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Energy Regulation and Energy Trade: International Evidence

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ABSTRACT

This study investigates the impact of energy regulation on energy trade by employing an extended gravity model with bilateral trade data from the CEPII BACI database and regulatory information from the World Bank's Regulatory Indicators for Sustainable Energy, covering 126 countries from 1996 to 2021. The findings reveal that stronger energy regulations significantly promote energy trade, with both exporter-side and importer-side regulations playing important roles. Disaggregated analysis shows that solar and wind, biomass, and geothermal energy trades are positively influenced by regulatory improvements, while hydro and marine energy show limited responsiveness. Further examination across income groups highlights that emerging markets benefit most from stronger regulations, advanced economies face trade reductions due to stricter regulatory frameworks, and low-income economies experience no significant regulatory effect. These findings underscore the importance of tailored regulatory policies that consider economic contexts and sector-specific characteristics. The study offers valuable insights for policymakers aiming to promote sustainable energy trade through effective regulation.

Keywords: Energy Trade, Energy Regulation, Energy Export
JEL Classifications: Q37; Q43; Q27

1. INTRODUCTION

Energy trade is a fundamental pillar of the global economy, shaping economic development, geopolitical relations, and the transition toward sustainable energy systems (World Bank, 2021; International Energy Agency, 2022). As countries work to meet rising energy demand and transition toward sustainable energy systems, international energy trade has become increasingly complex and strategically significant (Kim and Shin, 2012; Bems et al., 2013). Traditional factors such as resource availability, infrastructure, and economic conditions have long influenced trade patterns. However, regulatory frameworks governing energy markets have emerged as equally crucial determinants of trade dynamics (Newbery, 2018; Eicke, 2025). Governments introduce energy regulations to enhance market stability, promote sustainability, and protect consumers (Joskow, 2008; International Energy Agency, 2023). Yet, these regulations also affect the ability of firms to export energy. While some policies improve market access by increasing transparency and reducing costs, others create trade barriers by imposing restrictions or administrative burdens (Shepherd and Wilson, 2009; Hoekman and Nicita, 2011; Cadot and Gourdon, 2016). Despite the significance of this issue, the role of energy regulation in shaping energy trade remains underexplored in empirical research, leaving a gap in the literature

The urgency of studying this relationship is underscored by rapid transformation of global energy markets. One major shift is the global push for clean energy and emissions reduction, driven by agreements such as the Paris Agreement and the European Green Deal. These policies aim to phase out fossil fuel subsidies, promote renewable energy, and integrate carbon pricing mechanisms (Newbery, 2018; International Energy Agency, 2023). These changes affect the competitiveness of energy exporters. Countries with clear and market-friendly regulations are likely to attract investment and expand energy exports (Lienert and Lochner, 2012; Taghizadeh-Hesary and Yoshino, 2019). In contrast, uncertain or restrictive regulations may discourage trade and limit market growth (Joskow, 2008; Newbery, 2018; Park and Park, 2021).

Another key factor is geopolitical instability and supply chain disruptions. Recent crises, such as the Russia-Ukraine war, have demonstrated how regulatory decisions—such as price caps and trade restrictions—affect energy markets (Hafner and Tagliapietra, 2020; International Energy Agency, 2022). Similarly, the U.S.-China trade tensions have highlighted how energy policies influence the supply of key technologies like solar panels and batteries (Zhang and Gallagher, 2016). These challenges show why it is crucial to examine how regulatory frameworks influence energy trade and export performance.

Despite the growing interest in energy policy, few studies have directly examine the impact of regulation on energy exports. Most research focuses on broad economic and geopolitical factors, such as market size, resource availability, and trade agreements (Koopman et al., 2010; Gonzalez et al., 2015). Some studies have look at regional trade policies and tariffs, but few have analyzed how domestic regulations shape export performance (Park and Park, 2021; Rahman et al., 2024). This is particularly relevant for renewable energy, where government policies play a crucial role in influencing trade and investment (Polzin et al., 2019; Popp et al., 2020). While research on electricity market deregulation has provided insights into domestic efficiency, its impact on international trade is still unclear (Newbery, 2018). Filling this gap is essential for policymakers who need to design effective regulatory frameworks that support trade while maintaining energy security and sustainability goals.

To address this research gap, this study conducts an empirical investigation into the relationship between energy regulation and energy exports. The study utilizes trade data from the CEPII BACI database and regulatory indicators from the World Bank's Regulatory Indicators for Sustainable Energy (RISE), offering a comprehensive and data-driven analysis of energy trade patterns across a broad set of countries. The research is guided by the following key questions: How do energy regulations in exporting and importing countries influence bilateral energy trade flows? Do the effects of energy regulations differ across various energy types? How does the relationship between energy regulation and trade vary across countries with different income levels?. By addressing these questions, this study provides both theoretical and practical insights into the role of regulation in shaping global energy trade.

The findings of this study reveal that well-designed energy regulations play a crucial role in enhancing energy trade. Countries with transparent, stable, and market-friendly regulatory frameworks tend to experience higher levels of energy exports, as improved regulations reduce investor uncertainty, lower transaction costs, and increase overall market efficiency. The results also show that both exporting and importing countries' regulations significantly influence energy trade flows. Notably, emerging markets benefit from stronger regulations, while middle-income economies may encounter trade barriers due to stricter policies. Notably, emerging markets benefit the most from stronger regulations while advanced economies experience trade reductions under stricter regulatory frameworks. The disaggregated analysis also highlights that while solar, wind, biomass, and geothermal energy trades respond positively to regulatory improvements, hydro and marine energy show limited sensitivity. These findings underscore the importance of tailored regulatory policies that balance oversight and trade facilitation while accounting for economic contexts and sector-specific characteristics. Such an approach is essential for promoting sustainable energy trade, supporting global market integration, and ensuring both energy security and long-term sustainability.

This study makes several important contributions to the literature. First, it expands traditional analyses of energy trade by incorporating regulatory quality as a key determinant, providing a more comprehensive understanding of the factors shaping cross-border energy flows. Second, it offers empirical evidence that can guide policy decisions on energy market design in the context of the global energy transition. By focusing on the role of regulations in both exporting and importing countries, the study contributes to discussions on how policy environments affect international trade relationships. Third, it adds to the debate on international energy cooperation by underscoring the importance of regulatory harmonization in facilitating cross-border energy trade. These contributions are particularly relevant for policymakers seeking to enhance their countries' participation in global energy markets while aligning with sustainability objectives. The research provides a practical framework for crafting tailored regulatory policies that consider both country-specific contexts and sector-specific needs, helping to promote energy trade competitiveness in an increasingly interconnected world.

The succeeding segments of the document are organized as follows: Section 2 encompasses an extensive review of the literature and establishes a hypothesis. Section 3 provides an elaborate description of the methodology and an in-depth examination of the dataset. Empirical results are outlined in Section 4. Concluding observations are presented in Section 5, along with the delineation of policy implications.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Energy Trade

Energy trade plays a pivotal role in global economic integration, with cross-border exchanges becoming increasingly significant amid growing energy interdependence. A substantial body of literature has explored how factors such as geopolitical tensions, infrastructure development, technological progress, and macroeconomic conditions influence international energy flows. For example, Cabalu and Manuhutu (2009) investigated the gas import dependency of eight Asian economies and identified diverse market risks using principal component analysis, highlighting varying levels of vulnerability among these countries. Similarly, Wood (2012) analyzed the liquefied natural gas (LNG) markets in Asia and Europe, emphasizing how commercial dynamics, political relations, and technical considerations jointly shape LNG trade.

China's efforts to establish a regional natural gas hub have also garnered attention. Tong et al. (2014) underscored the strategic advantages of Shanghai's geographical location and robust energy infrastructure, complemented by supportive government policies and the development of financial instruments like spot and futures markets, which collectively enhance China's regional competitiveness. Examining the European context, Chen et al. (2016) analyzed LNG trade networks between 2005 and 2014, revealing shifts in supply chains, including instances of LNG re-exportation from countries like Spain and Belgium due to fluctuating domestic demand. Notably, despite the global surge in U.S. shale gas production, its influence on established LNG export routes remained limited.

In Northeast Asia, energy security concerns and volatile oil prices have reshaped regional trade strategies. Kim (2017) highlighted Russia's use of price negotiations to counter U.S. LNG competition and the evolving Sino-Russian energy partnership aimed at strengthening regional energy stability. Complementing this, Holzer et al. (2017) examined how rising LNG shipments impact maritime ecosystems, projecting a substantial increase in ballast water discharge volumes by 2040—a byproduct of intensified U.S. LNG exports.

On a global scale, trade flow analyses employing gravity models have provided valuable insights. Zhang et al. (2018) found that pipeline natural gas often substitutes for LNG in certain markets, with Asian LNG demand displaying heightened sensitivity to price fluctuations and investments in research and development. Similarly, Varahrami and Haghighat (2018) analyzed LNG consumption patterns in OECD countries, identifying cyclical demand shifts across short and long-term horizons.

Focusing on geopolitical influences, Taghizadeh-Hesary et al. (2021) explored Russia's energy trade with Asia-Pacific nations, revealing a positive correlation between economic growth in importing countries and Russian energy exports. The imposition of sanctions on Russia since 2014, paradoxically, spurred a reorientation of its energy trade toward Asian markets. Górecka et al. (2021) further emphasized the importance of logistics performance in facilitating liquid energy exports, though transportation challenges remain more pronounced for solid and gaseous fuels. Economic sanctions' broader implications on resource trade were highlighted by Larch et al. (2022), who demonstrated that punitive trade measures could significantly curtail mining exports, with sanctions reducing global mining trade by an estimated 44%.

2.2. The Effect of Energy Regulation on Energy Trade

While energy trade has been extensively studied, the role of regulatory frameworks in shaping cross-border energy exchanges is comparatively underexplored. Regulations governing energy markets—including market liberalization policies, environmental standards, price controls, and technical regulations—can either facilitate or hinder international energy flows (Newbery, 2018; Taghizadeh-Hesary and Yoshino, 2019). Effective regulations enhance market transparency, reduce transaction costs, and promote investment in energy infrastructure, thereby supporting trade (Sovacool, 2013; Polzin et al., 2019). Conversely, overly restrictive or poorly coordinated regulations can raise trade costs, limit market access, and create uncertainties that deter investment (Love et al., 2007).

Market liberalization is one area where regulatory changes have shown significant trade impacts. Manova (2013) found that liberalizing energy markets can increase cross-border trade flows by reducing entry barriers and fostering competition. Similarly, Park and Park (2021) highlighted that regional trade agreements, combined with market liberalization policies, improve trade volumes in energy sectors.

Environmental and sustainability regulations, while primarily aimed at reducing carbon footprints, also shape energy trade dynamics. Studies show that stringent environmental standards incentivize cleaner energy imports and foster investment in renewable energy technologies. For instance, De Marchi et al. (2013) highlight how environmental considerations in global value chains influence trade patterns in energy-intensive industries. Similarly, Ponte (2019) emphasizes that sustainable regulations have become crucial in reshaping global trade flows through corporate responsibility measures. However, fragmented technical standards in renewable energy sectors can act as non-tariff barriers, impeding international trade. Lopez-Gonzalez et al. (2015) point out that divergent certification requirements create compliance costs for exporters, limiting market access for renewable technologies. In a similar vein, Fernandes et al. (2020) observe that regulatory misalignments between countries slow down cross-border renewable energy investments.

Geopolitical considerations further complicate the regulatory landscape. Park and Park (2021) demonstrated that energy-specific trade restrictions, such as export bans or import quotas, are often enacted in response to geopolitical tensions and can significantly affect energy market stability. For instance, during the Russia-Ukraine conflict, European regulatory measures like price caps and diversification efforts rapidly reshaped energy trade flows. Demir and Javorcik (2018) highlight how trade restrictions during geopolitical crises disrupt global energy supply chains, while Chor and Manova (2012) show that trade flows in critical sectors, including energy, are highly sensitive to such political tensions.

Despite these insights, most existing studies either focus on domestic market impacts of regulation or consider broader geopolitical influences without directly addressing how specific regulatory frameworks affect energy export performance, especially across different energy sectors and economic contexts.

Building on the above discussion, we raise the following hypotheses:

H_1: Energy regulation positively affects energy trade.

H_2: The impact of energy regulation on energy trade varies across different energy sectors.

H_3: The effect of energy regulation on energy trade differs across countries with varying income levels.

3. METHODOLOGY

To assess the impact of energy regulation on energy trade, this study employs an extended gravity model, following methodologies used in previous research (Zhang et al., 2018; Taghizadeh-Hesary et al., 2021; Górecka et al., 2021; Larch et al., 2022). The model is specified as:

$$ETrade_{ijt} = exp[\beta_0+\beta_1 RISE_{it}+\beta_2 GRA_{ijt}+\mu_{jt}]+\varepsilon_{ijt}, \quad (1)$$

where the superscripts *i* and *j* denote the exporting and importing countries, respectively, and t represents the year. The term μ_{jt} captures importer-year fixed effects, allowing for the control of time-varying multilateral resistance factors and other country-specific characteristics that might influence trade flows. This approach aligns with the framework established by Anderson and Van Wincoop (2003), ensuring that both observable and unobservable factors affecting trade are adequately addressed. The error term is denoted by ε_{ijt}. To account for potential intra-cluster correlation, we apply a multi-level clustering technique following Egger and Tarlea (2015).

The dependent variable, $ETrade_{ijt}$, represents the volume of energy exports between country pairs. Trade data are drawn from the BACI-CEPII database, which utilizes the Harmonized System (HS) classification at the six-digit level. Energy products are categorized into six groups: Solar, wind, hydro, biomass, geothermal, and marine energy. The BACI HS96 dataset was selected for its comprehensive coverage of over 200 countries from 1996 to 2021. HS codes were standardized to the 1996 version based on conversion tables from the UNCTAD database, ensuring consistency over the sample period. All trade values are expressed in billions of current U.S. dollars. For estimation, the Poisson Pseudo Maximum Likelihood (PPML) method, as proposed by Silva and Tenreyro (2006), is employed. The PPML estimator offers distinct advantages: (i) it effectively handles heteroskedasticity in trade data, a common issue that can bias Ordinary Least Squares (OLS) estimates; and (ii) its multiplicative form allows for the inclusion of zero trade flows without data transformation, preserving valuable information that might otherwise be lost. This approach ensures robust and consistent parameter estimates, even in the presence of data irregularities

Our primary independent variable is the Regulatory Indicators for Sustainable Energy (RISE) scorecard developed by The World Bank, which assesses the alignment of countries' energy policies with global best practices for sustainability. RISE serves as a comprehensive evaluation tool for sustainable energy policies worldwide. The RISE report encompasses a wide spectrum of energy policies implemented across various countries. The scorecard is structured into three main categories: Energy access (comprising 8 indicators), energy efficiency (comprising 12 indicators), and renewable energy (comprising 7 indicators). Each of these indicators is assigned equal weight on a scale from 0 to 100. Moreover, each indicator is derived from a set of subindicators and inquiries. An aggregate "overall" RISE score is then computed as the average of the three main sections. RISE functions as a collection of metrics that facilitate the comparison of national policies and regulatory frameworks with regard to sustainable energy. It furnishes a reference framework that enables policymakers to gauge their sector-specific policies and regulations against those of peers on both regional and global scales. Furthermore, RISE serves as a robust tool for the formulation of policies and regulations that drive the achievement of sustainable energy objectives.

To illustrate the evolution of energy trade and energy regulation over time and across countries, Figure 1 presents the average values of energy trade (ETrade) and regulatory (RISE) from 2010 to 2021. *RISE* demonstrates a steady upward trajectory throughout the period, reflecting continuous improvements in energy policy and regulatory frameworks. In contrast, *ETrade* remains relatively stable, fluctuating around a value of 18 between 2010 and 2016. However, following 2016, *ETrade* experiences a marked increase, suggesting a potential link between regulatory enhancements and the expansion of energy trade during the latter part of the observed period.

The vector GRA_{ijt} includes bilateral variables frequently used in the gravity model framework. These variables consist of Gross Domestic Product (*LnGDP*), weighted distance (*D*), shared official language (*comlang_off*), shared colonizer post-1945 (*comcol*), geographical contiguity (*contig*) and participation in the same regional trade agreements (*fta_wto*). Weighted distance and shared borders serve as proxies for transportation costs, while shared language, religion, and colonial ties reflect cultural and historical linkages. Regional trade agreements are incorporated to account for the effects of tariff reductions on trade flows. These factors are obtained from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Detailed descriptions of these variables are provided in Table A1 of the Appendix. After applying winsorization to address outliers and removing incomplete observations, the final dataset comprises 122,086 entries covering 126 countries from 1996 to 2021[1]. Table A2 in the Appendix present the lists of energy-exporting and importing countries. Table 1 offers a statistical summary of all variables.

4. EMPIRICAL RESULTS

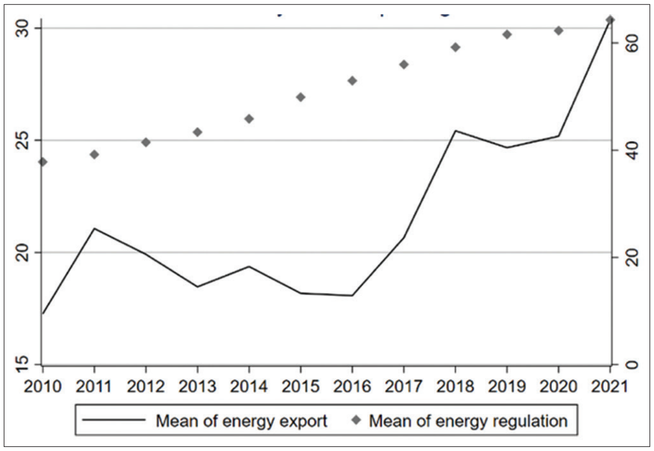
4.1. Baseline Results

The baseline regression results, presented in Table 2, reveal the significant role of regulatory quality in shaping energy trade flows. Column (1) displays the impact of RISE of exporting countries ($RISE_i$), while Column (2) presents the corresponding effects for importing countries ($RISE_j$). Across both models, the coefficients for *RISE* are positive and statistically significant at the 1% level, supporting our hypothesis (H_1) that stronger energy regulations facilitate energy trade. The estimated coefficients are similar: 0.03 for exporting countries and 0.04 for importing countries. This consistency indicates that robust energy policies, whether implemented by exporters or importers, contribute to enhanced trade in energy products.

These findings align with previous literature emphasizing the importance of regulatory frameworks in facilitating cross-border energy trade. For instance, Demir and Javorcik (2018) highlight that transparent energy policies reduce trade costs by clarifying market rules, thus enhancing cross-border transactions. Similarly, De Marchi et al. (2013) find that harmonized technical standards promote the international diffusion of renewable technologies, improving trade efficiency. Our results extend these insights

1 The data that support the findings of this study are available from the corresponding author upon reasonable request.

Figure 1: Distribution of energy trade and energy regulation over year



The mean values of *energy export* are on the left-hand scale, and the mean value of *energy regulation* is on the right-hand scale

Table 1: Statistical summary

Variables	count	mean	sd	min	max
ETrade	122086	21.66	228.67	0.00	18446.35
RISE	122086	51.36	24.10	1.00	92.00
LnGDP	122086	3.56	1.97	−1.08	7.85
D	122086	8.63	0.83	3.14	9.89
comlang_off	122086	0.13	0.33	0.00	1.00
comcol	122086	0.07	0.26	0.00	1.00
contig	122086	0.03	0.17	0.00	1.00
fta_wto	122086	0.19	0.39	0.00	1.00

Table 2: Baseline results

Variables	(1)	(2)
	ETrade	ETrade
RISEi	0.04***	
	(0.001)	
RISEj		0.03***
		(0.001)
LnGDP	0.31***	0.28***
	(0.027)	(0.027)
D	−0.96***	−0.95***
	(0.053)	(0.045)
comlang_off	−0.30***	0.41***
	(0.073)	(0.072)
comcol	−0.91***	−0.90***
	(0.111)	(0.134)
contig	0.01	−0.04
	(0.099)	(0.085)
fta_wto	−0.06	0.09
	(0.094)	(0.075)
Constant	7.83***	9.51***
	(0.451)	(0.461)
Observations	122,086	122,086
Country-year FE	YES	YES
Pseudo R2	0.571	0.743
Robust standard errors in parentheses		

***P<0.01, **P<0.05, *P<0.1

by demonstrating that both exporting and importing country regulations matter for energy trade, echoing conclusions drawn by Love et al. (2007), who emphasize how regulatory-driven trade facilitation can significantly enhance international trade flows.

Regarding the control variables, several key factors show significant effects on energy trade flows. Economic size (GDP) is positively associated with trade, reflecting larger markets' higher production and consumption capacities. Distance (*D*) exhibits a negative and significant effect, consistent with the gravity model's predictions. Interestingly, both shared official language (*comlang_off*) and common colonial history (*comcol*) display negative and significant effects on energy trade. This contrasts with typical gravity model expectations, where cultural and institutional proximity usually facilitates trade. A possible explanation is that energy trade, particularly in global markets for commodities like oil, gas, and renewables, is less influenced by historical or linguistic ties and more driven by resource endowments, price competitiveness, and infrastructure connectivity. Moreover, geographical contiguity (*contig*) and participation in a regional trade agreement (*fta_wto*) are insignificant, suggesting that formal trade partnerships and shared borders play a less critical role in energy trade than in other sectors—likely due to the globalized nature of energy markets and infrastructure investments like pipelines and LNG shipping routes.

To better understand how energy regulation impacts various energy product categories, we disaggregate energy trade (*ETrade*) into six groups: Solar, wind, hydro, biomass, geothermal, and marine energy. Panel A of Table 3 presents the effects of exporter regulations ($RISE_i$) on these categories, while Panel B shows the corresponding results for importer regulations ($RISE_j$). In Panel A, $RISE_i$ positively and significantly affects all energy categories. This suggests that improvements in the regulatory environment of exporting countries—such as policies supporting production, innovation, and export facilitation—can enhance trade across a wide range of energy products. These findings align with the literature emphasizing the role of supportive domestic policies in strengthening energy sector competitiveness (Taghizadeh-Hesary et al., 2021).

In contrast, Panel B reveals a more nuanced pattern. $RISE_j$ exerts a significant positive impact on most energy categories, including solar, wind, biomass and geothermal. These findings highlight the importance of strong regulatory frameworks in importing countries, which may include measures like import incentives, clear technical standards, and streamlined customs procedures, in facilitating energy imports. The responsiveness of solar and wind trade to importer regulations reflects global efforts to expand renewable energy deployment, where favorable import policies can significantly lower market entry barriers for foreign suppliers. These results align with studies such as Zhang and Gallagher (2016), which highlight how regulatory clarity and technology transfer mechanisms boost renewable energy investments and trade, and Polzin et al. (2019), who emphasize the critical role of policy frameworks in mobilizing private finance, fostering innovation, and enhancing international market access for emerging energy technologies.

However, the coefficients for hydro and marine energy in Panel B are insignificant, indicating that improvements in importing countries' regulatory environments do not significantly affect

Table 3: Estimation results with components of energy trade

Variables	(1) ETrade_Solar	(2) ETrade_Wind	(3) ETrade_Hydro	(4) ETrade_Bio	(5) ETrade_Geo	(6) ETrade_Marine
Panel A						
RISEi	0.04***	0.05***	0.05***	0.03***	0.04***	0.05***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
LnGDP	0.10***	0.31***	0.13***	0.69***	0.46***	−0.01
	(0.029)	(0.027)	(0.018)	(0.032)	(0.025)	(0.027)
D	−0.92***	−0.88***	−0.73***	−1.18***	−0.81***	−0.71***
	(0.074)	(0.050)	(0.045)	(0.060)	(0.046)	(0.039)
comlang_off	−0.35***	−0.44***	−0.47***	−0.15*	−0.42***	−0.45***
	(0.100)	(0.082)	(0.073)	(0.088)	(0.098)	(0.096)
comcol	−1.04***	−0.57***	−0.42***	−1.25***	−1.10***	−1.17***
	(0.140)	(0.117)	(0.160)	(0.153)	(0.151)	(0.104)
contig	0.11	−0.12	0.77***	−0.16*	0.29***	0.82***
	(0.141)	(0.106)	(0.098)	(0.099)	(0.097)	(0.106)
fta_wto	−0.29**	0.04	0.37***	−0.07	0.07	1.30***
	(0.124)	(0.094)	(0.082)	(0.110)	(0.085)	(0.095)
Constant	7.77***	5.23***	2.76***	6.85***	2.14***	2.47***
	(0.640)	(0.452)	(0.398)	(0.475)	(0.430)	(0.327)
Observations	122,086	122,086	122,086	122,086	121,942	122,038
Country-year FE	YES	YES	YES	YES	YES	YES
Pseudo R2	0.467	0.577	0.437	0.657	0.539	0.542
Robust standard errors in parentheses						
Panel B						
Variables	**(1) ETrade_Solar**	**(2) ETrade_Wind**	**(3) ETrade_Hydro**	**(4) ETrade_Bio**	**(5) ETrade_Geo**	**(6) ETrade_Marine**
RISEj	0.03***	0.03***	0.00	0.03***	0.02***	0.00
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LnGDP	0.30***	0.28***	0.45***	0.19***	0.46***	0.40***
	(0.034)	(0.024)	(0.025)	(0.039)	(0.026)	(0.032)
D	−1.02***	−0.76***	−0.65***	−1.13***	−0.76***	−0.82***
	(0.047)	(0.046)	(0.028)	(0.060)	(0.033)	(0.038)
comlang_off	0.22**	0.38***	0.58***	0.51***	0.45***	0.58***
	(0.092)	(0.079)	(0.077)	(0.098)	(0.085)	(0.084)
comcol	−1.21***	−0.43***	0.41***	−1.49***	−0.49***	0.11
	(0.220)	(0.112)	(0.105)	(0.236)	(0.161)	(0.123)
contig	0.05	−0.05	0.54***	−0.35***	0.23***	0.60***
	(0.100)	(0.096)	(0.067)	(0.110)	(0.079)	(0.083)
fta_wto	0.10	0.20**	0.27***	−0.06	0.05	0.90***
	(0.081)	(0.084)	(0.060)	(0.107)	(0.062)	(0.074)
Constant	9.12***	6.45***	4.44***	10.18***	4.01***	5.39***
	(0.480)	(0.462)	(0.249)	(0.630)	(0.336)	(0.380)
Observations	121,429	121,628	118,217	121,168	108,766	108,413
Country-year FE	YES	YES	YES	YES	YES	YES
Pseudo R2	0.764	0.704	0.628	0.694	0.676	0.674
Robust standard errors in parentheses						

***P<0.01, **P<0.05, *P<0.1

trade in these categories. For hydro energy, this may be due to its localized nature—hydropower projects are typically domestically sourced, given their reliance on geographical conditions and high transportation costs. Meanwhile, the insignificance of marine energy could be attributed to the early-stage development of this technology and its limited international market presence.

4.2. Heterogeneous Analysis

The impact of energy regulation on energy trade can differ according to a country's income classification. To investigate this potential variation, the sample is divided into three categories following the IMF income classification: Low-income Economies, Emerging Markets and Advanced Economies. Equation (1) is re-estimated for each subgroup, with the corresponding results summarized in Table 4.

The findings reveal notable differences across income groups. In Emerging Markets, the coefficients for energy regulation—both for exporting countries ($RISE_i$) and importing countries ($RISE_j$)—are positive and statistically significant, indicating that improvements in regulatory quality in these countries are associated with increased energy trade. This suggests that emerging economies, which often face institutional and infrastructure challenges, benefit substantially from policy reforms that enhance market transparency, reduce trade barriers, and attract foreign investment. On the exporter side, stronger regulations may improve production efficiency and export competitiveness, while on the importer

Table 4: Subsample by income group

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	ETrade	ETrade	ETrade	ETrade	ETrade	ETrade
RISEi	0.01	0.05***	−0.02***			
	(0.015)	(0.002)	(0.004)			
RISEj				0.00	0.03***	−0.01**
				(0.002)	(0.002)	(0.004)
LnGDP	0.53***	0.02	0.41***	0.10**	0.19***	0.57***
	(0.188)	(0.028)	(0.061)	(0.047)	(0.030)	(0.064)
D	−0.65***	−0.80***	−1.10***	−1.01***	−1.17***	−0.90***
	(0.207)	(0.134)	(0.045)	(0.078)	(0.136)	(0.042)
comlang_off	−0.62	−0.26	−0.25**	0.84***	1.31***	−0.03
	(0.438)	(0.187)	(0.116)	(0.133)	(0.128)	(0.117)
comcol	0.24	−0.86***	−1.19***	0.67***	−1.36***	−1.58***
	(0.487)	(0.151)	(0.270)	(0.170)	(0.269)	(0.367)
contig	0.84	0.64***	−0.07	−0.27*	−0.01	0.05
	(0.542)	(0.163)	(0.131)	(0.138)	(0.138)	(0.131)
fta_wto	1.94***	0.06	−0.28**	0.40***	0.03	−0.36***
	(0.290)	(0.154)	(0.113)	(0.145)	(0.157)	(0.095)
Constant	3.59**	7.47***	13.01***	10.67***	12.30***	10.07***
	(1.816)	(1.193)	(0.656)	(0.746)	(1.189)	(0.777)
Observations	23,677	43,826	19,697	23,878	43,360	19,495
Country-year FE	YES	YES	YES	YES	YES	YES
Pseudo R2	0.595	0.406	0.707	0.661	0.695	0.805
Robust standard errors in parentheses						

***P<0.01, **P<0.05, *P<0.1

side, clear regulations can facilitate smoother import processes and market access. These results align with the findings of Taghizadeh-Hesary et al. (2021), who emphasize the importance of financial and regulatory development in promoting energy trade, and Kalamova et al. (2011), who highlight the role of investment policies and regulatory improvements in facilitating trade and foreign investment in transitional markets.

Conversely, in Advanced Economies, the coefficients for both $RISE_i$ and $RISE_j$ are negative and statistically significant, suggesting that stronger regulations may constrain energy trade. One possible explanation is that highly regulated energy markets in advanced economies impose stricter environmental and technical standards, increasing compliance costs and potentially deterring cross-border energy transactions. Additionally, trade frictions related to regulatory misalignment or domestic energy self-sufficiency policies may reduce the volume of international energy exchanges. Given that advanced economies already have well-established regulatory frameworks, further regulatory tightening could dampen trade flows rather than facilitate them.

In Low-Income Economies, the coefficients for both $RISE_i$ and $RISE_j$ are insignificant, indicating that regulatory improvements do not have a discernible impact on energy trade in these countries. This may reflect structural constraints, such as limited infrastructure, weaker institutional capacity, and low integration into global energy markets, which can inhibit the effectiveness of regulatory reforms. Additionally, informal trade mechanisms and regulatory enforcement challenges may weaken the link between formal policy changes and actual trade outcomes.

Overall, these findings underscore the importance of tailoring regulatory policies to national contexts. While regulatory improvements generally promote energy trade, their effectiveness depends on a country's economic structure, institutional capacity, and market maturity. One-size-fits-all approaches may produce unintended consequences, particularly in economies with varying capacities to implement and comply with policy changes

5. CONCLUSION AND POLICY IMPLICATIONS

This study examines the relationship between energy regulation and energy trade using an extended gravity model and data from 1996 to 2021. The analysis provides empirical evidence on how regulatory frameworks in both exporting and importing countries influence cross-border energy trade. The main findings reveal that energy regulations positively affect energy trade. Improvements in regulatory quality enhance trade flows by reducing market uncertainties, lowering transaction costs, and fostering investor confidence. Both exporter-side ($RISE_i$) and importer-side ($RISE_j$) regulations play significant roles. This underscores the importance of market access conditions and the regulatory environment in destination countries for facilitating energy imports.

Disaggregated analyses across different energy product categories show that solar and wind, biomass, and geothermal energy trades are significantly influenced by regulatory improvements in both exporting and importing countries. In contrast, hydro and marine energy trade flows are less responsive to importer-side regulations, likely due to localized production characteristics and the early-stage development of marine energy markets. These findings highlight the need for sector-specific regulatory approaches that consider the technological maturity and market dynamics of various energy sources.

Further examination of heterogeneous effects across income groups reveals notable differences. In Emerging Markets, regulations in both exporting and importing countries significantly promote energy trade, reflecting the substantial benefits of regulatory reforms in addressing institutional weaknesses and facilitating market integration. Conversely, in Advanced Economies, stronger regulations are associated with decreased energy trade, potentially due to stricter compliance requirements, regulatory misalignment, or domestic policies that prioritize energy self-sufficiency, which may inadvertently restrict cross-border transactions. Meanwhile, in Low-Income Economies, regulatory improvements do not exhibit a significant effect on energy trade, suggesting that structural barriers, limited institutional capacity, and weak integration into global markets may hinder the effectiveness of policy reforms.

From a policy perspective, these findings offer important implications. Policymakers in emerging and developing economies should prioritize regulatory reforms that enhance market transparency, streamline trade processes, and align with international best practices to maximize the benefits of global energy trade. In advanced economies, careful consideration is needed to avoid excessive regulatory constraints that may inadvertently suppress trade activity.

Overall, this study contributes to the literature by providing robust empirical evidence on the role of regulatory quality in shaping global energy trade flows. It underscores the significance of tailored regulatory policies that account for both country-specific economic contexts and sectoral differences in energy markets. Future research could expand on these insights by exploring the dynamic effects of regulatory changes over longer horizons or incorporating the interplay between energy regulations and geopolitical factors.

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APPENDIX

Table A1: Variable description

Variable	Description	Source
ETrade	Energy export	BACI
RISE	Regulatory indicators for sustainable energy	World Bank
LnGDP	Natural logarithm of gross domestic product	World Bank
D	Natural logarithm of the distance between country *i* and *j*, and 0 otherwise.	CEPII
contig	A binary variable taking a value of 1 if there is a contiguity between two countries.	CEPII
comlang_off	A binary variable taking a value of 1 if they have the same official language.	CEPII
comcol	A binary variable taking a value of 1 if a country is a common colonizer post 1945.	CEPII
fta_wto	A binary variable taking a value of 1 if a country has a regional trade agreement.	CEPII

CEPII: The Centre d'Etudes Prospectives et d'Informations Internationales

Table A2: List of countries

Reporter	Percent	Reporter	Percent	Reporter	Percent	Reporter	Percent	Reporter	Percent
AFG	0.55	COD	0.44	IRL	1.12	MOZ	0.78	SGP	1.13
AGO	0.72	COG	0.78	IRN	0.67	MRT	0.69	SLB	0.24
ALB	0.69	COL	1.02	ISR	0.98	MWI	0.69	SLE	0.64
ARE	1	CRI	0.88	ITA	0.19	MYS	0.56	SLV	0.74
ARG	1.01	CZE	1.13	JAM	0.63	NER	0.67	SOM	0.3
ARM	0.72	DEU	0.58	JOR	1	NGA	0.95	SVK	1.08
AUS	1.14	DNK	1.11	JPN	1.14	NIC	0.74	SWE	1.11
AUT	1.12	DOM	0.84	KAZ	0.83	NLD	1.14	TCD	0.41
AZE	0.75	DZA	0.81	KEN	0.96	NPL	0.74	TGO	0.63
BDI	0.51	ECU	0.9	KGZ	0.62	NZL	1.09	THA	1.14
BEL	0.29	EGY	1.08	KHM	0.77	OMN	0.86	TJK	0.44
BEN	0.68	ESP	1.14	KOR	1.13	PAK	0.58	TKM	0.37
BFA	0.72	ETH	0.42	KWT	0.79	PAN	0.73	TUN	0.99
BGD	0.91	FIN	1.09	LAO	0.5	PER	0.97	TUR	1.13
BGR	1.01	GBR	1.14	LBN	1.01	PHL	1.06	TZA	0.91
BHR	0.88	GEO	0.84	LBR	0.52	PNG	0.35	UGA	0.85
BIH	0.91	GHA	0.9	LKA	0.95	POL	1.13	UKR	1.07
BLR	0.99	GIN	0.61	MAR	1.05	PRT	1.08	URY	0.88
BOL	0.7	GRC	1.07	MDA	0.8	PRY	0.73	UZB	0.62
BRA	1.1	GTM	0.76	MDG	0.83	QAT	0.87	VEN	0.26
CAF	0.47	HND	0.74	MDV	0.42	ROU	0.78	VNM	0.52
CAN	1.12	HRV	0.98	MEX	1.05	RWA	0.68	VUT	0.26
CHL	0.99	HTI	0.53	MLI	0.68	SAU	1.07	YEM	0.26
CHN	1.13	HUN	1.02	MMR	0.79	SDN	0.04	ZAF	0.29
CMR	0.84	IDN	0.57	MNG	0.55	SEN	0.94	ZMB	0.76
								ZWE	0.72