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The Relationship among Fossil Fuel Energy, Economic Development, Institutional Quality, Globalization, Foreign Direct Investment and Forest in European Countries

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ABSTRACT

Currently, the harmful nature of fossil fuel is being discussed in the forest context in Europe. Therefore, this research examines the effect of fossil fuel energy on forest area in the panel of 39 European countries during the period 2000-2024. For the empirical estimations, Quantile regression estimated through the Method of Moments framework is employed which is robust to heteroscedasticity. The findings reveal that fossil fuel energy negatively and significantly impacts on forest area across all the quantiles from 10% to 90%. Policy implications should prioritize the role of fossil energy in shaping forest policy.

Keywords: Fossil Fuel Energy, Forest Area, MMQR, European Countries
JEL Classificatios: Q4, Q57, C33

1. INTRODUCTION

The widespread use of fossil fuels is increasing climate change and negatively affecting forest ecosystems. The UN (2023) notes that energy production and forest resources are closely linked. fossil fuel combustion results in increased CO_2 emissions, increasing the risk of forest fires, drought, and degradation. The widespread use of fossil fuels is increasing climate change and negatively affecting forest ecosystems. According to the study by World Bank (2023), extensive use of fossil fuels severely damages forest ecosystems. CO_2 and other polluting gases degrade air quality, impair photosynthesis in forests, and slow down tree growth. Greenhouse gases, on the other hand, increase climate change and increase the risk of drought and fire. Huang (2022) noted that fossil fuels and dead organic matter negatively affect forest soils. The extraction and burning of fossil fuels disrupts the physical structure of the soil, activates chemical pollution and causes a weakening of the activity of microorganisms. Mismanagement of dead organic matter causes the soil to lose track of food circulation. As a result, the stability of forest soils decreases and ecosystem functions weaken. As well as, Union of Concerned Scientists (2023) states that greenhouse gases generated by burning fossil fuels increase global warming and increase the risk of forest fires. Temperature rises, droughts, and dry plant masses cause fires to spread rapidly. As a result, forests suffer, soil fertility decreases and carbon cycle is disrupted. Also, fossil fuel energy causes both direct and indirect damage to forests. Greenhouse gases from combustion increase climate warming, making forests more vulnerable to drought

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and fire hazards, while extraction and transportation processes disturb soil structure, reduce productivity, and negatively affect biodiversity (Wang and Azam, 2024). Moreover, the process of substituting fossil fuel energy with forest biomass has two distinct effects on forest ecosystems. When trees are felled for energy, forest carbon storage initially decreases, which can be environmentally harmful. However, if biomass is replanted in fast-growing areas and energy conversion efficiency is high, this practice can benefit the climate by reducing fossil fuel use in the long run (Marland and Schlamadinger, 1997).

Furthermore, Schulze et al. (2021) argue that using biomass as energy or product through sustainable forest management reduces the demand for fossil fuels, which benefits the climate, but the impact on the forest's carbon storage and ecology depends on growth rate, replanting and product yield. Additional to that, an article by Harfoot et al. (2018) concludes that fossil fuel mining activities pose a serious threat to forests and other natural environments — specifically in terms of biodiversity. If new mining blocks, infrastructure and exploration plans are implemented in biologically rich and unprotected areas, forest cover, primary habitat, and endemic species can be heavily damaged. Also, Deluca (2025) argue that fossil fuel energy damages forests not only by direct logging and fragmentation, but also by increasing atmospheric CO_2 load and creating environmental pressure. Therefore, reducing the use of fossil fuels and integrated ecosystem management is necessary to protect forests and maintain carbon storage function. In addition, Wang (2024) highlights that fossil fuel energy consumption has a negative impact on forest ecosystems. This effect occurs both directly (deforestation of biomass for fuel or other resources) and indirectly (climate change through CO_2 emission, drought, and slowing plant growth) fossil fuel energy consumption has a negative impact on forest ecosystems. This effect occurs both directly (deforestation of biomass for fuel or other resources) and indirect. According to the research by Idroes et al. (2024), the consumption and extraction of fossil fuel energy negatively affect forest ecosystems. This effect occurs in direct (deforestation, biomass depletion, infrastructure construction) and indirect (climate change through CO_2 emission, drought, fire hazard, and biodiversity depletion) ways. The consumption and extraction of fossil fuel energy negatively affect forest ecosystems. Also, Röser et al. (2008) analyze that the consumption and extraction of fossil fuel energy negatively affect forest ecosystems. This effect occurs in direct (deforestation, biomass depletion, infrastructure construction) and indirect (climate change through CO_2 emission, drought, fire hazard, and biodiversity depletion) ways. The consumption and extraction of fossil fuel energy negatively affect forest ecosystems.

The literature clearly indicates that theoretically fossil fuel energy has a negative effect on forest area. Moreover, in Europe the environmental awareness is one of the issues that central government pay considerable attention to achieve environmental sustainability. However, the literature suffers from the gap which should investigate the impact of fossil fuel energy on forest area in the case of European economies. In order to fill this gap of the literature, the current work assesses the effect of fossil fuel energy on forest area in European nations. To this end, a robust methodology for heteroscedasticity issue, Method of Moments Quantile Regression is employed.

2. LITERATURE REVIEW

2.1. Impact of Fossil Fuel Energy on Forest Area

In literature, the interest to investigate the impact of fossil fuel energy on forest area is gaining huge attention recently. More precisely, Landry and Matthews (2016) aim of this research was to demonstrate the effects of the key differences in the idle of fossil fuel combustion and non-deforestation fires by using 1,000-year simulations of a coupled climate–carbon model with interactive vegetation. The results indicate that comparing CO_2 emissions from non-deforestation fires and fossil fuels as if they have equivalent climate impacts should be avoided, especially when referring to gross fire emissions, since the carbon sources involved have vastly different storage durations in the Earth's system. As well as, Apergis et al. (2023) studied the effect of fossil (fuel) and renewable energy consumption on CO_2 emissions in Uzbekistan between 1985 and 2020. According to the results, renewable energy like hydropower reduces CO_2 emissions and benefits the environment, while fossil fuels increase emissions and harm forests. Moreover, Shabeer and Rasul (2024) studied the effects of fossil fuel consumption, forests, and the environment by world country between 2011 and 2021. The results showed that effective forest use in reducing fossil fuel consumption and pollution was one of the most sustainable solutions. Furthermore, Kuziboev et al. (2023) the effects of renewable energy and human capital on CO_2 emissions in Europe and Central Asia. The results showed that renewable energy and human capital would reduce CO_2 emissions, which would slow down climate change and protect forests. Therefore, the development of renewable energy infrastructure and the strengthening of education ensure environmental sustainability.

Also, Zanuncio et al. (2024) have studied the effects of fossil fuel consumption on forest ecosystems and climate. They analyzed how CO_2 exiting the atmosphere affects the carbon cycle, growth and environmental sustainability of forests. According to the results of the investigation, fossil fuel combustion causes direct and indirect damage to forests, increases climate warming, increases the risk of drought and fire, and reduces the ability of forests to absorb carbon. As well as, Wang and Azam (2024) researches the nexus in the middle of agricultural nitrous oxide emissions and natural resource scarcity, taking into account the dynamics of fossil fuels in top-emitting countries between 1971 and 2020. The results showed that heavy use of fossil fuels would exacerbate natural resource shortages and increase greenhouse gas emissions. This increases the pressure on forests and negatively affects their natural recovery. In additional that, Kasting and Walker (1993) examined changes in atmospheric carbon dioxide (CO_2) levels from activating fossil fuels and deforestation, and the effects of this process on climate and forests. The study found that activating fossil fuels in large quantities and reducing forests dramatically increases the amount of CO_2 in the atmosphere, leading to global warming and deforestation.

2.2. Theoretical Background

The association between fossil fuel energy and forest area is affected by control variables such as economic development, institutional quality, globalization and foreign direct investment. More specifically, the use of fossil fuel energy accelerates economic growth, but this process increases environmental pressure and negatively affects forest ecosystems. Moreover, fossil fuel energy accelerates economic growth, but increases CO_2 emissions and ecological footprint, negatively affecting forests. According to Idroes et al. (2024) study, renewable energy mitigates this effect and supports the role of forests in maintaining ecological balance. Therefore, the coherence between energy policy and forest conservation is the main theoretical foundation for sustainable development. Furthermore, fossil fuel energy promotes economic development, but widespread use damages forest ecosystems, increases CO_2 emissions, and reduces the ability of forests to absorb carbon, limiting green development opportunities in the long run (Sohail et al., 2024). Additional to that, fossil fuel energy consumption increases CO_2 emissions, degrading the environment, and can lead to forest depletion. At the same time, economic development and industrialization increase the use of resources and accelerate deforestation by changing land areas. Thus, the combined effects of fossil fuel energy and economic development increase pressure on forests, which requires a sustainable energy policy and forest conservation measures (Agusti et al., 2020). Also, fossil fuel energy consumption and economic development together influence forest ecosystems. With economic growth, the rising demand for energy leads to greater fossil fuel use, which can cause deforestation and environmental degradation. Nevertheless, forests serve as natural moderators by capturing carbon and supporting ecological balance, reducing the harmful effects of energy consumption and economic activities. Therefore, maintaining forest cover is crucial for ensuring that economic growth remains environmentally sustainable (Matenda et al., 2024).

Azam et al. (2021) fossil fuel energy consumption is a major reducing factor in forests, increasing CO_2 emissions and ground pressure. However, strong institutional quality can mitigate these negative effects by enforcing environmental regulations and promoting sustainable energy policies. Therefore, institutional quality acts as a moderating factor that weakens the adverse impact of fossil fuel energy on forests (Zhang et al., 2022). Institutional quality—through effective governance, law enforcement, and environmental regulation—can mitigate these adverse effects, moderating the impact of energy use on forests. Thus, the combined effect of fossil fuel energy and institutional quality determines forest outcomes: high-quality institutions help buffer forests from the harmful impacts of energy-intensive activities (Jahanger et al., 2022). In addition, AmuakwaMensah and Adom (2017) state that forest ecosystems are shaped by the combined effects of fossil fuel energy consumption and institutional quality. Consequently, forests tend to be better maintained in settings where institutions successfully manage energy use and support sustainable land practices. Also, Adu and Okai (2022) argue that forest conditions are shaped by the joint effects of fossil fuel energy use, including wood fuel, and institutional quality. As a result, forests are better conserved in areas where institutional quality ensures sustainable energy use and upholds environmental protection.

Wang et al. (2021) argue that fossil fuel energy consumption increases CO_2 emissions and contributes to forest degradation through intensified industrial activity and land-use change. Globalization can influence forests in two ways: It may exacerbate deforestation via expanded trade and resource exploitation, or it may promote sustainable practices through the transfer of green technologies and environmental standards. Together, fossil fuel energy and globalization shape forest outcomes, with high energy consumption and unregulated globalization increasing deforestation risk, while environmentally conscious globalization can mitigate these impacts. According to the research by Wang et al. (2024), fossil fuel energy use and globalization together shape forest outcomes: high energy consumption drives emissions and land-use pressures that can degrade forests, while globalization can either worsen deforestation through increased trade and resource exploitation or promote forest protection via green technologies and sustainable practices. Shafik and Sinha (2014) argue that fossil fuel energy use raises CO_2 emissions and may contribute to forest loss through industrial activities and intensive land utilization. Combined, high levels of fossil fuel consumption and globalization influence forest conditions, where unchecked globalization can heighten deforestation risks, while environmentally responsible globalization can help reduce them. According to the research by Raihan et al. (2024), forest ecosystems are affected by the combined effects of fossil fuel energy consumption and globalization. While extensive fossil fuel use drives deforestation and heightens environmental pressure, globalization can help counteract these effects by encouraging sustainable practices, technology transfer, and compliance with international environmental standards. As a result, forests are better preserved in regions where globalization supports sustainable energy use even amid high fossil fuel consumption.

The combined effects of fossil fuel energy and foreign direct investment are complex and context-dependent on forests (Eweade et al., 2024). Consumption of fossil fuel energy promotes industrialization, urbanization, and infrastructure development, increasing the risk of deforestation and degradation. Foreign direct investment, on the other hand, has a negative or positive effect on the forest area, depending on the type: foreign direct investment directed towards the resource and energy sectors enhances forest degradation, while sustainable investments can provide protection (Usman et al., 2022). Additionally, Zhang et al. (2023) state that forest ecosystems are shaped by the combined impact of fossil fuel energy consumption and foreign direct investment. While intensive fossil fuel use and resource-heavy FDI can drive deforestation and environmental degradation, these negative effects can be reduced through sustainable investment strategies and robust institutional frameworks. Consequently, forests are better conserved when foreign direct investment is responsibly managed and energy consumption is regulated within a supportive governance context.

3. DATA AND METHODOLOGY

3.1. Data

The work examines the impact of fossil fuel energy, economic development, institutional quality, globalization, foreign direct investment on forest in 39 European countries[1] spanning time from 2000 to 2024. The dependent variable is forest area, whereas the main explained variable is fossil fuel energy. The control variables are economic development, institutional quality, globalization and foreign direct investment. The definition also evidence of the indicators are given in Table 1, the data summary is represented in Table 2, and Table 3 presents the correlation matrix.

3.2. Methodology

Theoretically, the association among fossil fuel energy, economic development, institutional quality, globalization, foreign direct investment and forest can be prescribed as follows:

$$LNFOREST_{i,t} = a_0 + a_1\ LNFFE_{i,t} + a_2 LNECDEV_{i,t} + a_3 IQ_{i,t} + a_4 LNGLB_{i,t} + a_5 FDI_{i,t} + \varepsilon_{i,t} \quad (1)$$

a_0 is an intercept, a_1, a_2, a_3, a_4 and a_5 are the coefficients, ε is an intercept, i denotes a country also t represents time.

Equation (1) is the general formulation of the Ordinary Least Squares model (OLS). However, in reality the relationship between fossil fuel energy and forest area is affected by several factors such as geopolitical tensions, wars and pandemic (Kuziboev et al., 2025). Consequently, the relationship between energy and environment becomes heteroscedastic. To cope with heteroscedasticity quantile regression approach is used. In literature, the studies investigating energy-environment nexus employ quantile regression. More specifically, Inglesi-Lotz et al. (2025) apply quantile regression based on a technique that estimates model parameters from statistical moments (MMQR) to assess the effect of energy uncertainty on CO_2 emissions. Kuziboev et al. (2023) estimate a quantile regression model employed to investigate the effect of renewable energy on CO_2 emissions.

Following previous studies, this work also employs quantile regression approach to analyze the effect of fossil fuel energy on forest area. For this purpose, the quantile regression based on estimation using sample moments (MMQR) is applied. MMQR is employed as a robust estimator to evaluate the impact of explanatory variables across different quantiles of energy risk. Accordingly, Equation (1) is transformed into the MMQR model as follows (Machado and Silva 2019):

$$LOGFOREST_{it} = \alpha_i + X_{it}^{'}\beta + \left(\delta_i + Z_{it}^{'}\gamma\right)U_{it} \quad (2)$$

β denoted the vector comprising the parameter estimates of the variables. α_i corresponds to the fixed effect for each individual, during δ_i denotes the fixed effect specific to each quantile within the country i. Zit denotes a sequence comprising the predefined smoothly transformable functions of the explanatory variables, which full fill the likelihood condition $P\left\{\delta_i + Z_{it}^{'}\gamma > 0\right\} = 1$. U_{it} is a latent stochastic variable which is unobserved also uncorrelated with the independent variable. It has been standardized to satisfy the subsequent moment conditions: The mean of U_{it} is zero, $E(U_{it}) = 0$, during the mean of the modulus of U_{it} takes the value of one $E(|U_{it}|) = 1$. The values associated with Equation (2), i.e., α_i, β', δ_i, γ' and $q(\tau)'$, are calculated based on the first-order moment conditions, considering the exogenous status of the explanatory variables. This modeling technique adopts the approach outlined by Machado and Silva (2019). Hence, the formulation of the model based on conditional quantiles is precisely defined as:

$$Q_{LOGFOREST_{it}}\left(\tau | X_{it}\right) = \left(\alpha_i + \delta_i q\left(\tau\right)\right) + X_{it}^{'}\beta + Z_{it}^{'}\gamma q\left(\tau\right) \quad (3)$$

This computes the quantiles conditional on the dependent factor ($LOGFOREST_{it}$) with respect to the covariates, also it examines a dataset of units tracked across several time periods. The factor-τ fixed impact of unit i, or with respect to the distribution impact of τ, is denoted by the scalar parameter $i(\tau) \equiv (\alpha_i + \delta_i\, q(\tau))$ in brackets.

1 Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, Serbia, Bosnia and Herzegovina, Moldova, Albania, Montenegro, Malta, Andorra, Liechtenstein, San Marino

Table 1: The meaning and source of the variables

Notation	Definition	Abbreviation	Logarithmic transformation	Source
Forest area	Forest area (sq. km)	FOREST	LNFOREST	World Bank Data
Fossil fuel energy	Fossil fuels (TWh)	FFE	LNFFE	Our World in Data
Economic development	GDP per capita (current US$)	ECDEV	LNECDEV	World Bank Data
Institutional quality	Rule of Law: Estimate	IQ	-	World Bank Data
Globalization	KOF globalization index	GLB	LNGLB	KOF Swiss Economic Institute
Foreign direct investment	Foreign direct investment, net inflows (% of GDP)	FDI	-	World Bank Data

Table 2: Descriptive statistics

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
Forest area	900	49177.93	66876.09	3.5	281630
Fossil fuel energy	750	486.461	670.634	8.271	3460.381
Economic development	947	33643.93	31898.85	440.538	207973.6
Institutional quality	873	0.898	0.836	−1.277	2.124
Globalization	851	74.963	11.454	41	90
Foreign direct investment	875	18.402	108.285	−1303.108	1282.607

The one-step GMM estimator proposed by Hansen (1982) is employed to estimate the model described[2].

4. EMPIRICAL RESULTS

The effect of fossil fuel energy, economic development, institutional quality, globalization, foreign direct investment on forest area investigated by MMQR method is given in Table 4. According to the results, an increase in fossil fuel energy leads to a fall in forest area, negative effect across all the quantiles from 10% to 90%. This validates the theoretical linkage. Moreover, the findings are coherent with those obtained by Soto et al. (2025) who indicate that fossil energy productivity has a negative impact on environmental quality in Latin American countries. The impact is weaker at lower quantiles, intensifies at middle quantiles, and is strongest at higher quantiles, indicating that higher fossil fuel use consistently contributes to forest degradation and increased ecological pressure (Zhu et al., 2025). In addition, Khurshid et al. (2024) also find that fossil fuel use negatively impacts forests and ecological sustainability across all quantiles (10-90%). The effect is weaker at lower quantiles, stronger at higher ones, indicating that greater reliance on nonrenewable energy consistently increases ecological pressure and forest degradation, highlighting the need for cleaner energy and better environmental governance.

2 For more information on the model's estimation steps, refer to Machado and Silva (2019).

Furthermore, economic development positively impacts on forest area at all quantiles, 10-90%. The outcome aligns with the findings by Toledo et al. (2022) who find that economic development positively affects forest area in all quantiles (10-90%). Higher economic development will expand the forest area, which will help increase carbon accumulation. The effect is stable in all quantiles, and economic growth serves to improve forest growth and environmental sustainability.

Institutional quality exhibits an adverse impact of forest area in the middle of the quantiles from 10% to 90%. The results are consistent with those by Chung and Jin (2025) who reveal that institutional quality negatively affects forest area across all quantiles (10-90%**)**. In resource-rich countries, stronger institutions are linked to reduced forest cover, likely due to prioritizing economic gains and resource extraction over conservation.

Globalization has negative effect on forest area at quantiles from 40% to 70%. The findings are similar to the ones by Li et al. (2025) who argue that globalization has a negative effect on forest area**.** Higher globalization index values—reflecting increased trade, investment, and economic integration—are associated

Table 3: Correlation matrix

Variable	LNFOREST	LNFFE	LNECDEV	IQ	LNGLB	FDI
LNFOREST	1.000					
LNFFE	0.577	1.000				
LNECDEV	−0.219	0.017	1.000			
IQ	−0.141	−0.028	0.880	1.000		
LNGLB	0.552	0.394	0.356	0.419	1.000	
FDI	−0.363	0.017	0.142	0.072	−0.285	1.000

Table 4: The results obtained by MMQR method

Variables	Dependent variable: LOGFOREST								
	Quantiles								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
LNFFE	−0.049	−0.047	−0.046	−0.045	−0.044	−0.043	−0.042	−0.041	−0.040
Std. error	0.019	0.017	0.015	0.014	0.013	0.012	0.012	0.012	0.013
Z-value	−2.49	−2.75	−2.96	−3.20	−3.38	−3.46	−3.43	−3.31	−3.04
P-value	0.013	0.006	0.003	0.001	0.001	0.001	0.001	0.001	0.002
IQ	−0.067	−0.065	−0.064	−0.063	−0.062	−0.061	−0.060	−0.059	−0.058
Std. error	0.017	0.015	0.014	0.012	0.011	0.010	0.010	0.009	0.010
Z-value	−3.87	−4.26	−4.60	−5.01	−5.40	−5.68	−5.91	−5.93	−5.74
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LNGLB	−0.228	−0.205	−0.188	−0.169	−0.150	−0.136	−0.118	−0.102	−0.083
Std. error	0.132	0.111	0.098	0.084	0.072	0.065	0.059	0.057	0.062
Z-value	−1.73	−1.85	−1.92	−2.01	−2.07	−2.08	−1.99	−1.77	−1.33
P-value	0.083	0.065	0.054	0.045	0.038	0.037	0.047	0.076	0.185
FDI	0.000	0.000	0.000	7.31	−2.68	−0.000	−0.000	−0.000	−0.000
Std. error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Z-value	0.99	0.74	0.50	0.21	−0.08	−0.33	−0.63	−0.90	−1.22
P-value	0.321	0.462	0.616	0.832	0.936	0.745	0.531	0.366	0.223
Constant	10.553	10.515	10.487	10.456	10.426	10.403	10.374	10.348	10.317
Std. error	0.401	0.343	0.305	0.267	0.238	0.220	0.209	0.209	0.225
Z-value	26.28	30.59	34.33	39.13	43.80	47.11	49.42	49.33	45.66
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively with reduced forest cover, especially in countries with moderate forest resources. The results indicate that globalization can intensify pressure on forests, highlighting the need for sustainable management policies to mitigate its environmental impact.

5. CONCLUSION, POLICY IMPLICATIONS AND LIMITATIONS

5.1. Conclusion

This research examines the effect of fossil fuel energy on forest area in the panel of 39 European countries during the period 2000-2024. For the empirical estimations, Quantile regression based on the method of moments is employed which is robust to heteroscedasticity. The findings reveal that fossil fuel energy negatively and significantly impacts on forest area across all the quantiles from 10% to 90%. This study analyses how fossil fuel energy influences forest area across 39 European countries from 2000 to 2024. Using the Method of Moments Quantile Regression—which effectively addresses heteroscedasticity—the results show that fossil fuel energy consistently and significantly reduces forest area at all quantiles (10-90%). These outcomes suggest that policymakers should give greater attention to the role of fossil energy when designing forest-related strategies.

Economic development reliance on fossil fuel energy can have a positive impact on forest ecosystems under certain conditions. As a result of the expansion of energy infrastructure and improved centralized energy supply, the population's need for biofuels — in particular, firewood and coal — is reduced. This will allow a decrease in the level of anthropogenic deforestation, stabilization or restoration of the forest cover.

Low Institutional quality combined with fossil fuel energy consumption increases pressure on forests. Weak institutions will pave the way for forest shrinkage as energy consumption increases due to poor environmental control, illegal use of resources, and inability to limit industrial activity. As a result, fossil fuel consumption has a stronger negative impact on forests in conditions of poor institutional quality.

The interaction of globalization and fossil fuel energy consumption exacerbates negative synergistic consequences for forests. Global integration increases the demand for energy, which accelerates the expansion of production and infrastructure. This expansion, which relies on fossil fuels, leads to shrinking forest areas, overexploitation of natural resources, and weakening of environmental control. As a result, globalization processes and high energy consumption combined create a stronger negative impact for forest ecosystems.

5.2. Policy Implications

As a result of the empirical analysis, several policy implications can be suggested:

1) The introduction of deep energy audits in energy-intensive industries and the formation of a clear priority system of modernization projects should become the main focus of political decisions. This will reduce the environmental burden and strengthen national energy security while maintaining the economic efficiency of the fossil fuel sector;
2) Tax incentives, subsidies, and the creation of public–private partnership credit lines, aimed at improving energy efficiency, serve as an important mechanism for policymakers. These measures reduce the cost of the transition to energy-saving technologies, and accelerate the macroeconomic positive effects of technological modernization;
3) Technical support for the sustainable performance of the energy efficiency program, the introduction of technologies that comply with international standards and the management of the technology transfer mechanism. Politicians should organize an institution that adapts with technical expertise to modernize the complex;
4) Regular monitoring of changes in energy intensity, primary energy consumption and CO_2 emission across sectors allows real-time adaptation of political decisions. Adaptive management based on outcome indicators increases investment efficiency and reduces the risk of misdirected funds.

5.3. Limitations

Even though the study investigated the effect of fossil fuel energy on forest area in Europe and obtained promising results, there are some limitations that need to be addressed. More specifically, the analysis with the disaggregated fossil fuel energy variables would shed light into the findings. However, this drawback does not effect on the scientific value of the work and can be done in future studies.

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