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Exploring the Impact of Women Governance on CO_2 Emissions in the European Union and Central Asia

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ABSTRACT

The study is novel to contribute to the literature investigating the relationship among CO_2 emissions, women governance, economic development, fossil fuel energy consumption and renewable energy consumption, using a balanced panel dataset of 27 European Union and 4 Central Asian countries over the period 1996-2020. As econometric tools, panel quantile and threshold regression models are employed. Overall, the quantile results document that women governance help to mitigate climate change both in European Union and Central Asia. Moreover, threshold findings suggest that women governance negatively impact on CO_2 emissions in European Union and Central Asia when economic growth is higher than 9.903%. Policy implications are proposed to enhance women governance in European Union and Central Asia.

Keywords: Women Governance, CO_2 Emissions, Quantile Regression, Threshold Regression, European Union, Central Asia
JEL Classifications: Q43, Q53

1. INTRODUCTION

Global emphasis has shifted in recent decades to the critical need for sustainable development and environmental care. The realisation that the state of our environment is closely linked to various aspects of human activity is central to this discourse and that tackling environmental degradation requires a broad and inclusive strategy. Climate change is a serious and imminent problem that requires immediate policy responses (Stern, 2008). While admitting the crucial importance of political commitment in resolving this global crisis, the mechanisms causing significant differences in such pledges among countries remain unknown. This research focuses on the significance of political identity, with a particular emphasis on the gender of politicians. Our investigation tries to determine whether the existence of female participation in political decision-making significantly contributes to global climate change policy initiatives.

Women's representation in parliaments across Europe and Central Asia has witnessed growth over the past 25 years, albeit with modest increases in the last decade (UNDP, 2020; World Bank, 2022). In 2019, Europe and Central Asia boasted the highest proportion of women in parliament, averaging 29% (World Bank, 2022). The rise in women's representation is accompanied by improvements in the World Bank's Women, Business, and Law Index. Regarding ministerial portfolios, women prominently lead in human rights, gender equality, and social protection portfolios. Despite being underrepresented, women hold noteworthy positions in other crucial areas, constituting 32% in the environment, 30% in public administration, and 30% in education portfolios (UN Women, 2023).

Female political representation leads to adopting of a more stringent climate change policy, showing lower carbon dioxide emissions (Mavisakalyan and Tarverdi, 2019). Furthermore, the governance quality level has important implications for CO_2 emissions reduction and the role of female leadership in these efforts (Lv et al., 2022). Women typically demonstrate greater awareness of climate change, environmental issues, and pro-environmental behaviour (Salamon, 2022). Despite similar levels of environmental concern between male and female legislators in the European Union, women displayed a notably higher inclination for endorsing environmental legislation, even after controlling for political ideology and nationality (Ramstetter and Habersack, 2019).

The role of women in governance has become more prominent and is considered a severe factor towards the success (or not) of environmental policies and programmes. Recognising the aspects of governance is not enough as understanding the specific contributions of women is important. UNDP (2023) stated specifically that the inclusion of women in decision-making can improve the adoption of climate change measures. The purpose of this study is to quantify the relationship between women's participation in governance and environmental degradation, providing insights on the potential of gender-inclusive decision-making processes to foster long-term solutions for the benefit of current and future generations.

2. LITERATURE REVIEW

There is a growing realization that the interplay of human activity and complex environmental factors in an ever-changing environment requires elaborate planning given their central role in behaviour-sustainable formation in female perspectives and leadership styles need to be recognized and actively welcomed as part of this holistic approach. Women have consistently demonstrated a unique ability to break down barriers, build networks, and lead community-based efforts that produce long-term positive impacts (Anwar et al., 2020).

This remarkable achievement in their structural reform campaign is evident, as women leaders have been instrumental in supporting ongoing development. Women have also led the way in the development of renewable energy technologies, demonstrating their commitment to innovative and environmentally friendly solutions (UN Women UNIDO, 2023). Active support for conservation enhances their impact on sustainable development by helping to preserve our natural resources (James et al., 2021). On the other hand, the positive effects of conservation do not always benefit women and may perpetuate existing inequalities if women are not taken into account (James et al., 2021).

As per Ramstetter et al. (2019), the continuous underrepresentation of women in legislative bodies leads to environmental policies being unduly influenced by men's preferences, notwithstanding women's stronger support for endorsing environmental legislation. Women have a critical role in leading society toward a more peaceful and sustainable future, where environmental issues are woven smoothly into the fabric of decision-making and progress by recognising and harnessing their particular leadership skills (Balabantaray, 2023).

Women in leadership positions emerge as a dynamic force in the expansive area of sustainable development, delicately intertwining creativity, inclusivity, and resilience. Including women in leadership roles has a positive impact on environmental and social performance and enhances the quantity, quality, and transparency of sustainability disclosure (Bannò et al., 2021). A careful review of the above statistics demonstrates indisputably that the facilitation and development of women's leadership are critical components in sustaining a flourishing planet and society. This demonstrates the enormous impact women in leadership positions can have on crafting a sustainable and prosperous future. Women in leadership positions allow the convergence of varied viewpoints, new ideas, and inclusive decision-making processes, contributing considerably to creating resilient communities and sustainable development practices. In essence, the advancement of women's leadership emerges as a critical catalyst in guiding societies toward a more harmonious and successful coexistence (Balabantaray, 2023).

Progress toward a more equitable and affluent future necessitates collaborative efforts by governmental entities, organisations, local communities, and individuals. This joint effort is critical for methodically removing barriers, challenging established conventions, and creating an environment conducive to the blossoming of women's leadership (Sahoo and Jena, 2023). Recognizing that fundamental progress requires collective efforts, this call for unity underscores the importance of working together to break down barriers that limit women's leadership potential. By questioning established norms and promoting an inclusive and supportive environment, a variety of stakeholders can help create an environment where women are empowered to lead effectively. This collaborative approach drives it forward by becoming a cornerstone of creating an environment that recognizes and actively fosters women's leadership.

The impact of politicians' gender identity on policy outcomes has been extensively studied. Several studies have shown that greater female political representation has a significant impact on domestic and foreign policies. For example, countries with higher numbers of female MPs spend more on health and education (Bhalotra and Klots-Figueras, 2014; Mavisakalyan, 2014). In addition, the presence of women in political decision-making has led to more legislation, increased spending on gender-specific needs (Chattopadhyay and Duflo, 2004; Clots-Figueras, 2011), and larger foreign aid packages provided by (Hicks et al., 2015). Women's participation in parliament has a significant impact on economic growth. According to Mirziyoyeva and Salahodjaev (2023), a 10% increase in female parliamentary representation leads to a 0.74% increase in GDP.

Gender differences in public attitudes towards climate change indicate that women are more aware of and concerned about climate change than men (McCright, 2010; McCright and

Dunlap, 2011). This difference can be attributed mainly to inequalities in beliefs and social expectations through social networking processes that emphasize gender social networking theories while women value climate change of action, such as cooperation and caution are given greater priority than the men (Beutel and Marini, 1995) wrote. Furthermore, gender differences in climate change concerns can be attributed to specific social roles played in society, where climate change is perceived to be closely related to the roles played.

Furthermore, climate change is predicted to manifest in gender-specific ways. Females are predicted to incur a disproportionate share of the costs associated with climate change due to "gendered labor and care duties, as well as social status" (Seager et al., 2016, p.13). This in-depth analysis of gender discrepancies in climate change beliefs and implications reveals the complicated interplay between societal expectations, roles, and the gendered characteristics of environmental concern and vulnerability.

3. METHODOLOGY AND DATA

3.1. Econometric Methodology

The baseline model to explore the relationship among CO_2 emissions (*logCO2*), women governance (*WG*), economic development (*logPGDP*), fossil fuel energy consumption (*FEC*) and renewable energy consumption (*REC*) can be described as the following (Eq. 1):

$$\text{logCO2}_{i,t} = a_0 + a_1\,\text{WG}_{i,t} + a_2\,\text{logPGDP}_{i,t} + a_3\,\text{FEC}_{i,t} + a_4\,\text{REC}_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where, a_0 is an intercept; a_1, a_2, a_3, a_4 are elasticity coefficients; ε is an error term, i is cross-sections, t is the time period.

It should be noted that economic fluctuations such as financial crises, natural disasters, geopolitical conflicts, etc., sometimes cause heteroskedasticity. In this case, the OLS estimator loses the estimation efficiency since it takes the variables' average values. A quantile regression model (Graham et al., 2015) can be used to cope with heteroskedasticity since quantile regression does not require a normal distribution of the data.

The panel quantile regression model is shown in equation (2).

$$Q_{logCO2_{i,t}}\left(\tau|x_{i,t}\right) = \beta_0 + \beta_1 WG_{i,t} + \beta_2 logPGDP_{i,t} + \beta_3 FEC_{i,t} + \beta_4 REC_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where $Q_{logHAP_{i,t}}\left(\tau|x_{i,t}\right)$ is the quantile distribution of $logCO2_{i,t}$ (explained variable), which is constrained by the position of the explanatory and control variables; τ represents the quantile of each section (i).

We also assume that women's governance (*WG*) on CO_2 emissions *logCO2* varies depending on the level of economic development (*logPGDP*) of European Union and Central Asian countries. This assumption leads us to apply a panel threshold regression model (Wang, 2015) to estimate the threshold relation of women's governance (*WG*) on CO_2 emissions (*logCO2*). The panel threshold regression model can be represented by equation (3):

$$logCO2_{i,t} = c_0 + c_1 WG_{i,t} {}^* I\left(logPGDP_{i,t} \le \gamma\right) + c_2 WG_{i,t} {}^* I\left(logPGDP_{i,t} > \gamma\right) + c_3 logPGDP_{i,t} + c_4 FEC_{i,t} + c_5 REC_{i,t} + u_i + \varepsilon_{i,t} \quad (3)$$

Where I() expresses the indicator function. The threshold regression model explores the effect of women's governance (*WG*) on CO_2 emissions (*logCO2*) with the changes in economic development regimes (*logPGDP*). c_0 is intercept, c_1, c_2, c_3, c_4 and c_5 are elasticity coefficients, u_i is the individual effect, $\varepsilon_{i,t}$ is the disturbance.

The important consideration for applying panel quantile and threshold regression models is testing for heteroskedasticity. To this end, we employ White's test (White, 1980) for heteroskedasticity. In order to check if cross-sectional dependence exists or not, we run the cross-sectional independence test proposed by Pesaran (2004). Moreover, as unit root tests, we perform IPS (Im et al., 2003) and the CIPS (Pesaran, 2004) unit root tests. Pedroni (2004) and Westerlund (2005) conduct panel cointegration tests to examine the long-run relations among the used variables. Furthermore, to control the endogeneity issue, we estimate equation (1) by means of the Hausman-Taylor (Amacurdy) estimator (Hausman and Taylor, 1981).

3.2. Data

To empirically study the relationship among CO_2 emissions, women governance, economic development, fossil fuel energy consumption and renewable energy consumption, a balanced panel dataset, including 27 European Union[1] and 4 Central Asian[2] countries, is developed for 1996-2020 using annual data. The study uses CO_2 emissions, measured in metric tons per capita, as the dependent variable. In contrast, women governance, measured in women percentage in parliament, is employed as the core explanatory variable. Economic development, measured in gross domestic product per capita in USD, fossil fuel energy consumption, percentage of total energy consumption, renewable energy consumption, and percentage of total energy consumption are applied as control variables. The data for CO_2 emissions, gross domestic product per capita, fossil fuel and renewable energy consumptions are obtained from World Development Indicators. In contrast, the data on women governance is derived from the United Nations Development Programme. Table 1 provides the definition and sources of the studied variables.

According to the descriptive statistics provided in Table 2, the average carbon dioxide (*CO2*) emissions per capita in the European Union and Central Asia during the period 1996-2020 amounted to 7.13 metric tons. Women's representation in parliament (*WG*) averages 21.74%. The per capita gross domestic product (*PGDP*)

1 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden.

2 Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan.

Table 1: Definition and sources of the variables

Variable types	Notation	Name	Definition	LOG transformation	Data source
Explained variable	CO_2	CO_2 emissions	Carbon dioxide emissions, metric tons per capita	*logCO*$_2$	World development indicators
Core explanatory variable	*WG*	Women governance	Share of seats in parliament, % held by women	-	United nations development programme
Control variables	*PGDP*	Economic development stage	GDP per capita, constant 2015 US$	*logPGDP*	World development indicators
	FEC	Fossil fuel energy consumption	% of fossil fuel energy consumption in total energy consumption	-	World development indicators
	REC	Renewable energy consumption	% of renewable energy consumption in total energy consumption	-	World development indicators

Table 2: Descriptive statistics of the studied variables

Definition	*CO*$_2$	*WG*	*PGDP*	*FEC*	*REC*
Mean	7.13	21.74	24799.73	72.30	20.45
Standard deviation	3.78	10.60	20835.74	22.34	18.93
Minimum	0.32	0	371.83	1.82	0
Maximum	25.60	47.30	112417.9	118.24	82.76
Observations	775	775	775	775	775

Table 3: The results of White's test for heteroskedasticity

White's test	
H0: Homoskedasticity	Chi2 (14) = 374.22
against Ha: Unrestricted heteroskedasticity	Prob >Chi2=0.00

For White's test for heteroskedasticity, we report the *P* value of Chi-square

is recorded at an average of 24,799.73 USD. Fossil fuel energy consumption (*FEC*) averages 72.30%, while renewable energy consumption (*REC*) constitutes an average of 20.45% of the total energy consumption.

4. EMPIRICAL RESULTS

Firstly, we conduct a test for heteroskedasticity, and the results are presented in Table 3. The null hypothesis posits that the data is homoscedastic, while the alternative hypothesis suggests the presence of heteroscedasticity. We reject the null hypothesis if the $P < 0.05$. Based on the results, we find evidence that heteroskedasticity exists in the data.

We proceed with the VAR (vector autoregressive) lag selection criteria. Table 4 displays the optimal lag orders determined by LR, FPE, AIC, SIC, and HQ criteria. Following the Schwarz information criterion (SIC), we select the optimal lag as 2.

Table 5 denotes the results of the cross-sectional dependence (CD) and unit root test (IPS, CIPS). The null hypothesis for the cross-section dependence (CD) test posits no cross-section dependence. While the null hypothesis for 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%. The results indicate the existence of cross-sectional dependence for all variables employed, namely *logCO2*, *WG*, *logPGDP*, *FEC*, *REC*. In terms of unit root tests, all variables are found to be integrated at the first differences, denoted as I(1), according to the CIPS unit root test.

Table 4: The results of lag selection criteria

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	−8319.745	NA	1300163.	28.267	28.304	28.281
1	−1765.362	12975.23	0.000	6.096	6.319	6.183
2	−1642.689	240.763	0.000	5.764	6.173*	5.923*
3	−1601.891	79.379	0.000	5.711	6.305	5.942
4	−1566.015	69.194	0.000*	5.674*	6.454	5.978
5	−1545.986	38.290	0.000	5.690	6.657	6.067
6	−8911.874	30.703	16166457	30.787	31.939	31.236

*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 5: Results of cross-section dependence tests and panel unit-root tests

Variables	CD test	IPS test		CIPS test	
		Level	1st difference	Level	1st difference
logCO$_2$	38.77***	5.838	−5.514***	−1.359	−4.278***
WG	70.50***	70.50***	1.14	-9.11***	−2.23**
logPGDP	88.29***	−3.817***	−3.498***	−2.525***	−3.241***
FEC	30.01***	6.39	−1.79**	−0.56	−3.39***
REC	46.31***	6.57	−6.43***	−1.96	−4.44***

*** and ** represent statistical significance at the levels of 1% and 5%, respectively. The null hypothesis of the cross-section dependence test is no cross-section dependence. Lag length are selected as 2, based on SIC criterion

Table 6: Results of panel cointegration tests

Pedroni test	Statistic	P-value
Modified Phillips-Perron t	2.480	0.00
Phillips-Perron t	−3.306	0.00
Augmented Dickey-Fuller t	−3.458	0.00
Westerlund test		
Variance ratio	−2.711	0.00

Lag length selection based on SIC criterion; ***P<0.01

Based on the evidence indicating that all studied variables are integrated at the first differences, we proceed to panel cointegration tests. To this end, we employ both Pedroni and Westerlund cointegration tests. The null hypothesis for both cointegration tests posits no long-run relationship among the variables. We reject the null hypothesis when the P-value is lower than 0.05 ($P < 0.05$), signifying statistical significance.

The results of cointegration tests, as presented in Table 6, indicate a long-run relationship among the variables under consideration, *logCO2*, *WG*, *logPGDP*, *FEC*, and *REC*. Consequently, we can proceed with model estimations.

Table 7: Estimation results of baseline models

Variables	Model (1)	Model (2)	Model (3)
	POLS	RE	FE
WG	−0.005***	−0.007***	−0.006***
logPGDP	0.483***	0.191***	0.153***
FEC	0.003***	0.008***	0.009***
REC	−0.009***	−0.012***	−0.012***
Constant	−2.793***	−0.280	0.040
Hausman test			64.72***
R^2	0.67	0.34	0.28
Observations	775	775	775

*** represents statistical significance at the levels of 1%

Table 7 displays the outcomes of POLS, fixed effect, and random effect regressions. Following the Hausman test, we concentrate on the fixed effect results for interpretation purposes. Given that the impact coefficients of women governance (*WG*) on CO_2 emissions (*logCO2*) are nearly identical in POLS (−0.005) and fixed effect regression (−0.006), we may posit the absence of unobserved heterogeneity. In this instance, we proceed to estimate panel quantile and threshold regression models using these variables.

According to the estimated results provided in Table 8, women governance *WG* has a positive impact on CO_2 emissions (*logCO2*) in lower quantiles (5%, 15%, 25%, 35%, 45%), whereas the relation is negative in higher quantiles (55%, 65%, 75%, 85%,

Table 8: The estimated coefficients by the means of quantile regression: Full sample combining EU and CA

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$logCO_2$	5%	15%	25%	35%	45%	55%	65%	75%	85%	95%
WG	0.004***	0.010***	0.005**	0.006***	0.007***	−0.003	0.004***	−0.007***	−0.002	−0.019***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.003)	(0.002)	(0.001)	(0.003)	(0.001)
logPGDP	0.598***	0.417***	0.485***	0.481***	0.498***	0.497***	0.430***	0.342***	0.404***	0.406***
	(0.010)	(0.006)	(0.011)	(0.012)	(0.007)	(0.003)	(0.009)	(0.011)	(0.009)	(0.016)
FEC	0.005***	0.004***	0.005***	0.005***	0.006***	0.006***	0.000	0.002	−0.004***	−0.002***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)	(0.000)	(0.002)	(0.001)	(0.000)
REC	−0.010***	−0.007***	−0.008***	−0.011***	−0.012***	−0.004	−0.011***	−0.008***	0.000	−0.005***
	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.002)	(0.002)	(0.000)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean acceptance rate	0.342	0.338	0.297	0.341	0.406	0.208	0.206	0.464	0.368	0.737
N	775	775	775	775	775	775	775	775	775	775

Standard errors in parentheses; *** and ** represent the significance at 1% and 5%, respectively

Table 9: The estimated coefficients by the means of quantile regression: Divided sample by EU and CA

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$logCO_2$	5%	15%	25%	35%	45%	55%	65%	75%	85%	95%
WG	−0.006***	−0.005***	−0.002***	−0.001***	−0.001***	−0.000**	−0.003***	−0.002***	−0.015***	−0.015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
logPGDP	0.349***	0.371***	0.404***	0.405***	0.388***	0.363***	0.373***	0.345***	0.380***	0.480***
	(0.000)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)	(0.021)
FEC	0.007***	0.007***	0.008***	0.008***	0.006***	0.004***	0.002***	0.001***	−0.004***	−0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
REC	−0.001***	−0.002***	−0.002***	−0.001***	−0.002***	−0.003***	−0.004***	−0.005***	−0.002***	−0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
*CA*WG*	−0.001***	−0.009***	−0.013***	−0.016***	−0.018***	−0.014***	−0.016***	−0.013***	0.001	0.002
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)	(0.005)
*CA*logPGDP*	0.036***	0.080***	0.180***	0.169***	0.164***	0.189***	0.153***	0.161***	0.085***	0.034**
	(0.000)	(0.003)	(0.011)	(0.002)	(0.001)	(0.008)	(0.004)	(0.005)	(0.019)	(0.017)
*CA*FEC*	−0.001***	−0.001***	−0.005***	−0.005***	−0.004***	−0.008***	−0.005***	−0.006***	−−0.002*	0.002***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
*CA*REC*	−0.024***	−0.026***	−0.032***	−0.030***	−0.031***	−0.033***	−0.032***	−0.035***	−0.041***	−0.034***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean acceptance rate	0.044	0.623	0.448	0.520	0.620	0.437	0.531	0.654	0.482	0.212
N	775	775	775	775	775	775	775	775	775	775

Standard errors in parentheses ***, ** and * represent the significance at the 1%, 5%, and 10% level, respectively. The coefficients of variables, non-interacted with dummies, refer to European Union countries. Central Asian countries refer to the corresponding dummies (CA)

95%) in European Union and Central Asian countries. This inconsistency prompts an exploration of the association between CO_2 emissions (*logCO2*) and women governance (*WG*) by dividing the sample separately into European Union and Central Asian countries. We use dummies to categorise the sample; the results are provided in Table 9.

According to Table 9, women governance (*WG*) exhibits a negative association with CO_2 emissions (*logCO2*) across all quantiles (5%, 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85%, 95%) in European Union. In Central Asian countries, women governance (*WG*) negatively impacts CO_2 emissions (*logCO2*) in quantiles, 5%, 15%, 25%, 35%, 45%, 55%, 65%, 75%, whereas there is no relation in quantiles 85% and 95%.

Considering our assumption about the varying importance of the stage of economic development (*logPGDP*) in examining women governance (*WG*) effect on CO_2 emissions (*logCO2*), we proceed with the estimation using a panel threshold regression model. In estimating the panel threshold regression model, we indicate economic development (*logPGDP*) as the threshold variable and women governance (*WG*) as regime-dependent variable.

A threshold effect test is conducted as an initial step in constructing the panel threshold regression model, and the results are provided in Table 10. The results indicate that a panel threshold regression model should be developed, considering a single threshold point, as the double threshold test yields a non-significant P-value.

In the next step, we estimate threshold values for a single threshold, the results are provided in Table 11.

Based on the results obtained from the threshold regression model (Table 12), women governance (*WG*) negatively impacts on CO_2 emissions (*logCO2*) in European Union and Central Asia when the growth rate of economic development (*logPGDP*) stage is higher than 9.903%.

Table 10: The results of the threshold effect test for single and double threshold

Threshold	RSS	MSE	Fstat	Prob	Crit10	Crit5	Crit1
Single	8.749	0.012	70.79	0.020	50.178	60.665	81.507
Double	8.444	0.011	27.05	0.400	46.859	54.486	72.871

Table 11: The threshold values for the single threshold model

Threshold variable	Number of thresholds	Threshold value	Confidence interval
logPGDP	Single	9.903	[9.901, 9.911]

Table 12: The results of the threshold regression model

Variables	Coefficients
WG *I (*logPGDP* >9.903)	−0.001
	(0.001)
WG *I (*logPGDP* >9.903)	−0.009***
	(0.001)
logPGDP	0.119***
	(0.023)
FEC	0.010***
	(0.001)
REC	−0.012***
	(0.001)
Constant	0.318
	(0.212)
R-square	0.606
N	775

Standard errors in parentheses; *** represents the significance at the 1% level

4.1. Endogeneity

We proceed with our estimations while controlling for endogeneity issues. To this end, we apply Hausman-Taylor and Amacurdy estimators for error-component models. The results are presented in Table 13.

The results from Table 13 indicate that women governance negatively influences CO_2 emissions in both the European Union and Central Asia, validating the findings obtained in Table 7, particularly in high quantiles as presented in Table 8, and consistently across all quantiles as shown in Table 9.

Table 13: The results of the Hausman-Taylor and Amacurdy estimators

Independent variables	Dependent variable: *logCO₂*							
	Model 1 Hausman-Taylor	Model 2 Amacurdy	Model 3 Hausman-Taylor	Model 4 Amacurdy	Model 5 Hausman-Taylor	Model 6 Amacurdy	Model 7 Hausman-Taylor	Model 8 Amacurdy
Time-varying exogenous								
WG			−0.006***	−0.006***	−0.006***	−0.006***	−0.006***	−0.006***
logPGDP	0.171***	0.171***			0.170***	0.171***	0.171***	0.171***
FEC	0.008***	0.008***	0.009***	0.008***			0.008***	0.008***
REC	−0.012***	−0.012***	−0.012***	−0.012***	−0.012***	−0.012***		
Time-varying endogenous								
WG	−0.006***	−0.006***						
logPGDP			0.159***	0.171***				
FEC					0.009***	0.008***		
REC							−0.012***	−0.012***
Time-invariant exogenous								
id	−0.025**	−0.025**	−0.026**	−0.025**	−0.025**	−0.025**	−0.025**	−0.025**
Constant	0.299	0.303	0.415	0.303	0.293	0.303	0.304	0.303
N	775	775	775	775	775	775	775	775

*** and ** represent the significance at the 1% and 5% level, respectively

The study's findings strongly emphasise the pivotal role of women governance in mitigating environmental degradation, both within the European Union and Central Asia.

5. CONCLUSION AND DISCUSSION

This study critically examines the intricate relationship between women's governance and environmental outcomes in the European Union and Central Asian countries from 1996 to 2020. Acknowledging the global discourse on sustainable development and environmental care, the research focuses on the urgent need for policy responses to climate change. It explores the unexplored mechanisms causing variations in outcomes among countries. The impact of politicians' gender identity on policy results is a central theme, particularly in the context of climate change initiatives.

The increase in women's representation in parliaments across Europe and Central Asia is highlighted as a significant trend, with a particular emphasis on its relationship with the adoption of stringent climate change legislation and decreased carbon dioxide emissions. The study of literature emphasises women's critical role in sustainability, recognising their efforts to break down obstacles, push legislative reforms, and spearhead good environmental advances. Despite their underrepresentation, women contribute greatly to renewable energy technology and conservation efforts.

This study's econometric methodology tries to decipher the complex relationship between CO_2 emissions, women's governance, economic development, fossil fuel energy use, and renewable energy consumption. Several major findings emerge from the investigation. First, the presence of heteroskedasticity in the dataset shows varying variability. The optimal lag selection criteria establish a lag of 2 based on several variables, laying the groundwork for the forthcoming assessments. All variables show cross-sectional dependence and unit root tests reveal that all variables are integrated at the first differences, emphasizing their dynamic nature. Cointegration experiments show a long-run link between CO_2 emissions, women's governance, economic progress, and fossil fuel and renewable energy usage. When it comes to regression outcomes, fixed effect regressions consistently produce negative results.

Quantile regression analysis adds granularity, demonstrating that women's governance has a beneficial impact on CO_2 emissions in lower quantiles but a negative impact in higher quantiles. Threshold regression refines our understanding by demonstrating that when the economic development growth rate exceeds 9.903%, women's governance has a negative impact on CO_2 emissions. The study applies the Hausman-Taylor and Amacurdy estimators to compensate for endogeneity concerns in order to assure the robustness of these findings. The findings repeatedly confirm that women's governance has a negative impact on CO_2 emissions, lending credence to the idea that gender-inclusive decision-making procedures might play an important role in preventing environmental deterioration.

The study's finding that women's governance has a negative impact on CO_2 emissions gives a unique potential for revolutionary policy innovation. Governments and environmental organizations can use this knowledge to restructure existing environmental policies or create new ones through gender-inclusive decision-making procedures. The constant trend of female leaders favouring ecologically sustainable measures suggests unrealised potential. Policymakers are ready to capitalise on this tendency, increasing the rigour of climate change regulations and setting ambitious targets for carbon reduction and increased use of renewable energy sources. The positive impact of women's governance on CO_2 emissions in lower quantiles suggests a sector-specific approach. Based on this discovery, efforts might be concentrated to improve sustainability practices in sectors where women leaders have shown success.

Furthermore, the commitment of women leaders to environmental protection opens the door to the creation and advocacy of comprehensive environmental education and awareness programs. Using the influence of female politicians, these programs play an important role in advocating and teaching sustainable practices at the individual and societal levels the threshold regression model highlights the nuanced nature of the relationship, suggesting that when economic growth crosses a certain threshold you can apply this knowledge in a way that is. This includes ensuring that development policies are long-term and consistent with climate and environmental goals. Policy makers can reduce CO_2 emissions by deliberately exploiting the observed negative effects of female governance.

Finally, this study reaffirms the important role of women in governance and leadership in promoting sustainable development and environmental protection. Women's political participation is associated with more effective climate change policy advocating inclusive governance to address global concerns. The study findings provide useful insights into the complex relationship between gender representation in government and environmental outcomes, and encourage the exploration of those dynamics revive it for the benefit of present and future generations.

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