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Article

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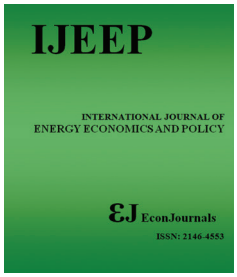
International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Supriyadi, Supriyadi/Kazi Sohag et. al. (2024). Role of institutional quality and financial developments in realizing clean energy legislation in Indonesia. In: International Journal of Energy Economics and Policy 14 (6), S. 161 - 173. https://www.econjournals.com/index.php/ijeep/article/download/16892/8302/39953. doi:10.32479/ijeep.16892.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(6), 161-173.

Role of Institutional Quality and Financial Developments in Realizing Clean Energy Legislation in Indonesia

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Received: 12 June 2024 **Accepted:** 15 September 2024 **DOI:** https://doi.org/10.32479/ijeep.16892

ABSTRACT

This study examines the intersection of financial markets and institutional quality (IQ) in enhancing clean energy production and access in Indonesia, a country that has placed a strong emphasis on renewable energy (RE) through its legislative framework. Utilizing various econometric methods, including Dynamic and fully-modified ordinary least squares (OLS), and dynamic simulated autoregressive distributed lag (ARDL) models, we analyze time series data from 1996 to 2022. The outcomes underscore the pivotal role of IQ (encompassing indicators like control of corruption, rule of law, regulatory quality, government effectiveness, political stability, and voice & accountability) in fostering the adoption of RE sources and broadening the reach of clean cooking energy. Although the impact of financial markets in isolation yields inconclusive findings, their intersection with IQ consistently bolsters Indonesia's transition towards clean energy. This study puts forth various practical implications for policymakers seeking to bolster the efficacy of clean energy policies.

Keyword: Renewable Energy, Rule of Law, Control of Corruption, Regulatory Quality, Government Effectiveness, Political Stability
JEL Classifications: K32,L51,P48,Q48

1. INTRODUCTION

As the world faces the pressing challenges of climate change and environmental degradation, renewable energy (RE) has emerged as a crucial component of sustainable development. For countries like Indonesia, with its vast natural resources and growing energy demands, the transition to RE is not just an environmental imperative but also an economic necessity. The National Energy Policy, established through Presidential Regulation No. 79/2014, outlines Indonesia's strategic approach to energy management. The policy sets ambitious targets for RE, aiming to achieve a 23% share of RE in the national energy mix by 2025 and 31% by 2050. This policy emphasizes energy security, sustainability, and affordability. However, the effectiveness of RE legislation in Indonesia is heavily influenced by the quality of its institutions. Given this backdrop, this study aims to explore the role of institutional quality (IQ) in shaping and implementing RE policies in Indonesia incorporating the role of financial market.

This study is motived by several strands of proposition. First, many prior studies, e.g. Gunningham (2011) Vowles (2008) argued that strong institutions are essential for the successful implementation and enforcement of climate policies, particularly in regulating energy use for environmental sustainability. Those proponents also emphasized that robust and stable governance structures are crucial for the effective application of RE initiatives and the management of consumption to maintain environmental standards. Consequently, scholars in environmental and political theory believe that high-quality institutions are necessary for the efficient execution of policies and regulations that support the transition to RE.

Second, the Paris Agreement on Climate Change, adopted in 2015 and effective as of November 4, 2016, represents a landmark effort

to combat global climate change (Milman, 2017). The primary goal of the Agreement is to strengthen the global response to climate change by keeping global temperature rise this century well below 2°C above pre-industrial levels, while also pursuing efforts to limit the increase to 1.5°C. Key provisions include the requirement for countries to submit Nationally Determined Contributions, which outline their plans to reduce greenhouse gas emissions and adapt to climate change impacts (European Council, 2024). Indonesia is among the 195 countries that signed the Paris Agreement, committing to international climate finance and participating in a global stocktake of emission reductions every 5 years (Indonesian Ministry of Environment and Forestry, 2016). While countries are encouraged to progressively strengthen their climate targets, there are no immediate penalties for failing to meet these goals (Indonesian Ministry of Environment and Forestry, 2016). Countries are encouraged to strengthen their climate targets over time, however there are no immediate consequences for failing to meet them (Mace, 2021).

Third, research highlights that the cost of transitioning from fossil energy (FE) to RE varies by country and the specific renewable sources being utilized (Oğuz and Smith, 2021). For Indonesia, the International Energy Agency estimates that a low-carbon transition could require about $3.5 trillion in annual energy sector investment, potentially increasing to $5.9 trillion/year by 2050 to rapidly transition the energy system (Ulya, 2022). Comparative examples illustrate the significant investment required for RE transitions. For instance, Turkey aims to double its RE capacity by adding 60 GW of solar and wind power by 2035, with estimated costs ranging from USD 75 billion to USD 100 billion (Spasić, 2023). Other studies echo these findings, highlighting the substantial financial commitments involved (Timmons et al., 2014; Wall et al., 2021). Several factors including technology, regulatory framework, and community support influence the costs associated with transitioning to RE (Isah et al., 2023; Qadir et al., 2023; Wall et al., 2021).

Fourth, considering the long-term benefits of RE, policies are crucial. Studies indicate that transitioning to 100% clean, RE can reduce energy costs by 61.1% and social costs by 89.6%, while also saving lives, creating jobs, and providing significant climate benefits (Jacobson et al., 2020). Other research suggests that transitioning to RE is more cost-efficient than continuing reliance on fossil fuels, despite variations based on transition rates (Satymov et al., 2021). A conducive legal and socio-economic climate is essential for the successful implementation of RE policies. IQ, as defined by the World Bank, is a critical factor in creating a favorable socio¬economic environment. The six dimensions of IQ include (Kaufmann and Kraay, 2023; World Bank, 2023):

Studies have shown that the enforcement of the rule of law is pivotal in implementing government policies related to the RE transition. Ensuring compliance with regulations and policies supports the growth of the RE sector and green industry practices. This involves enforcing international climate and trade regulations and coordinating supervision and enforcement mechanisms to facilitate the green transformation of the energy industry (Monti, 2023; North et al., 2013; Woolley, 2023). Strategic actions involving law enforcement can also enhance the successful implementation of vocational correctional programs in RE, which not only reduce recidivism but also contribute to a low-carbon future. This highlights the interconnectedness of criminal justice reform and climate action (Shen et al., 2022; Milman, 2017; Woolley, 2023). Legal actions and legislation can provide communities and rights-holders with pathways to climate justice, emphasizing the need for a rights-centered approach by corporate actors and governments in the new energy transition (Shen et al., 2022), The legal framework in Indonesia is crucial for supporting the transition to RE sources. By integrating a socio-ecological governance framework, Indonesia aims to address flaws in current natural resource management practices and promote polycentric governance that fosters social trust and reduces uncertainties about ownership (Suratin et al., 2023).

Indonesia's plans to reduce CO_2 emissions include increasing RE generation and expanding access to clean cooking policies. However, these efforts face challenges due to economic, social, and environmental issues. A dynamic hypothesis suggests that energy prices may limit the transition to renewables, underscoring the need for supportive policies such as fossil fuel depletion measures (Hollands and Daly, 2022; Newell and Daley, 2022; Zahari and McLellan, 2023; Vassiliades et al., 2022). Legal action and legislation are key, as impacted communities seek climate justice through "just transition litigation" to ensure human rights are respected in the new energy paradigm (Sekaringtias et al., 2023). In light of the preceding research, this article contributes to the discussion of IQ, encompassing six dimensions, and its role in supporting Indonesia's energy transition. The analysis draws on the World Bank's measurements of IQ performance to inform economic growth (Financial Development [FD]), which in turn supports Indonesia's RE transition program (RE in British Thermal Unit) and facilitates increased access to clean energy for cooking (Access to clean fuel and technologies for cooking % population [ACFTC]). The six measurement indicators of IQ include control of corruption, rule of law, regulatory quality, government effectiveness, political stability, and voice and accountability (Azam et al., 2021).

Given the crucial role of finance and IQ, this study empirically assessed their dynamic impact on key indicators of energy transition, specifically RE and Access to Clean Fuels and Technologies for Cooking (% of population, ACFTC). This pioneering study employed various econometric approaches to simulate potential outcomes, providing valuable insights for policy making and implementation. The analysis revealed several novel findings, including that finance alone cannot promote clean energy transition without the support of robust institutions. Notably, IQ is significantly more important than the deepening of financial markets in fostering clean energy in Indonesia. The findings of this study underscore the paramount importance of strengthening IQ to drive the clean energy transition in Indonesia. Policymakers should prioritize reforms that enhance governance, regulatory frameworks, and institutional effectiveness, as these elements are more critical than merely expanding financial markets. Efforts should be directed towards building robust institutions that

can effectively support and implement clean energy initiatives. Additionally, financial policies should be designed to complement and reinforce institutional reforms, ensuring that financial resources are efficiently utilized within a strong institutional framework to achieve sustainable energy goals. This integrated approach will be essential for advancing RE adoption and improving access to clean fuels and technologies for cooking in Indonesia.

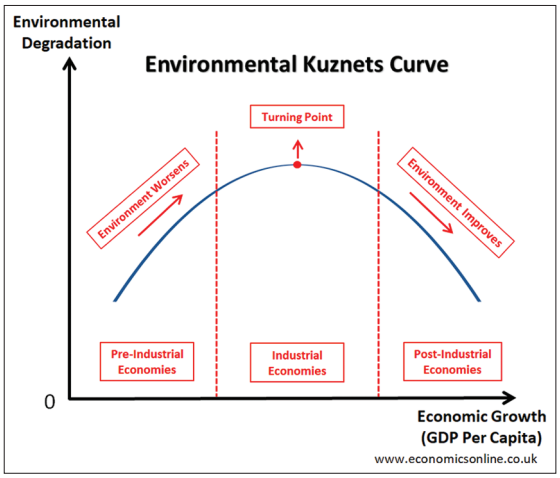
2. LITERATURE REVIEW

2.1. RE and Sustainability

Several studies discovered that the utilization of renewable energy consumption (REC) led to a decrease in Carbon emissions. This finding was confirmed through research conducted in various countries such as Indonesia, Malaysia, and Poland. The role of Research and Development and innovations in facilitating the transition to RE was deemed crucial, with support from academic institutions (Mahmood et al., 2023; Mahmood and Houaneb, 2023). Additionally, it was observed that FD has a positive impact on both environmental quality and performance (Kayani et al., 2023). The influence of Economic growth on carbon emissions was also noted. The importance of Green finance and technological innovations in addressing climate change was highlighted, alongside the significance of regulatory interventions in green financing to enhance emission reduction efforts (Shah et al., 2023). Green growth outcomes were seen to be achieved through sustainable actions against climate change. The study also found that RE has a positive effect on the financial returns of organizations. Solar energy emerged as a prominent source for generating positive returns, while both Solar and biomass energy were deemed viable options for financial gains. Wind and hydro energy were shown to have potential (Adhikari et al., 2023), although their success depended on regional factors. The study concluded that investing in RE aligns with sustainability goals and leads to increased returns (Odilova et al., 2023). It was also observed that there is a positive correlation between RE and financial returns. The impact of FD on carbon emissions was highlighted, providing valuable insights for future research directions concerning economic growth and emissions (Joshi and Dash, 2023). The study also delved into the impacts of climate change on various sectors, risks involved, and the transition towards a low-carbon economy. By bridging the literature gap on climate investing, the study presents future research prospects in this area.

Additionally, a review of 60 papers on the Environmental Kuznets Curve – EKC, (Figure 1) in the US revealed that 41 studies supported the EKC theory, while 19 did not. The study indicated that the impact of REC on emissions contributes to the confirmation of the EKC. Moreover, it was found that disaggregated data had an insignificant effect on EKC validation. REC was found to play a role in shaping the second phase of EKC, with Biomass, innovation, transport REC, and nuclear energy influencing EKC validation (Mahmood and Houaneb, 2023). Furthermore, a review of carbon accounting research conducted between 2011 and 2022, which analyzed 62 articles from 9 countries published in 21 journals, focused on aspects such as carbon emission measurement, disclosure, and accountability (Kiswanto et al., 2023). It emphasized the necessity for further research in the development of carbon accounting, advocating for standardization in the recognition, measurement, and disclosure of carbon emissions. The study also called for interdisciplinary collaboration among different fields.

Figure 1: EKC environmental degradation versus GDP growth (Ansari, 2023)



2.2. FD and RE Deployment

Access to clean fuels and technologies for cooking is intricately linked to RE policy, financing development, and GDP growth. Studies show that there is a chronic shortfall in finance for clean cooking solutions, especially at early business growth stages, highlighting the need for reforms in public funding (Owusu and Asumadu-Sarkodie, 2016). Additionally, research indicates that FD can impact REC, with an increase in GDP positively influencing REC (Bandyopadhyay, 2017). Furthermore, the long-term equilibrium relationship between FD, non-FE consumption, and economic growth is emphasized, with REC not compromising economic growth. In Egypt, enhancing finance for clean energy resources is crucial for reducing unemployment, showcasing the importance of domestic credit allocation to the RE sector for job creation (Coldrey et al., 2023a).

FD has differing effects on renewable and FEC. Recommendations include regional integrated RE policies and strong institutions. A lack of central administrative authority can impede progress to access RE. Detailed mechanisms and financial strategies are essential for RE access projects. Policymakers should prioritize financial deepening and intermediation for sustainable development. Energy access, particularly renewable cooking energy, plays a critical role in achieving Sustainable Development Goals. Focus should be on off-grid systems, gender impacts, technology roles, and energy planning for effective outcomes. The importance of energy in economic transformation, social well-being, and human development is highlighted in various contributions addressing access challenges, SDG connections, electrification benefits, and energy planning (Amin et al., 2021; Ponce et al., 2021).

Other study presents precise energy access estimates for policy planning at a microregional level, pokenhancing survey efforts during intercensal periods or in conflict areas. It aids in monitoring

progress towards Sustainable Development Goals in the absence of accurate data. The model's diagnostic capabilities reveal slow advancements and limited access to clean fuel, particularly for cooking purposes. Financial systems play a crucial role in shaping the energy mix by influencing the adoption of renewable technologies, with a focus on balancing economic gains and sustainability benefits through a sustainability-weighted return on investment (Mulugetta et al., 2019). The three pillars of sustainability - economics, environment, and society - are central in embedding sustainability considerations into economic frameworks to drive the adoption of cleaner technologies. Efforts are needed to develop market mechanisms and regulatory frameworks that support the integration of sustainable technologies, identify finance gaps hindering the development of the clean cooking sector, and recommend reforms in public funding to address the chronic shortage of finance for early-stage clean cooking enterprises, emphasizing the importance of effective data sharing among funders (Coldrey et al., 2023b; Pokhriyal et al., 2022).

2.3. IQ and RE Deployment

The Worldwide Governance Indicators (WGI) serve as a tool to evaluate perceptions of governance globally, utilizing data aggregated from a variety of reputable sources selected based on credibility, capacity for cross-country comparisons, and regular information updates. By incorporating input from a diverse range of stakeholders, the WGI aim to capture a broad spectrum of perspectives on governance worldwide. Recommendations for improving data sources are encouraged and can be submitted to wgi@worldbank.org. The WGI consist of six comprehensive governance metrics covering over 200 countries and regions from 1996 to 2022, addressing areas such as:

1. The Voice and Accountability indicator the level to which the populace of a nation can engage in the election of their governing body, along with the liberties of speech, association, and an unrestricted press.
2. Political Stability and Absence of Violence/Terrorism are assessed through the perceived probability of political unrest and/or violence driven by political motives, such as terrorism.
3. Government Effectiveness is an evaluation of the standard of public services, the efficiency of the bureaucratic system, and the autonomy of the latter from governmental influences. Furthermore, it evaluates the caliber of policy development and execution, along with the trustworthiness of the government's dedication to these policies.
4. Regulatory Quality pertains to the assessment of the governmental ability to devise and execute efficient policies and regulations that promote the advancement of the private sector.
5. Rule of Law is a measure of the extent to which agents have confidence in and abide by the rules of society. It specifically focuses on the effectiveness of upholding contracts, the protection of property rights, the function of law enforcement agencies, and the judicial system, along with the probability of criminal activities and acts of aggression.
6. Control of Corruption pertains to the evaluation of the degree to which governmental authority is utilized for personal benefits, covering various scales of corruption ranging from minor to major. Moreover, it involves the concept of the appropriation of governmental power by privileged groups and individual entities.

These indicators are primarily intended for general international assessments and monitoring long-term trends. For more detailed analyses of governance changes in specific countries, it is recommended to supplement the WGI with country-specific data. As the WGI rely on information from various sources provided by different organizations, they do not necessarily reflect the views of any single entity. Founded in 1999 by Daniel Kaufmann and Aart Kraay, researchers at the World Bank, the Global Governance Indicators are updated annually in September, Figure 2 (Kaufmann and Kraay, 2023).

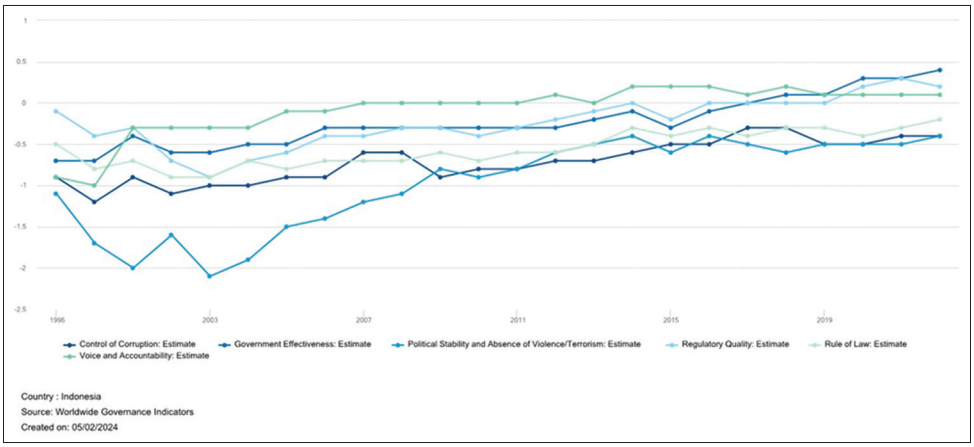
2.4. IQ to Access to Clean Fuels and Technologies for Cooking

Institutional reforms and policies designed to enhance energy access for cooking and promote sustainable development should adopt a comprehensive approach. It is essential for strategies to involve the identification of alternative energy sources, technologies, and enabling policies customized for rural communities in developing regions (Vassiliades et al., 2022). Furthermore, the social and political acceptance of reforms to fossil fuel subsidies is critical, necessitating adjustments according to the specific context of each nation or locality to ensure effectiveness (Halkos and Aslanidis, 2023). Energy policies play a significant role in promoting the expansion of electrification, clean cooking, energy efficiency, and renewable electricity capacity, with strategies proving more impactful than legislation or rules in certain contexts (Chen et al., 2022). Additionally, the shift towards universal access to clean cooking must be integrated into comprehensive decarbonization pathways to tackle both energy access and climate mitigation goals (Jones and Cardinale, 2023).

The quality of institutions significantly influences access to energy for cooking, with factors such as political stability, administrative capability, and democratic accountability playing key roles (Sun et al., 2022). Moreover, the presence of neighboring countries with strong institutional frameworks positively impacts domestic energy efficiency (Azam et al., 2021). Urbanization can also impact energy intensity, with IQ serving as a mediating factor, particularly concerning FEC in OECD and non-OECD nations. Moreover, IQ moderates the impact of energy consumption on CO_2 emissions, enhancing its efficacy in emission reduction, especially when combined with the use of RE (Haldar and Sethi, 2021). These conclusions underscore the significance of IQ in shaping energy access and consumption patterns, demonstrating variations across regions and countries.

The quality of institutions is crucial in influencing the availability of energy for cooking in households (Azam et al., 2021; Sun et al., 2022). Studies suggest that favorable IQ has a positive effect on energy efficiency and consumption (Chen and Zhou, 2021). Furthermore, the influence of IQ extends to energy intensity, where strong institutions can help counteract the impact of urbanization on energy intensity. Robust institutions are indispensable for effective environmental policies, which are crucial for mitigating environmental degradation and enhancing environmental quality,

Figure 2: Estimate of Indonesia's instiutrional quality by World Bank 1996-2022 (six indicators namely control of corruption, rule of law, regulatory quality, government effectiveness, political stability and voice and accountability)



ultimately impacting the availability of energy for household cooking. Hence, robust institutional frameworks are essential for promoting energy efficiency, reducing energy consumption, and ensuring a sustainable energy supply for household cooking (Coldrey et al., 2023b; Hollands and Daly, 2022; Vassiliades et al., 2022).

2.5. Correlation of Corruption Control, the Rule of Law, and Regulatory Quality in a Country

The control of corruption positively influences the rule of law and regulatory quality in a country. Research shows that effective corruption control reduces growth volatility and enhances IQ, including the rule of law (Struthmann et al., 2023). Additionally, the impact of anti-corruption measures, such as China's Rule 18, has been linked to improved financial reporting quality, particularly in regions with developed financial markets and efficient judiciary systems (Hope et al., 2020). Moreover, governance quality, encompassing corruption control, rule of law, and government effectiveness, significantly affects fraud recovery rates in firms operating in countries with poor governance (Curti and Mihov, 2018). Overall, the control of corruption plays a crucial role in shaping the rule of law and regulatory quality, contributing to a more stable economic environment and improved governance standards (Usman et al., 2022).

High levels of corruption are influenced by various factors. Government expenditures, regulations, and officials' discretionary power contribute to corruption. High levels of corruption are associated with increased regulation and government expenditures, impacting the rule of law negatively. Scandinavian countries show that a large regulatory state correlates with more corruption. Factors contributing to high corruption levels include economic influence on political systems, weak political competition, and officials' discretionary power. Corruption hinders the rule of law and regulatory quality, impacting economic development. (Bokayev et al., 2022; Holcombe and Boudreaux, 2015; Soliman and Cable, 2011). Cultural backgrounds, education levels, and personal experiences with corruption shape individuals' perceptions of corruption levels (Bokayev et al., 2022). Additionally, religious heritage and political instability play roles in corruption persistence and rule of law development.

Corruption negatively impacts the rule of law and regulatory quality by hindering judicial efficiency, reducing compliance with regulations, and exacerbating disasters due to high-level corruption. Experimental research has explored the interaction among the rule of law, dishonesty, and a country's religious heritage to clarify the link between faith and financial growth. Furthermore, the research indicates a shift in results when certain variables are taken into account, despite data limitations for all countries in the study sample. These discrepancies are attributed to alterations in sample demographics rather than the influence of control variables (North et al., 2013; Damania et al., 2004). These factors collectively highlight the complex interplay between corruption, governance, and societal perceptions, ultimately affecting the development of the rule of law and regulatory quality.

2.6. Correlation of Government Effectiveness, Political Stability, and Voice and Accountability to Economic Growth and FD

Economic growth and FD in a country are significantly influenced by various factors. Research indicates that economic freedom, inclusive growth, capital stock, protection of property rights, government spending, monetary freedom, and financial freedom positively impact FD and economic growth (De la Cruz, 2020; Yang et al., 2023). Additionally, the level of FD, income per capita, education level, financial deepening, and average inflation rate play crucial roles in determining the impact of FD on economic growth (Paun et al., 2019). Furthermore, the relationship between economic growth, FD, and national governance is highlighted, emphasizing the importance of national governance, FD, and output shocks in different types of economies (Iqbal et al., 2021). Overall, a combination of factors such as economic freedom, inclusive growth, financial sector development, and national governance significantly influences a country's economic growth and FD (Öncel et al., 2024).

Additional research shows that government effectiveness influences the earnings quality of politically connected firms, with improved effectiveness leading to higher earnings quality (Wolak, 2018). Additionally, government effectiveness impacts political participation, as declining government effectiveness in Britain has been linked to decreasing political engagement,

emphasizing the importance of effective governance for citizen involvement (Harymawan and Nowland, 2016). Furthermore, citizen perceptions of political efficacy are influenced by opportunities for political voice and policy congruence, indicating that effective government structures can enhance feelings of political effectiveness among citizens (Whiteley, 2009). Overall, the effectiveness of government plays a crucial role in shaping political stability, economic outcomes, and citizen engagement in the political process.

Research indicates that government failures, such as high public debt and governmental ineffectiveness, significantly impact non-performing loans (NPLs) in Asian countries, highlighting the correlation between IQ and financial sector health (Giammanco et al., 2023). Moreover, institutional instability, both de jure and de facto, has been found to have a strong negative effect on income and growth, with de facto instability being particularly influential. This instability can lead to insecurity of property rights and weaken institutions, ultimately hindering long-term growth and development (Iqbal et al., 2021). Therefore, addressing political instability and enhancing government effectiveness are crucial steps for fostering economic growth and FD within a country (Campos et al., 2020; Hartmann and Spruk, 2021; Maher and Zhao, 2022). Another study about examines Australia's renewable hydrogen strategies in the context of energy democracy. Analyzes the degree of citizenship engagement in the green hydrogen sector. Identifies the absence of citizen voices and its accountability in shaping the hydrogen economy (Beasy et al., 2024).

The literature reviews within this study have adequately demonstrated the significance of IQ. The reviews highlight the crucial role played by law enforcement, political stability, regulatory quality, corruption eradication, government effectiveness, and public representation in facilitating a favourable economic environment, as indicated by the GDP growth rate. The aim is that through this conducive economic setting, nations can formulate and execute policies for RE transition. The focus of this research includes assessing access to RE for daily cooking requirements and governmental strategies pertaining to energy transition.

3. MODEL, DATA AND METHODOLOGY

3.1. Model Specification

In order to examine our propositions that FD, IQ and their joint role to promote RE legislation as well as access to clean fuels and technologies for cooking, we formulate follow two different models.

Model 1:

$$REP_t = \beta_0 + \beta_1 GDPG_{t-1} + \beta_2 FD_{t-1} + \beta_3 IQ_{t-1} + \beta_4 FD*IQ_{t-1} + \varepsilon_t$$

REP_t = *Renewable Energy Porduction*
$GDPG_{t-1}$ = *lag GDP growth Rate*
FD_{t-1} = *lag Financial Deepening*
IQ_{t-1} = *lag Institutional Quality*
$FD*IQ_{t-1}$ = *lag interaction of FD and IQ*

Model 2:

$$ACFTC_t = \beta_0 + \beta_1 GDPG_{t-1} + \beta_2 FD_{t-1} + \beta_3 IQ_{t-1} + \beta_4 FD*IQ_{t-1} + \varepsilon_t$$

ACFTCt = *Access to clean fuels and technologies for cooking (% of population)*
$GDPG_{t-1}$ = *lag GDP growth Rate*
FD_{t-1} = *lag Financial Deepening*
IQ_{t-1} = *lag Institutional Quality*
$FD*IQ_{t-1}$ = lag interaction of FD and IQ

3.2. Data and Sources

Definition and list of variables are presented in Table 1.

3.3. Econometric Techniques

This study uses Dynamic Simulated Autoregressive Distributed Lag (DSARDL), Dynamic Ordinary Least Squared (DOLS) and Fully Modified Least Squared (DOLS). This technique is specifically designed to dynamically simulate a variety of ARDL models, including error-correction models. This allows users to gain a better understanding of the substantive significance of their results through meaningful counterfactual scenarios. This is particularly useful for understanding the effects of changes in the independent variable over different time periods, including short- and longer-run changes. This method allows us to automatically identify the impact of positive and negative shocks from any independent variable while treating the rest as constant. This approach addresses the issue of endogeneity, which can be challenging in traditional regression models. Additionally, the DSARDL method has several advantages over the standard autoregressive distributed lag model (ARDL) for evaluating long- and short-term associations. The DSARDL was developed by Jordan and Phillips (2018) as an extension of the ARDL model.

Dynamic Ordinary Least Square (DOLS) is an estimation method that takes into account the limitations in the OLS (Ordinary Least Square) model. DOLS is used when the data has both long-run and short-run relationships. Unlike OLS which ignores the correlation between variables and residuals, DOLS takes it into account better. In DOLS, we take into account the correlation between the variables involved in the model. This method modifies OLS to be more accurate in estimating the model parameters. Thus, DOLS is more suitable when we want to understand the relationship between variables that have both long-run and short-run effects. Fully Modified Ordinary Least Squares is an estimation method that modifies the OLS (Ordinary Least Square) model to more accurately estimate the parameters. In FMOLS, we take into account the correlation between variables and residuals, and overcome the bias that may occur in OLS. FMOLS takes a more comprehensive approach by accounting for co-integration and modifying the OLS estimation to better fit the time series data. ARDL, DOLS and FMOLS do not require strictly stationary data.

4. RESULTS AND DISCUSSION

Pre estimation tests indicate that the respective variables exhibit a mixed order of integration. As a result, we have employed DOLS (Dynamic Ordinary Least Squares), FMOLS (Fully

Table 1: Definition of variables

List of variables	Definition	Sources
Dependent variable: Measure of clean energy		
RE	Renewable Energy (RE) Production quadrillion (1015) British thermal units (BTUs)	Energy information administration
ACFTC	Access to clean fuels and technologies for cooking % of population (ACFTC)	The Quality of Government (QoG) Institute, Department of Political Science at the University of Gothenburg
Independent variable: Measures		
FD	Domestic credit disbarment to private sector by financial institute is the main indicator of Financial Development (FD) (share of GDP)	World development Indicator
IQ	We generate average value of Institutional quality (IQ) out of six indictors including, Control of Corruption, Rule of Law, Regulatory Quality, Government Effectiveness, Political Stability and voice and accountability. The value of each indicator ranging from−2.5 to+2.5.	World Governance Indicator
GDPG	Gross Domestic Products annual growth rate (GDPG)	World development Indicator

Modified Ordinary Least Squares), and dynamic simulated ARDL (Autoregressive Distributed Lag) analysis techniques. DOLS takes into consideration the nuisance parameters and addresses the autocorrelation and heteroskedasticity phenomena of the residuals. On the other hand, FMOLS corrects the bias that may occur in ordinary OLS estimation and accounts for cointegration. Both methods are instrumental in comprehending the long-run relationship between the variables in the ARDL model. Table 2 presents the outcomes of the DOLS and FMOLS estimations for RE. These estimations provide valuable insights into the relationship between the analyzed variables in the context of RE.

According to the data presented in Table 2, it is evident that FD exerts a significant negative influence on RE production. Specifically, both the DOLS and FMOLS approaches indicate that an increase of one unit in the lagged value of FD results in a decrease of 0.0145 and 0.145 units in RE, respectively, with statistical significance at the 1% level. The DOLS method suggests that GDPG has a significant negative impact (−0.0759) on RE, while FMOLS indicates a significant positive impact (0.0431) on RE. Moreover, the impact of IQ on RE is notably positive (0.385) according to DOLS, and this finding is reinforced by FMOLS, which shows a higher magnitude of significant positive impact (2.861). Notably, both methods indicate that the interaction term of FD and IQ (FD*IQ) has a significant positive impact on RE.

It is noteworthy that for all regressors, the FMOLS method yields higher coefficient values compared to the DOLS method. The R-squared value of 0.986 for the DOLS method suggests a very high level of explanatory power for the model. Conversely, the FMOLS method's R-squared value of 0.704 is lower than that of the DOLS method.

The relationship between RE and IQ is visualised in Figure 3.

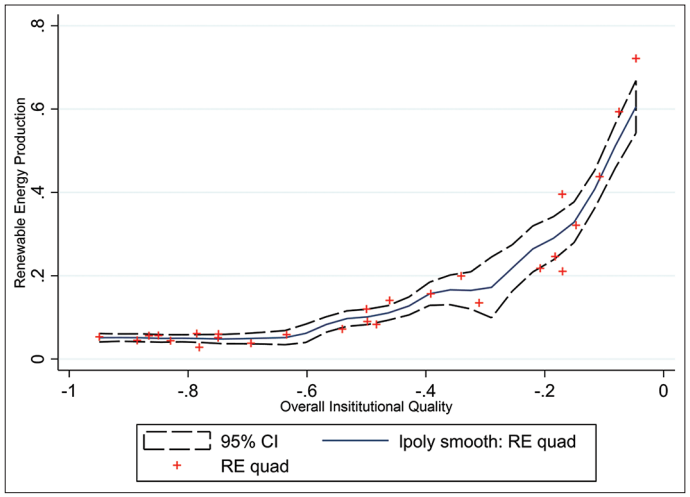
According to the information provided in Figure 3, there is a positive relationship between RE production and IQ. The locally weighted polynomial regression line, labeled "lpoly smooth: RE quad", illustrates an increasing trend in RE production as overall IQ improves (moving towards zero on the X-axis). The dashed lines surrounding the regression line represent the 95% confidence interval, indicating that the data points are expected to lie within this range with 95% certainty. This suggests that improved IQ is associated with increased RE production. The results presented in Figure 3 have important implications for policy formulation and strategic planning in the areas of energy management and sustainability efforts. The positive correlation between IQ and RE production highlights the potential for policymakers to leverage

Table 2: DOLS and FMOLS estimation on renewable energy

Variables	RE-DOLS	RE-FMOLS
FD_{t-1}	−0.0145***	−0.145***
	(0.0032)	(0.0073)
$GDPG_{t-1}$	−0.0759***	0.0431***
	(0.0067)	(0.010)
IQ_{t-1}	0.385**	2.861***
	(0.166)	(0.141)
$FD*IQ_{t-1}$	0.0137**	0.0142***
	(0.0066)	(0.0024)
Constant	1.262***	5.481***
	(0.123)	(0.262)
Observations	27	27
R-squared	0.986	0.704

***, ** & * indicate 1%, 5%, and 10% significance level

Figure 3: Visualisation of the relationship between RE and institutional quality



improvements in IQ to drive increased adoption and utilization of RE sources. Table 3 provides the result for ACFTC based on DOLS and FMOLS methods.

According to Table 3, we get FD has a significant positive impact on Access to Clean Fuels and Technologies for Cooking (% of population) (ACFTC). From DOLS we see the magnitude of this positive impact is 0.0194 and 0.0193 according to FMOLS which are significant at 1% level. GDPG has a significant negative impact on ACFTC. According to DOLS and FMOLS this negative impact is −0.0258 and −0.00263 respectively. While both methods show that there is a significant positive impact of IQ on ACFTC. Finally, the interaction of FD and IQ (FD*IQ) has also a significant positive impact on the ACFTC. All the coefficients are significant at 1% level of significance. The R-squared value of 0.997 for the DOLS method suggests a very high level of explanatory power for the model. Conversely, the FMOLS method's R-squared value of 0.951 is slightly lower than that of the DOLS method.

The relationship between ACFTC and IQ is visualised in Figure 4.

Figure 4 depicts that there is also a positive nexus between IQ and ACFTC. The blue line shows that as IQ improves, people's access to clean cooking fuels and technologies tends to improve as well. This relationship appears to be positive and slightly exponential, as the fitted line curves upwards as it moves from left to right. Figure 4 is interesting because it visually illustrates the potential relationship between the quality of institutions in a country or region and people's access to clean cooking fuels. This could imply that a better institutional framework could positively contribute to improved living standards by providing cleaner cooking options. Table 4 provides the result for RE based on DARDL method.

Using the DARDL simulation technique, we discover that the ECM coefficient is significantly negative at the 1% level. This finding suggests that the short-term asymmetrical state is transitioning towards a long-term symmetrical state by mitigating economic shockwaves correcting it at 55.69%/year. Based on this model, we observe that a 1 unit increase in FD leads to a long-term increase in the RE productivity by 0.587 unit which is not significant and a short-term decrease by 0.788 unit which is significant at 10% level of significance (Table 4). 1 unit increase in IQ leads to a long-term increase in the RE by 26.649 units (significant at 10% level) and a short-term decrease by 21.575 unit (not significant). 1 unit increase in the interaction term (FD*IQ) leads to a long-term increase in the RE by 1.2608 unit (significant at 5% level) and a short-term decrease by 0.8873 unit (significant at 10% level). Ultimately, 1 unit increase in GDPG leads to a long-term decrease in RE by −0.3869 unit (significant at 1% level) and a short-term decrease by −0.171 unit (insignificant).

Response of RE to a counterfactual (+) shock to IQ is depicted in Figure 5. The DARDL simulation plot depict the dynamic interplay between various regressed variables, RE and ACFTC, in response to positive perturbations from specific regressors such as IQ. These simulations cover a 30-year forecast horizon in Indonesia. The plots feature red dots representing mean value predictions and fat blue and thin light blue lines indicating 75%, 90%, and 95% confidence intervals.

Figure 5 shows that a 1% positive shock to IQ contributes to positively impacting RE in the forecasting 30 years period where long-run magnitude of influence become insignificant from 11

Table 3: DOLS and FMOLS estimation on ACFTC (Access to clean fuels and technologies for cooking % of population)

Variables	DOLS-ACFTC	FMOLS-ACFTC
FD_{t-1}	0.0194***	0.0193***
	(0.00234)	(0.00121)
$GDPG_{t-1}$	−0.0258***	−0.00263***
	(0.00415)	(0.000499)
IQ_{t-1}	0.534***	0.213***
	(0.117)	(0.0493)
$FD*IQ_{t-1}$	0.0112***	0.0256***
	(0.00431)	(0.00152)
Constant	0.422***	0.361***
	(0.0845)	(0.0389)
Observations	25	25
R-squared	0.997	0.951

Figure 4: Relationship visualization Access to clean fuels and technologies for cooking % of population with Institutional Quality

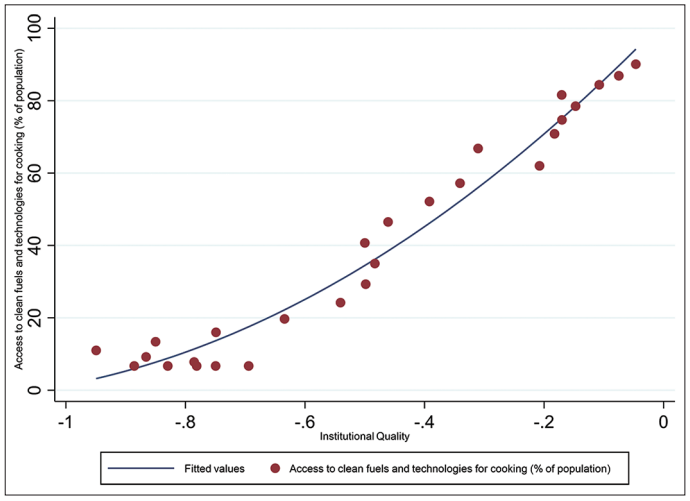
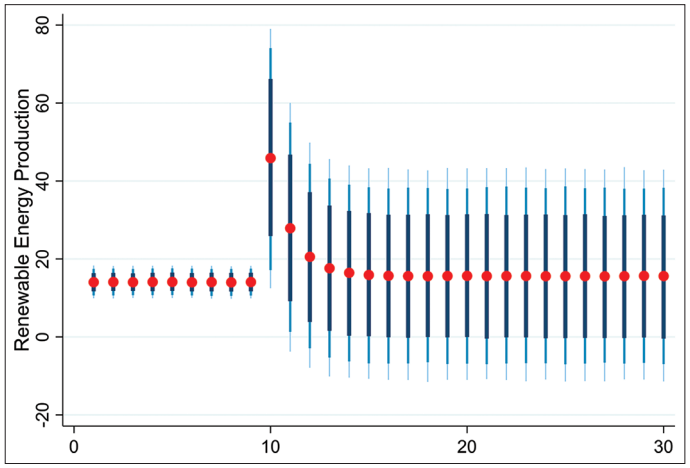


Figure 5: Response of renewable energy to change of Institutional quality



to 30 years compared to short-run. In the 10th year we see much higher significant positive impact compared to initial significant positive effects.

Response of RE to a counterfactual (+) shock to FD is depicted in Figure 6.

Figure 6 shows that a 1% positive shock to FD contributes to positively impacting RE in the forecasting 30 years period and throughout the 30 years this impact remains statistically significant.

Response of RE to a counterfactual (+) shock to FD*IQ is depicted in Figure 7.

Figure 7 depicts that a 1% positive shock to FD*IQ also positively impacting RE in the forecasting 30 years period and throughout the 30 years this impact remains statistically significant. Table 5 represents the result for ACFTC based on DARDL method.

By employing the DARDL method we find that the ECM coefficient is significantly negative at the 1% level. This negative ECM suggests that the short-term asymmetrical state is moving towards a long-term symmetrical state by mitigating economic shockwaves correcting it at 20.45%/year. Based on this model, we observe that a 1 unit rise in the FD leads to a long-term increase in the ACFTC by 0.0002 unit (insignificant) and a short-term decrease by −0.0021 unit (significant at 1% level of significance). 1 unit increase in IQ leads to a long-term increase in the ACFTC by 0.0706 unit (significant at 1% level) and a short-term increase by 0.0118 unit (not significant). 1 unit increase in the GDPG leads to a long-term decrease in ACFTC by 0.0010 unit (significant at 5% level) and a short-term increase by 0.0002 unit (insignificant). Ultimately, 1 unit increase in the interaction term (FD*IQ) leads to a long-term increase in the RE by 0.0026 unit (significant at 1% level) and a short-term decrease by −0.0002 unit (insignificant).

Table 4: Dynamic simulated ARDL with dependent variable renewable energy

RE	Coefficient	Std. error	T- values	P-values
Error Correction$_{t-1}$	−0.5569	0.177	−3.13	0.006
Long Run				
FD$_{t-1}$	0.587	0.481	1.22	0.240
IQ$_{t-1}$	26.649	14.456	1.84	0.084
FD*IQ$_{t-1}$	1.2608	0.587	2.15	0.046
GDPG$_{t-1}$	−0.3869	0.118	−3.26	0.005
Short Run				
Δ*FD*	−0.788	0.422	−1.86	0.081
Δ*IQ*	−21.575	16.120	−1.34	0.199
Δ*FD*IQ*	−0.8873	0.454	−1.95	0.069
Δ*GDPG*	−0.171	0.233	−0.74	0.472
Constant	18.141	9.980	1.82	0.088

Table 5: Dynamic simulated ARDL with dependent variable access to clean fuels and technologies for cooking by % population

ACFTC	Coefficient	Standard error	T-value	P-value
Error Correction$_{t-1}$	−0.2045	0.0513	−3.98	0.001
Long Run				
FD$_{t-1}$	0.0002	0.0005	0.38	0.712
IQ$_{t-1}$	0.0706	0.0200	3.51	0.003
GDPG$_{t-1}$	0.0010	0.0004	2.58	0.020
FD*IQt$_{-1}$	0.0026	0.0006	3.83	0.001
Short Run				
Δ*FD*	−0.0021	0.0004	−4.73	0.000
Δ*IQ*	0.0118	0.0247	0.48	0.640
Δ*GDPG*	0.00024	0.0003	0.80	0.438
Δ*FD*IQ*	−0.0002	0.0007	−0.35	0.729
Constant	0.0595	0.0184	3.24	0.005

Response of ACFTC to a counterfactual (+) shock to IQ is depicted in Figure 8.

Figure 8 depicts that a 1% positive shock to IQ contributes to positively impacting ACFTC in the forecasting 30 years period where long-run magnitude of influence become more profound from 10th year and onwards compared to short-run. The trend of positive response of ACFTC from 10 to 30 years is cyclical i.e., there is a seasonal upward and downward trend.

Response of ACFTC to a counterfactual (+) shock to FD is depicted in Figure 9.

Figure 6: Response of renewable energy to change of financial development

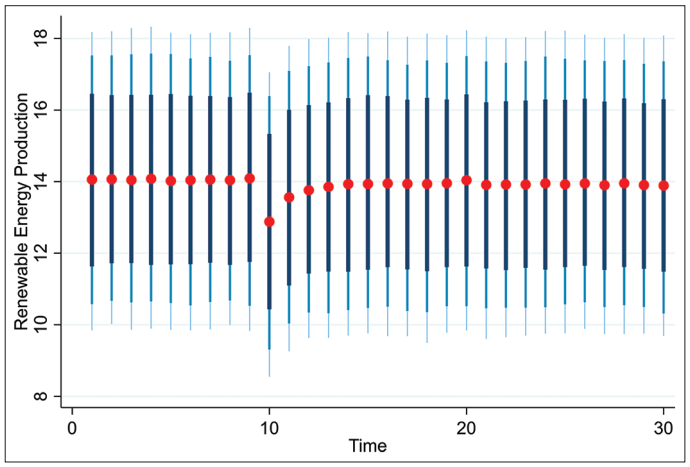


Figure 7: Response of renewable energy to change of interaction of FD and IQ

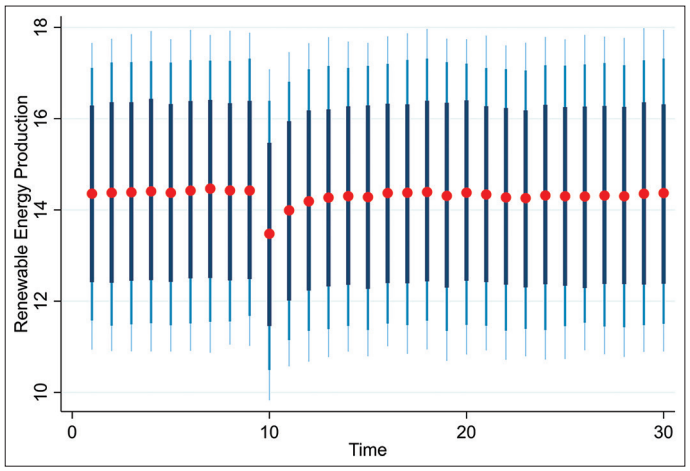


Figure 8: Response of access to clean fuels and technologies for cooking by % population to Change of Institutional quality

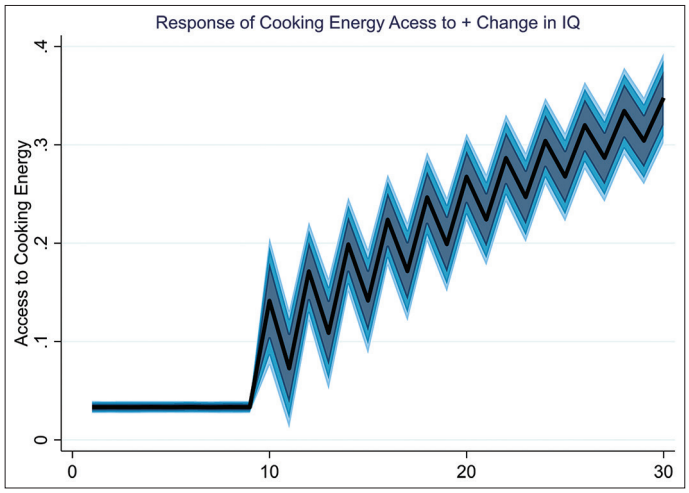


Figure 9: Response of access to clean fuels and technologies for cooking by % population to change of financial development

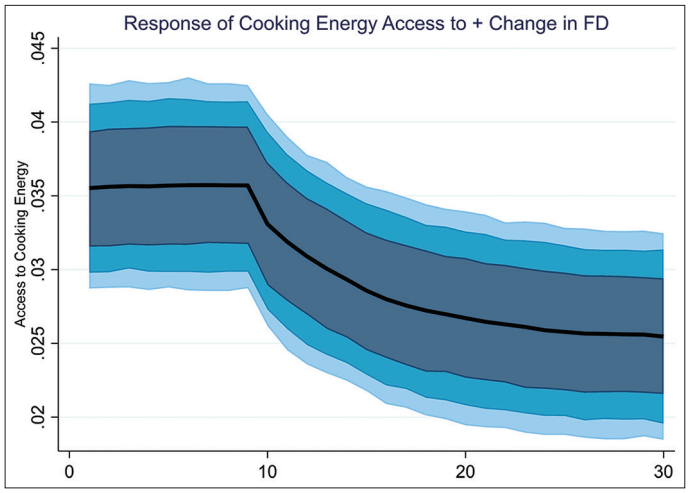
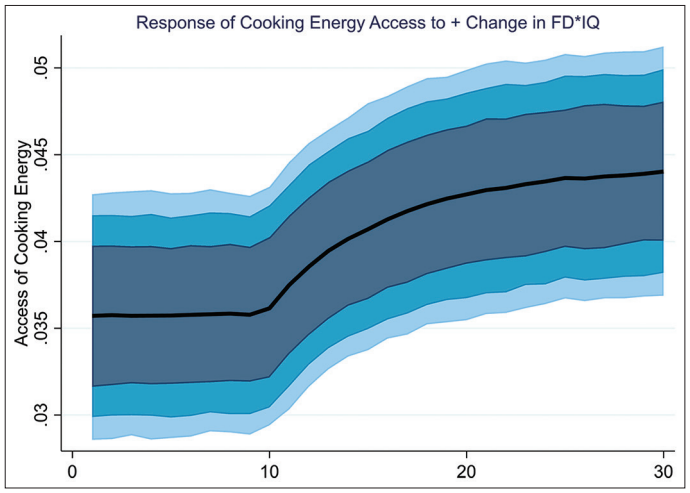


Figure 9 depicts that a 1% positive shock to FD contributes to positively impacting ACFTC in the forecasting 30 years period where long-run magnitude of influence tends to be weaker from 10th year and onwards compared to short-run. The plot indicates that the relationship between FD and access to clean cooking energy may be complex, with initial positive effects likely followed by negative effects as FD continues. The graph also highlights that this relationship has different levels of certainty at different stages of FD.

Response of ACFTC to a counterfactual (+) shock to FD*IQ is depicted in Figure 10.

Figure 10 presents the relationship between Access to Cooking Energy (ACFTC) as a percentage of the population and the interaction between FD and IQ. The graph illustrates a positive trend, indicating that as the value of the interaction between FD and IQ increases, there is a corresponding increase in access to clean cooking energy. This suggests that the combined influence of FD and IQ can contribute to the improvement of ACFTC. However,

Figure 10: Response of access to clean fuels and technologies for cooking by % population to change of interaction of FD and IQ



it is important to note the presence of uncertainty, as indicated by the shaded area surrounding the ACFTC response. As we move farther along the horizontal axis, this shaded area widens, reflecting increasing uncertainty over time or at different levels of changes in FD and IQ. This highlights the need to consider and account for the varying levels of uncertainty in understanding the relationship between FD, IQ, and access to clean cooking energy.

The positive and significant coefficient for the interaction term FD*IQ in both the DOLS and FMOLS models implies that there is a synergistic effect between FD and IQ on the RE growth. This indicates that FD is more effective in environments with strong institutions (Al Mamun et al., 2018). In other words, the capacity of FD to enhance RE outcomes is contingent upon the level of institutional integrity and efficiency (Zeqiraj et al., 2020). This can be explained by recognizing that high-quality institutions can create conducive environments for financial markets to function effectively by ensuring transparency, enforcing property rights, and upholding the rule of law (Al Mamun et al., 2018). Such an environment is essential for reducing uncertainty and transaction costs, which, in turn, could lead to more investments in long-term and sustainable projects like RE. Our findings align with those of Sohag et al. (2024), Zeqiraj et al. (2020), Sohag et al. (2021), and Al Mamun et al. (2018), who document that FD plays a crucial role in promoting RE by enabling financial availability to investors in the clean energy industry. Furthermore, robust institutions can implement and oversee policies that incentivize or mandate the use of clean energy, thereby providing a stable investment climate for financial markets to channel funds into RE projects (Uzar, 2020). This complementary relationship may also facilitate innovative financing mechanisms like green bonds or carbon financing, which can be pivotal in attracting investment towards RE initiatives (Sohag et al., 2023). In essence, the interaction term suggests that IQ can act as a multiplier of the benefits of FD, reinforcing the argument for a holistic approach to policy design that integrates financial, legal, and regulatory aspects to boost the RE sector. Therefore, for countries like Indonesia, strengthening institutional frameworks might be as critical as fostering financial market development to achieve clean energy goals.

5. CONCLUSION AND POLICY IMPLICATIONS

RE includes resources such as solar, wind and hydro-power. Its dependence on economic and institutional factors is critical. FD reflects the availability of credit and financial support. This factor influences investments in the RE sector. Credit availability accelerates the development of green energy infrastructure. IQ involves political and legal stability. Strong institutions facilitate investment and favourable regulations for RE.

Economic growth affects overall energy demand, including demand for RE. The effect of FD in the previous period on people's access to clean fuels and technologies for cooking is positive. That is, if it increases, the access also tends to increase. However, GDP growth in the previous period has a negative influence on access. So, if GDP growth increases, access to clean fuels and technologies for cooking will decrease. Meanwhile, the effect of IQ and FD on RE is not statistically significant.

An increase in GDP growth is associated with a decrease in RE. The interaction between FD and IQ may strengthen the impact on access to clean cooking fuels and technologies. The higher the access to clean cooking fuels and technologies, the lower the level of RE. IQ also plays an important role in increasing such access. Changes in FD and GDP growth seem to have different impacts on access to clean cooking fuels and technologies.

Governments need to ensure the availability of credit and financial support for RE projects. This will accelerate the development of green energy infrastructure. Focus on improving policies and governance that support the RE sector. The quality of institutions, including political and legal stability, plays an important role in facilitating investment and favourable regulation of RE. Policies that combine economic growth with RE use can help reduce overall environmental impacts. Understanding the relationship between FD and IQ will help take appropriate action. Governments need to increase public awareness of the benefits of RE and clean technologies for cooking through effective education.

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