025) to add the interaction term between FDI and government spending to examine the moderating role of government spending in attracting FDI inflows and developing renewable energy utilization.

$$\begin{aligned} \text{REC}_{i,t} = & \beta_0 + \beta_1 \text{FDI}_{i,t} + \beta_2 \text{GE}_{i,t} + \beta_3 \text{FDI}_{i,t} * \text{GE}_{i,t} + \beta_4 \text{ATC}_{i,t} + \beta_5 \text{LNCO2}_{i,t} + \beta_6 \text{LNEPE}_{i,t} \\ & + \beta_7 \text{GDP_GROWTH}_{i,t} + \alpha_i + \alpha_t + \mu_t \end{aligned} \quad (4)$$

3.4 Estimation Method

To identify the best-suited estimate methods among OLS, FEM, and REM, we use the Hausman, Redundant Fixed Effect, and Breusch-Pagan tests. We then perform the Wald test to check for heteroskedasticity issues because conventional panel data estimations often have heteroskedasticity issues. If there is a heteroskedasticity problem, we apply the two-step dynamic system GMM to solve the endogeneity and heteroskedasticity issue (Le et al., 2024; Duong et al., 2022). Le et al. (2024) found that the two-step estimator is more efficient than the one-step estimator. The GMM estimator utilizes instrumental variables to effectively address endogeneity issues arising from potential correlations between the regressors and the error terms in the regression model (Çoban & Topcu, 2013; Le et al., 2024). This approach ensures unbiased and consistent parameter estimation by mitigating biases caused by omitted variable bias, reverse causality, or simultaneity.

4. Empirical Results

4.1 Descriptive Statistics

Table 1 reports the summary statistics of our sample. The average renewable energy consumption in Europe and Central Asia between 2000 and 2019 is 19.06%. Additionally, the average FDI is 7.49%. Similarly, the average government spending of the region for the sampling period is 18.01%.

Table 1. Descriptive statistics

VARIABLES	MEAN	MAX	MIN	STD. DEV	N
REC (%)	19.065	81.070	0.050	16.590	939
FDI (%)	7.496	280.132	-57.532	19.899	939
GE (%)	18.017	27.935	5.941	4.219	939
ATC (%)	91.995	100	36.5	14.23717	939
LNCO2	10.666	14.348	7.396	1.581	939
LNEPE	1.546	3.483	0.278	0.502	939
GDP_GROWTH (%)	3.099	33.030	-14.759	4.133	939

Note: This table displays descriptive statistics for the main variables of the study. The sample includes 45 European and Central Asian countries from 2000 to 2019. Appendix B reports all the variable definitions.

4.2 Pearson Correlation Matrix

Table 2 reports the correlation coefficients across independent variables. All correlation coefficients are moderate because they are less than 0.6. Therefore, our sample contains no multicollinearity concerns (Duong et al., 2022; Tran et al., 2023)

Table 2: Pearson correlation matrix

	FDI	GE	ATC	LNCO2	LNEPE	GDP_GROWTH
FDI	1					
GE	-0.036 (0.262)	1				
ATC	0.030 (0.345)	0.261*** (<0.001)	1			
LNCO2	-0.135*** (<0.001)	0.161*** (<0.001)	0.417*** (<0.001)	1		
LNEPE	-0.076** (0.019)	-0.076** (0.019)	-0.184*** (<0.001)	-0.029 (0.365)	1	

GDP_GRO	0.008	-0.423***	-0.192***	-0.141***	-0.284***	1
WTH	(0.808)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	

Note: The sample includes 45 European and Central Asian nations from 2000 to 2019. Appendix B reports all the variable definitions. Expressions of significance at the 1%, 5%, and 10% levels are shown in ***, **, and *, respectively. P-values are in parentheses.

4.3 Regression Results From the Fixed Effects Model

We implement the Hausman, Breusch-Pagan, and Redundant fixed effect tests to determine if the OLS, FEM, or REM is the best fit for our sample data. These test results suggest that FEM meets all requirements of the selection method, so we report the FEM results in Table 3. The findings show that higher FDI inflow discourages renewable energy consumption in Models 1 and 3 and is positive in Model 4, but this relationship is statistically insignificant. Government spending is also statistically insignificant in Models 2 and 3. The R-squared values in all models are about 0.97, which means that our independent variables explain 97% of the dependent variable's variability, indicating our models' reliable goodness of fit.

Table 3. The regression results from the FEM method

	Model 1	Model 2	Model 3	Model 4
FDI	-0.003 (0.638)		-0.002 (0.766)	0.097** (0.025)
GE		-0.328*** (<0.001)	-0.327*** (<0.001)	-0.293*** (<0.001)
FDI_GE				-0.005** (0.021)
ATC	0.064** (0.038)	0.085*** (0.006)	0.084*** (0.006)	-0.082*** (0.008)
LNCO2	-18.466*** (<0.001)	-18.940*** (<0.001)	-18.932*** (<0.001)	-18.797*** (<0.001)
LNEPE	-5.784***	-4.752***	-4.750***	-4.8038***

	(<0.001)	(<0.001)	(<0.001)	(<0.001)
GDP_GROWTH	-0.021 (0.469)	-0.067*** (0.028)	-0.067** (0.029)	-0.075** (<0.015)
C	219.192*** (<0.001)	226.749*** (<0.001)	226.681*** (<0.001)	224.974*** (<0.001)
R_squared	0.965	0.967	0.966	0.967
Adj R_squared	0.96	0.964	0.964	0.965
F-statistic	483.248	493.729	483.917	477.399
F-test(P-value)	<0.001	<0.001	<0.001	<0.001
Durbin Watson	0.327	0.332	0.333	0.345
Wald test (P-value)	<0.001	<0.001	<0.001	<0.001
Hausman (P-value)	<0.001	<0.001	<0.001	<0.001
Redundant Fixed Effect (P-value)	<0.001	<0.001	<0.001	<0.001
N	939	939	939	939

Note: The sample includes 45 European and Central Asian nations from 2000 to 2019. Appendix B reports all the variable definitions. Expressions of significance at the 1%, 5%, and 10% levels are shown in ***, **, and *, respectively. P-values are in parentheses.

4.4 Regression Results From GMM Estimations

The Wald test and Durbin-Watson test results suggest that FEM estimation has heteroskedasticity and autocorrelation issues. However, FEM often violates heteroskedasticity and autocorrelation assumptions. REC(-1) represents the lagged value of renewable energy consumption at time $t-1$, indicating past renewable energy consumption. The purpose of using REC(-1) is to capture the persistent effects of renewable energy consumption over time while controlling for unobserved factors that may influence current renewable energy usage. This approach aligns with the methodology of Le et al. (2024), who also employed lagged dependent variables as instrumental variables in dynamic system GMM models to address endogeneity issues.

Table 4 reports that REC(-1) is statistically significant across all models, with coefficients ranging from -1 to 1, confirming its relevance and validity as an instrument in the estimation process. The AR(1) probability is below 5%, indicating the presence of first-order autocorrelation, validating these instruments for use in dynamic system GMM estimation. Additionally, the Hansen J-test probability exceeds 5%, indicating that the overidentified models are valid. Therefore, we proceed with analyzing the GMM results in Section 5.

Table 4: The regression results from the GMM estimations

	Model 1	Model 2	Model 3	Model 4
REC (-1)	0.426*** (<0.001)	0.444*** (<0.001)	0.422*** (<0.001)	0.426*** (<0.001)
FDI	-0.020*** (<0.001)		-0.023*** (0.0015)	-0.073*** (<0.001)
GE		0.038*** (<0.001)	0.038** (0.0267)	0.031*** (<0.001)
FDI_GE				0.002*** (<0.001)
ATC	0.2392*** (<0.001)	0.229*** (<0.001)	0.241*** (<0.001)	0.234*** (<0.001)
LNCO2	-12.526*** (<0.001)	-12.288*** (<0.001)	-12.575*** (<0.001)	-12.350*** (<0.001)
LNEPE	-3.272*** (<0.001)	-3.492*** (<0.001)	-3.279*** (<0.001)	-3.485*** (<0.001)
GDP_GROWTH	-0.077*** (<0.001)	-0.076*** (<0.001)	-0.069*** (<0.001)	-0.069*** (<0.001)
Cross-section fixed (first differences)	Yes	Yes	Yes	Yes
J-statistic	47.739	43.725	43.274	40.042
Prob(J-statistic)	0.286	0.398	0.374	0.468
N	843	843	843	843
Instrument rank	49	48	48	48

AR1	<0.001	<0.001	<0.001	<0.001
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Note: The sample includes 45 European and Central Asian countries from 2000 to 2019. Appendix B reports all the variable definitions. Expressions of significance at the 1%, 5%, and 10% levels are shown in ***, **, and *, respectively. P-values are in parentheses.

5. Discussion

Table 4 shows that each percentage point increase in net FDI inflows partially lowers renewable energy use by 0.071% in Model 4. FDI through technology development discourages clean energy via the lack of rigorous environmental restrictions (Khan et al., 2021). Moreover, the FDI firms in less developed countries prefer conventional energy to reduce production costs because renewable energy is expensive (Tan & Uprasen, 2022; Rej et al., 2023; Kilicarslan, 2019; Khan et al., 2021). With limited financial resources, FDI enterprises find conventional supplies like coal and natural gas cheaper and more accessible due to existing infrastructure and favorable regulatory regimes. This finding also supports the pollution haven hypothesis (Laldjebaev et al., 2021). This finding supports H1.

Furthermore, we discovered a positive nexus between government spending and renewable energy use. An increase in government funding increases renewable energy utilization by around 0.033% in Model 4. Our findings are consistent with those of Feng et al. (2022) and Aguirre and Ibikunle (2014). European and Central Asian governments have played key roles in determining renewable energy usage through various policies, investments, and regional projects. The European Green Deal, which targets net-zero emissions by 2050, has been a cornerstone of renewable energy policy, leading to a considerable shift toward cleaner energy sources (Gajdzik et al., 2024). Furthermore, the European Union’s renewable energy objectives and financial assistance for renewable technologies have stimulated significant investments in wind, solar, and biomass energy (Bórawski et al., 2022). Likewise, in Central Asia, the Kazakhstan

government has implemented feed-in tariffs, public-private partnerships, and auctions to attract investment in wind and solar energy to generate 15% of its electricity from renewable energy by 2030, with significant government funding and international aid to promote renewable energy development (David & Causevic, 2022). This finding supports H2.

Our findings report the moderating role of government spending in attracting FDI and increasing renewable energy consumption. Table 4 reports that the interaction variable between FDI and government spending positively impacts renewable energy consumption. The coefficient of the interaction term is 0.002, implying that government spending affects the nexus between FDI and renewable energy consumption. Government expenditure moderates the relationship between net FDI and renewable energy consumption in European and Central Asian nations by addressing structural constraints and enhancing policy effectiveness that jointly shape the investment environment for renewable energy. Theoretically, public economics theory posits that government spending can internalize positive externalities associated with renewable energy by funding complementary infrastructure, offering fiscal incentives, and stabilizing economic conditions (Stiglitz & Rosengard, 2015). In this context, public investment in grid modernization, energy storage, and transmission networks enhances the absorptive capacity of host countries, allowing them to more efficiently utilize FDI in renewable energy sectors (Asongu & Odhiambo, 2020). Additionally, targeted expenditures on regulatory institutions and subsidy programs reduce transaction costs and mitigate risks, fostering a more predictable and attractive investment climate (Apergis & Payne, 2011). Theoretical insights from institutional theory (North, 1990) further support the role of public spending in strengthening institutional quality, facilitating policy enforcement, and long-term planning, which is critical for sustaining foreign investor confidence. Empirical evidence from Viglioni et

al. (2025) shows that in countries with robust renewable energy policy frameworks, often underpinned by public spending, FDI more effectively contributes to green energy development. Similarly, Dossou et al. (2023) demonstrate that the interaction between FDI and governance-related expenditure significantly enhances renewable energy outcomes, affirming the moderating role of public sector effectiveness. Nonetheless, the impact of government expenditure is contingent on the quality of governance and fiscal discipline; misallocated spending or regulatory inefficiencies can distort markets and diminish the productive impact of FDI. Hence, while government spending can complement FDI to accelerate renewable energy consumption in Europe and Central Asia, its effectiveness hinges on institutional capacity and strategic allocation. Our findings are consistent with H3.

Table 4 reports the impacts of control variables on renewable energy consumption in Europe and Central Asia. Access to clean fuels and technologies for cooking increases the proportion of people using renewable energy. Renewable energy is clean energy that emits few pollutants when used, so using renewable energy in cooking creates demand for developing the renewable energy market, lowering reliance on fossil fuels. Our findings are consistent with Nguyen and Su (2022).

Table 4 suggests a negative relationship between carbon dioxide emissions and renewable energy consumption. Countries with higher carbon dioxide emissions mainly rely on fossil fuels. Therefore, these countries have lower renewable energy consumption. The findings we obtained are consistent with Khan et al. (2021).

Our results show the positive influence of primary energy intensity on renewable energy. The higher energy demand requires governments to seek energy efficiency policies. Moreover, as energy efficiency improves, the rising competitiveness of

renewable energy sources also contributes to the development of renewable energy consumption. Our findings are consistent with Nguyen and Su (2022).

Finally, there is a positive relationship between economic growth and renewable energy consumption. Using the annual GDP growth rate to study the impact of FDI and government spending on renewable energy consumption allows for a more detailed analysis of the economic scale, the ability to invest in renewable energy, and the direct relationship between economic factors, as well as effective comparisons across countries that are not influenced by population size. Higher economic growth leads to higher living standards and environmental responsibility. Economic growth also leads to more perceptions of sustainable social and economic development. Therefore, more developed economies are developing renewable energy projects and increasing renewable consumption. This finding is consistent with Nguyen and Su (2022).

6. Conclusion and Recommendations

This study investigates the influence of FDI and government spending on renewable energy usage in the Europe and Central Asia regions. We utilized the dynamic system GMM to analyze an unbalanced panel of 939 annual observations in 45 European and Central Asian countries from 2000 to 2019. Our research yields three significant findings on the relationship between FDI, government spending, and renewable energy consumption. Firstly, increasing net FDI inflow reduces renewable energy consumption in European and Central Asian nations. This is due to the notion that FDI firms often prioritize cost-cutting and adopt outdated, energy-intensive technologies, favoring cheaper conventional energy sources over renewables (Tan & Uprasen, 2022; Rej et al., 2023; Kilicarslan, 2019; Khan et al., 2021). Secondly, government spending significantly empowers renewable energy utilization, consistent

with prior studies (Feng et al., 2022; Aguirre & Ibikunle, 2014). Policies like the European Green Deal and Kazakhstan's renewable energy initiatives illustrate the pivotal role of government investments and regulatory frameworks in fostering renewable energy transitions (Gajdzik et al., 2024; David & Causevic, 2022). Finally, government expenditures moderate the impact of FDI on renewable energy consumption by creating infrastructure, education systems, and financial incentives such as subsidies and favorable lending rates, encouraging FDI firms to incorporate renewable energy into their operations and promote sustainable energy use. Our findings align with the pollution haven hypothesis, public economics, and institutional theories.

This study offers important policy insights for Europe and Central Asia in fostering sustainable energy transitions. The negative nexus between net FDI inflows and renewable energy consumption in Europe and Central Asia suggests that foreign investments predominantly flow into non-renewable or less sustainable sectors, undermining the region's energy transition goals. Therefore, the empirical findings support policymakers in developing renewable energy consumption in the following ways. First, governments should introduce green investment screening mechanisms that prioritize and incentivize FDI projects toward renewable energy while discouraging inflows into fossil-fuel-intensive industries through environmental performance standards and sectoral restrictions. Second, governments should align national energy and investment policies to ensure coherence between sustainability objectives and foreign capital allocation. Aligning investment promotion strategies with renewable energy targets can help reorient FDI flows toward environmentally beneficial projects. Third, targeted fiscal reforms, such as conditional tax incentives and climate-linked subsidies, should be employed to shift investor behavior, making renewable energy ventures more competitive and financially viable for foreign stakeholders.

These measures would help to correct the current misalignment revealed by the data and ensure that FDI becomes a supportive, rather than detrimental, force in advancing renewable energy consumption across the region.

The empirical findings also show a positive nexus between net government expenditure and renewable energy consumption in Europe and Central Asia, highlighting the instrumental role of public sector investment in advancing the region's sustainable energy transition. In light of these findings, three key policy implications emerge. First, sustained and strategically directed public expenditure toward renewable energy infrastructure, particularly in grid modernization, energy storage systems, and distributed generation, can enhance the systemic capacity to integrate renewable sources and crowd in complementary private and foreign investments. Second, increased fiscal allocations should target the strengthening of institutional and regulatory frameworks to improve policy coherence, enforcement capacity, and market predictability, thereby fostering an enabling environment for long-term investment in renewable energy projects. Third, the design and implementation of green fiscal policies should incorporate performance-based budgeting and environmental impact assessments to ensure allocative efficiency and policy alignment with national and regional sustainability objectives. These measures collectively underscore the importance of a proactive and well-governed public sector in leveraging fiscal tools to reinforce renewable energy development and support broader environmental and economic goals in Europe and Central Asia.

Even though our research contributes to the expanding literature on the 7th and 8th SDGs, it has the following drawbacks. First, the GMM method's reliance on many instruments can lead to overfitting and weakened validity of the Hansen test for instrument validity, resulting in potentially unreliable inferences (Roodman, 2009).

Second, while it addresses endogeneity, dynamic system GMM may still suffer from bias if the instruments are not sufficiently strong or relevant, which can compromise the robustness of the findings (Blundell & Bond, 1998). Third, the method's complexity and the requirement for careful specification make it challenging to apply, particularly in sustainable development studies that involve diverse and multidimensional data sources. This issue can lead to difficulties in ensuring the model's assumptions hold, potentially impacting the generalizability and interpretation of results in sustainability research. As a result, we propose that subsequent research adopt the panel Autoregressive Distributed Lag estimations to investigate determinants of renewable energy consumption.

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Data Availability Statement

The datasets analyzed during the current study are available in the Dataverse repository: <https://doi.org/10.7910/DVN/M1N1FT>.

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Appendix A. Country list

Albania	Denmark	Kazakhstan	Russian Federation	Turkiye
Armenia	Estonia	Kyrgyz Republic	Slovak Republic	Turkmenistan
Austria	Finland	Latvia	Czechia	Ukraine
Azerbaijan	France	Lithuania	Italy	United Kingdom
Belarus	Georgia	Moldova	Romania	Uzbekistan
Belgium	Germany	Netherlands	Slovenia	
Bosnia and Herzegovina	Greece	North Macedonia	Spain	
Bulgaria	Hungary	Norway	Sweden	
Croatia	Iceland	Poland	Switzerland	
Cyprus	Ireland	Portugal	Tajikistan	

Appendix B. Variable definitions

Notation	Variable	Definition	Citations
REC	Renewable energy consumption	Renewable energy consumption is from renewable sources such as geothermal heat, waves, rain, tides, and sunlight. Renewable energy consumption is measured as a percentage of total energy consumption.	Akadiri et al. (2019)
FDI	Foreign Direct Investment	The net investment inflows as a percentage of GDP.	Duong et al. (2022) Le et al. (2024)
GE	Government expenditure	General government final consumption expenditure in total GDP.	Nguyen & Su (2022)
ATC	Access to clean fuels and technologies	The proportion of the population that has access to clean fuels and technologies in the total population.	Nguyen & Su (2022)
CO2	CO2 emissions	CO2 emissions come from the burning of fossil fuels. They consist of carbon dioxide from solid, liquid, and gas fuels and gas flaring.	Khan et al. (2021) Tran et al. (2023)
EPE	Primary energy intensity level	Log of the Energy intensity level of primary energy.	Nguyen & Su (2022)
GDP_GROWTH	GDP growth rate	GDP annual percentage growth rate.	Duong et al. (2022)

Data source: World Bank.