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Does institutional quality condition the impact of renewable energy on income inequality? Evidence from 28 Asian economies

Khin OO[1]
Paravee Maneejuk[2]
Woraphon Yamaka[3+]

[1]*Faculty of Economics, Chiang Mai University, 50200, Thailand.*
[1]*Email: saikhinoo.mm@gmail.com*
[2,3]*Center of Excellence in Econometrics, Faculty of Economics, Chiang Mai University, 50200, Thailand.*
[2]*Email: mparavee@gmail.com*
[3]*Email: woraphon.econ@gmail.com*

(+ Corresponding author)

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ABSTRACT

The transition toward renewable energy is often assumed to yield inclusive economic benefits, yet empirical evidence remains mixed. The purpose of this study is to examine the moderating influence of governance on the relationship between renewable energy consumption and income distribution across 28 Asian economies over the period from 2001 to 2021. The study employs a dynamic panel regression model using the System Generalized Method of Moments (GMM) estimator to address potential endogeneity problems and unobserved country-specific heterogeneity. Furthermore, a composite institutional quality index is constructed using principal component analysis to capture the multidimensional nature of governance. The findings demonstrate the critical influence of institutional quality on the correlation between renewable energy consumption and income inequality. In particular, in nations characterized by weak governance, the consumption of renewable energy correlates with increased income inequality, suggesting early-stage renewable investments may disproportionately benefit capital owners. However, in countries with stronger institutional frameworks, this relationship changes. When the quality of governance surpasses a certain median threshold, using renewable energy helps to close the income inequality gap. The practical implications of these results emphasize that policymakers should not rely solely on green energy to achieve equitable growth. Instead, governments must pair environmental targets with targeted institutional reforms, market entry facilitation, and regulatory transparency to ensure that the financial benefits of the energy transition are distributed fairly among all populations.

Contribution/Originality: This research provides new evidence on the conditional relationship between renewable energy consumption and income inequality. Rather than assuming clean energy inherently equalizes wealth, we evaluate the moderating role of institutional quality across Asian economies. Many previous studies have focused only on the direct effect of renewable energy. In contrast, this paper uses an interaction term in a dynamic panel model to demonstrate that this impact depends heavily on a country's institutional quality.

1. INTRODUCTION

The world is moving toward cleaner energy, and Asia is leading the way. This is because the economy is changing, the electricity demand is going up quickly, and there is still a problem with income inequality. In 2025, the area is expected to use almost half of all the electricity in the world. This is due to both population growth and industrial growth (Maneejuk & Yamaka, 2026). In many Asian economies, inequality is still a big problem. This is because economic growth hasn't always helped everyone (Blancheton & Chhorn, 2021). These changes are similar, which makes us wonder: will switching to renewable energy make the income gap smaller or bigger? It's especially important to focus on Asia because it's such a diverse place. Countries differ greatly in terms of their economic growth and the quality of their institutions. Some have advanced economies with strong governance systems, while others are still developing and have limited institutional capacity (Miao, Gillani, Abbas, & Zhan, 2023; Prasetyia, Wicesa, Hans, Trapsila, & Ariestiningtyas, 2026). This variation provides a useful framework for examining whether the distributional effects of renewable energy depend on institutional contexts. Many Asian countries are also working hard to increase their ability to use renewable energy by investing in it and supporting it through public policy. But these programs might not be good for everyone. Asia is a good place to see if renewable energy can help with inclusive growth because it is going through a lot of changes and has a lot of problems with inequality (Uzar, 2020).

In theory and in practice, the link between renewable energy and income inequality is still not clear. On the one hand, increasing the use of renewable energy can help lower inequality by creating jobs, lowering long-term energy costs, and making it easier for people to get electricity, especially in rural and underserved areas (Apergis, 2015). Decentralized energy systems may also generate new employment opportunities for low-income families. Investing in renewable energy, on the other hand, usually costs a lot of money and requires a lot of skill, which may help higher-income groups and big businesses, especially at the start of the transition (Churchill, Ivanovski, & Munyanyi, 2021; McGee & Greiner, 2019). These opposing forces imply that renewable energy does not inherently result in more equitable outcomes; instead, its impacts are likely influenced by country-specific circumstances.

The quality of the institutions could be one important reason why these results are different. Governance has a big effect on how policies are made, put into action, and enforced. This, in turn, changes who benefits from the growth of clean energy. Strong institutions can make things more open, cut down on people trying to get something for nothing, and get more people interested in energy markets. They also help fairly distribute subsidies and make it easier to get to infrastructure.

On the other hand, weak institutional frameworks may allow politically connected people or wealthy groups to take advantage of benefits, which would keep inequality going. Previous studies have explored the relationship between institutional quality and energy or economic outcomes (Polcyn, Us, Lyulyov, Pimonenko, & Kwilinski, 2022; Shahbaz, Raghutla, Chittedi, Jiao, & Vo, 2020); however, there is a lack of research focusing on how institutions affect the connection between renewable energy and income inequality. Most contemporary studies either treat institutional quality as a control variable or analyze governance and energy outcomes in isolation. As a result, it is unclear if renewable energy can reduce inequality only when strong institutions are present. This gap is particularly significant in rapidly changing contexts, as inequality is a persistent issue intricately connected to structural and policy-related challenges.

Against this backdrop, this study examines the role of renewable energy consumption in the reduction of income inequality in 28 Asian economies during the period 2001-2021 and whether the effect is conditioned by the quality of institutions.

The analysis uses dynamic panel estimation techniques that control for endogeneity, persistence, and unobserved heterogeneity to examine whether strong institutions are an important precondition for the expansion of renewable energy to be associated with more inclusive outcomes. This study makes three main contributions. First, it challenges the common assumption that the transition to renewable energy will automatically generate more equitable outcomes by showing that its distributional effects are conditional on institutional quality. Second, it highlights the role of governance as a key moderating factor in the relationship between renewable energy expansion and income inequality, thereby extending the literature beyond analyses that focus only on the direct effects of renewable energy. Third, it provides empirical evidence that renewable energy expansion can contribute to reducing income inequality, but that this effect is more likely to materialize in countries with stronger governance frameworks.

The paper proceeds as follows. Section 2 provides a review of the related literature, followed by Section 3, which introduces the data and methodological framework. Section 4 presents the empirical results. Finally, Section 5 provides the conclusion and recommendations.

2. LITERATURE REVIEW

The literature on the relationship between renewable energy consumption and income inequality is inconclusive. The expansion of renewable energy is often linked to several mechanisms that can help to reduce inequality. It can create local jobs, reduce long-term energy costs, and provide access to electricity, especially in rural and underserved areas, for instance. Moreover, decentralized energy systems can contribute to income diversification and the expansion of economic opportunities, especially for lower-income households (Farghali et al., 2023; Sovacool, 2016). The effects are likely to be more pronounced in developing economies where access to energy is still limited. But there are problems with developing renewable energy as well. It's usually capital intensive and reliant on sophisticated technology and skilled labour. This may result in benefits being concentrated in higher-income groups, big firms, and skilled workers, especially in the initial transition phase. Further, low-income households' participation may be limited due to a lack of access to finance and technology. Under such conditions, the growth of renewable energy may in fact contribute to the widening of income inequality rather than reducing it (Mariev, Iliyasu, & Mamman, 2025; McGee & Greiner, 2019). The two opposing opinions imply that the distributional implications of renewable energy are context-dependent and depend on the development level of a country.

The empirical findings reflect this ambiguity. Micro-level studies usually find that decentralized renewable energy projects are beneficial for household welfare and contribute to poverty alleviation (Farghali et al., 2023). In contrast, the macro-level evidence is still mixed. Apergis (2015) documents that the effect of renewable energy on inequality depends on countries and development stage. McGee and Greiner (2019) found that the relationship was bidirectional, meaning that income inequality can also affect renewable energy adoption. Churchill et al. (2021) further showed that these effects vary over time, with inequality-reducing effects in the initial stages and inequality-increasing effects as benefits become more concentrated over time. However, recent studies have been interested in the role of structural factors such as financial development, technological capacity, and policy conditions in achieving these outcomes (Li, Yang, & Wang, 2025). Table 1 summarizes the main findings from the existing literature on renewable energy and income inequality.

Besides economic factors, socio-political conditions are also very important. High levels of inequality may hinder collective action and reduce public support for renewable energy policies and influence the distribution of subsidies in favor of higher-income groups (Berthe & Elie, 2015; Uzar, 2020). These interactions imply that the relationship between renewable energy and inequality is not linear but embedded in wider institutional contexts. Thus, institutional quality is a key determinant of these differences. Strong institutions, such as good regulation, rule of law, political stability, and control of corruption, improve policy implementation and reduce rent-seeking behavior. In the case of renewable energy, good governance can bring about greater participation, better access to infrastructure, and a more equitable distribution of benefits. On the other hand, renewable energy expansion can help to reduce inequality, but the benefits are likely to be captured by politically connected actors or higher-income groups if institutions are weak (Acheampong, Dzator, & Savage, 2021; Blancheton & Chhorn, 2021; Xu et al., 2023).

Nevertheless, several gaps remain in the literature. First, most studies examine renewable energy and institutional quality separately, without explicitly analyzing their interaction in shaping income inequality. Second, many empirical analyses rely on static models and do not account for the persistence of inequality or the potential endogeneity between energy consumption and distributional outcomes. Third, institutional quality is often measured using single indicators, which may fail to capture its multidimensional nature (Efayena & Olele, 2024). To address these limitations, this study examines whether the impact of renewable energy consumption on income inequality is conditional on institutional quality within a dynamic panel framework. By incorporating a composite index of institutional quality and accounting for endogeneity and persistence, the analysis provides more robust evidence on the distributional effects of renewable energy across Asian economies.

Table 1. Summary of key previous studies on renewable energy and inequality.

Author	Sample	Methodology	Key Findings
Apergis (2015)	Global panel of developed and developing countries	Panel regression	The distributive impact of renewable energy is highly heterogeneous and varies significantly depending on a country's level of development.
McGee and Greiner (2019)	Global macro-level analysis	Dynamic modeling	Identifies a bidirectional relationship between renewable energy and inequality; renewable energy tends to be skill-biased and capital-intensive, which may lead to unequal income distribution.
Uzar (2020)	Cross-country panel	Macroeconomic panel analysis	High levels of income inequality weaken collective environmental action and result in uneven adoption of renewable energy.
Churchill et al. (2021)	Panel of 17 nations	Time-varying effects model	The impact of renewable energy on inequality changes over time; it may reduce inequality in early stages but increase it as benefits become more concentrated.
Blancheton and Chhorn (2021)	Asia and the Pacific (1988–2014)	Panel regression	Strong government intervention and institutional quality are essential to mitigating inequality, although the benefits may take time to materialize.
Xu et al. (2023)	South Asian economies	Panel models	Institutional quality plays a crucial role in the effectiveness of green finance and renewable energy development; strong governance helps prevent elite capture.

3. DATA AND METHODOLOGY

3.1. Data Sources and Variable Selection

Our empirical framework relies on a balanced panel dataset encompassing 28 Asian economies over 21 years (2001–2021), yielding 588 country-year observations. The complete list of the 28 Asian economies is provided in Appendix A. We collected data from standard international databases. These include the World Development Indicators (WDI), the International Energy Agency (IEA), and the Worldwide Governance Indicators (WGI). We use the Gini coefficient as our primary dependent variable to measure wealth distribution. Our main independent variable is renewable energy consumption (REC). Testing the moderating effect of governance is a main objective of this study. We built a comprehensive Institutional Quality (IQ) index instead of relying on a single metric. We used Principal Component Analysis (PCA) to combine six WGI dimensions. These are government effectiveness, regulatory quality, control of corruption, rule of law, political stability, and voice and accountability. We standardized these metrics using Z-scores before extraction. The resulting index is robust, with a Kaiser–Meyer–Olkin (KMO) statistic of 0.804. The first principal component explains about 88% of the total variance, indicating these variables represent a unified governance structure. The model includes several socioeconomic controls. These are GDP per capita (with a squared term for the Kuznets curve hypothesis), the Human Development Index (HDI), and electricity access rates. We limited our control variables for two reasons. First, they have strong theoretical links to income distribution. Second, they have consistent data available across all 28 countries during the entire study period.

3.2. Econometric Strategy

In this study, our baseline empirical model can be written as follows:

$$LnGINI_{i,t} = \alpha_0 + \alpha_1 LnGINI_{i,t-1} + \beta_1 LnGDPC_{i,t} + \beta_2 (LnGDPC_{i,t})^2 + \beta_3 LnREC_{i,t} + \beta_4 LnHDI_{i,t} + \beta_5 LnAccEle_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where i denotes country and t denotes time. α_0, α_1, and β_1–β_5 are the parameters to be estimated. $\varepsilon_{i,t}$ is the error term. To better understand how governance influences the distributional effects of renewable energy, we extend the baseline model by including an interaction term between renewable energy consumption and institutional quality. This allows us to examine whether the impact of renewable energy on income inequality depends on the strength of governance across countries. The extended model is specified as follows:

$$LnGINI_{i,t} = \alpha_0 + \alpha_1 LnGINI_{i,t-1} + \beta_1 LnGDPC_{i,t} + \beta_2 (LnGDPC_{i,t})^2 + \beta_3 LnREC_{i,t} + \beta_4 IQ_{i,t} + \beta_5 (LnREC_{i,t} * IQ_{i,t}) + \beta_6 LnHDI_{i,t} + \beta_7 LnAccEle_{i,t} + \varepsilon_{i,t} \quad (2)$$

Equations 1 and 2 are estimated using the System Generalized Method of Moments (System GMM) developed by Arellano and Bover (1995) and Blundell and Bond (1998). This method is well suited to our analysis because it helps deal with endogeneity, captures the dynamic nature of income inequality, and controls for unobserved differences across countries. In the estimation, renewable energy consumption (LnREC) and its interaction term are treated as endogenous variables. This is because reverse causality is likely; income inequality itself can influence environmental policies and the adoption of renewable energy. Institutional quality (IQ), in contrast, is treated as a predetermined variable. Governance structures and institutional frameworks typically evolve slowly over time and are unlikely to respond immediately to short-term changes in income inequality.

We use robust two-step standard errors with a finite-sample correction for statistical validity. We also collapse the instrument matrix and restrict lag depths based on Roodman (2009) to avoid instrument proliferation. We report the instrument count with our diagnostic tests to show it stays below the number of cross-sectional units. This ensures the high Sargan test p-values indicate valid instruments rather than an overfitted model. We use the Arellano–Bond AR (2) tests to check for second-order serial correlation in the differenced residuals.

The moderating effect of institutional quality is evaluated through the interaction coefficient β_5 and the corresponding marginal effect of renewable energy is as follows:

$$ME = \frac{\partial\, ln(Y)}{\partial\, ln(REC)} = \beta_3 + \beta_5 \times IQ \quad (3)$$

Marginal effects are calculated at different levels of institutional quality, using various percentiles of its distribution. This helps show how the effect of renewable energy consumption on income inequality changes across different institutional environments.

4. EMPIRICAL RESULTS

4.1. Baseline Diagnostics

Before estimating the main models, we first checked the quality and reliability of the dataset. The descriptive statistics reported in Table 2 indicate that there is sufficient variation across both countries and time periods for the 28 economies included in the sample. We then conducted panel unit root tests using the Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS) approaches. The results consistently reject the null hypothesis of a unit root for all variables at conventional significance levels. This suggests that the variables are stationary, allowing us to proceed with the dynamic panel estimation without the need to differencing the data.

Table 2. Descriptive statistics and panel unit root tests.

Variables	Mean	Std. Dev.	Min.	Max.	LLC	IPS
LnGDPC	8.512	1.227	6.322	11.123	-5.538 ***	-1.333 *
LnGINI	3.674	0.174	2.719	4.010	-2.174 ***	-1.47 *
LnREC	1.978	1.648	-2.303	4.514	-3.220 ***	-2.724 ***
IQ	0.000	2.206	-4.458	5.043	-4.356 ***	-5.104 ***
LnHDI	-0.336	0.174	-0.819	-0.042	-8.911 ***	-6.095 ***
LnAccEle	4.501	0.273	2.251	4.605	-3.177 ***	-8.416 ***

Note: *** and * indicate statistical significance at the 1% and 10% levels, respectively.

Furthermore, the Variance Inflation Factor (VIF) results reported in Table 3 show a mean value of 2.62, indicating that multicollinearity is not a concern in our model.

Table 3. Variance inflation factors.

Variables	VIF
LnHDI	4.52
IQ	2.48
AccEle	1.79
REC	1.69
Mean VIF	2.62

4.2. The Baseline Distributional Impact of Renewable Energy

Table 4 reports the baseline dynamic GMM results before adding the interaction with institutional quality. The coefficient on the lagged dependent variable is positive and highly significant across all specifications (0.876 in the System GMM), indicating a strong persistence in income inequality. In other words, past inequality continues to influence current levels, which supports the use of a dynamic framework.

Considering the main variable, renewable energy consumption shows a positive but relatively small coefficient in the System GMM results. Since the model is specified in logarithms, this coefficient can be interpreted as an elasticity. This means that a 10% increase in renewable energy consumption is associated with about a 0.04% increase in the Gini coefficient. Although the effect is small, the positive sign is still meaningful. It provides some support for the "green transition penalty" argument, suggesting that in the early stages, renewable energy investments may benefit capital owners and skilled workers more than others. This is likely because such investments tend to be capital-intensive and require specialized skills, which can widen the income gap (Li et al., 2025; Mariev et al., 2025).

The control variables generally behave in line with expectations. Both human development and access to electricity have a negative and statistically significant effect on income inequality, suggesting that improvements in these areas help promote more inclusive outcomes.

The diagnostic tests also support the reliability of the model. The Arellano–Bond AR(2) test shows no evidence of second-order serial correlation, which is an important requirement for consistency. In addition, the number of instruments is kept below the number of countries by collapsing the instrument matrix, helping to avoid problems related to having too many instruments. The Sargan test also confirms that the instruments used in the model are valid.

Table 4. Baseline results.

Variables	Difference GMM		System GMM	
	Coefficient	Std. Error	Coefficient	Std. Error
$LnGINI_{t-1}$	0.731 ***	0.046	0.876 ***	0.025
LnGDPC	-0.157 ***	0.024	-0.019	0.097
$LnGDPC^2$	0.008 ***	0.003	0.003	0.006
LnREC	0.002	0.003	0.004 **	0.002
LnHDI	-0.162 ***	0.045	-0.177 ***	0.055
LnAccEle	-0.256 ***	0.006	-0.045 **	0.021
Constant	0.339	0.263	0.216	0.484
AR (2) (P-value)	0.110		0.232	
Sargan Test (P-value)	0.555		0.783	
Number of Instruments	14		18	

Note: *** and **, indicate statistical significance at the 1% and 5% levels, respectively. The instrument set is restricted to lag 2 to mitigate instrument proliferation.

4.3. The Moderating Role of Institutional Quality

Table 5 incorporates the critical interaction between renewable energy deployment and governance. The isolated coefficient for renewable energy loses its statistical significance when we introduce this interaction. This change supports our main hypothesis: the distributional impact of green energy is not uniform but depends entirely on the institutional environment.

Table 5. Dynamic GMM estimates on socioeconomic with interaction terms.

Variables	Difference GMM		System GMM	
	Coefficient	Std. Error	Coefficient	Std. Error
$LnGINI_{t-1}$	0.750 ***	0.043	0.843 ***	0.040
LnGDPC	0.019 ***	0.045	0.231**	0.117
$(LnGDPC)^2$	-0.010 ***	0.003	-0.124 *	0.070
LnREC	0.004	0.003	0.001	0.006
IQ	0.012 ***	0.004	0.025 ***	0.008
LnREC*IQ	-0.002 *	0.001	-0.005**	0.003
LnHDI	-0.1800 ***	0.028	-0.256 ***	0.038
LnAccEle	-0.023 ***	0.007	-0.028	0.021
Constant	0.093	0.187	0.698	0.639
AR (2) (P-value)	0.112		0.308	
Sargan Test (P-value)	0.546		0.246	
Number of Instruments	16		24	

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The instrument set is restricted to lag 2 to mitigate instrument proliferation.

The interaction term between renewable energy and institutional quality is negative and statistically significant, implying that stronger institutional quality could mitigate the effect of renewable energy on income inequality. In other words, the impact of renewable energy on income distribution is conditional rather than independent. In countries with weak institutional frameworks, renewable energy expansion may exacerbate inequality; however, as institutional quality improves, this adverse effect diminishes and may eventually reverse.

At first glance, the positive coefficient on institutional quality (0.025) may appear counterintuitive, as it suggests that improvements in governance are associated with higher levels of inequality. However, this coefficient should not be interpreted in isolation. The total effect of institutional quality depends on both its direct impact and its interaction with renewable energy. In the early stages, institutional reforms may disproportionately benefit higher-income groups, particularly those with better access to capital, information, and political networks (Blancheton & Chhorn, 2021). However, the negative interaction term becomes increasingly relevant as renewable energy adoption expands. Stronger institutions enhance regulatory effectiveness, reduce rent-seeking behavior, and improve the allocation of resources, thereby enabling a more equitable distribution of the benefits associated with renewable energy. This result highlights the complementary role of governance in ensuring that the energy transition contributes to inclusive development.

Figure 1 plots the marginal elasticity of renewable energy on the Gini coefficient across institutional quantiles to visualize this governance effect. A clear transition is visible. Expanding green infrastructure actively widens the wealth gap in environments with weak governance (the 10th to 30th percentiles). This penalty shrinks as administrative frameworks mature. The mathematical relationship completely reverses once a nation passes the median institutional threshold. In the uppermost quantiles (the 60th to 90th percentiles), renewable energy definitely suppresses inequality. These findings indicate that transparent, high-functioning institutions actively prevent elite capture, guaranteeing that green subsidies and modernized grids genuinely uplift marginalized households rather than merely subsidizing corporate developers (Uzar, 2020; Xu et al., 2023).

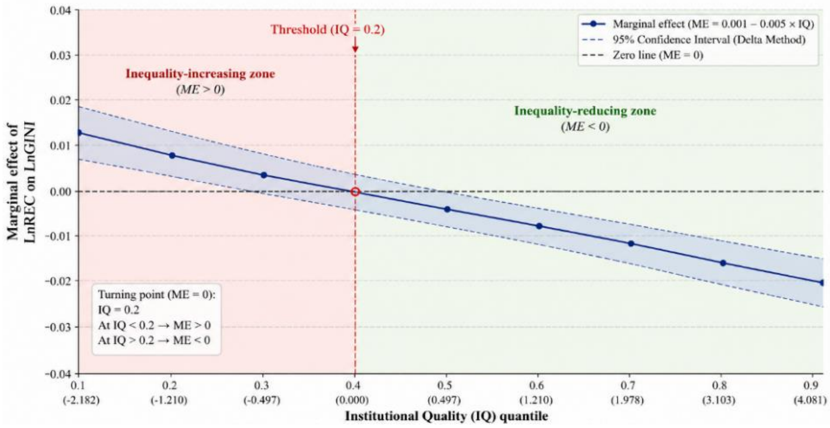

Figure 1. Marginal effects of renewable energy across institutional quality quantiles 0.1 to 0.9.

5. CONCLUSION AND POLICY IMPLICATIONS

This study examines how renewable energy consumption is related to income inequality across 28 Asian economies from 2001 to 2021, with a particular focus on the role of institutional quality. Using a dynamic panel approach to deal with endogeneity and persistence, the results suggest that the effect of renewable energy is not the same everywhere. Instead, it seems to depend quite strongly on the institutional environment. In countries where governance is weaker, expanding renewable energy is linked to higher inequality. But in countries with stronger institutions, the pattern is different; renewable energy appears to help reduce inequality. This points to the idea that the benefits of the energy transition are not automatic, and whether they are shared more widely depends on the quality of governance. From a policy point of view, this means renewable energy policies cannot really be considered on their own. In settings where governance is weak, financial access is limited, or regulations are not well enforced, the gains from renewable energy are more likely to end up benefiting higher-income groups. By contrast, where institutions function better, through clearer rules, more transparency, and better access to markets, the benefits are more likely to be spread more broadly. This suggests that renewable energy policies need to go hand in hand with institutional improvements. Measures such as strengthening regulatory systems, lowering entry barriers, and improving transparency can make a real difference. At the same time, it is also important to limit rent-seeking and make sure that incentives are not captured by a small group. Without these kinds of improvements, the transition to clean energy may not deliver the inclusive outcomes that policymakers often expect. There are also some limitations to keep in mind. Using national-level data means that differences within countries are not fully captured, especially when it comes to institutional quality and inequality. In addition, the composite index used here may not reflect every aspect of governance in detail. Future research could look more closely at these issues, for example by using subnational data or focusing on specific components such as corruption control or regulatory quality. It may also be useful to explore other channels, such as financial inclusion or labor market dynamics. Finally, examining whether there are clear threshold effects in institutional quality would help provide a deeper understanding of how these relationships evolve.

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Appendix A.

Table A1. List of the 28 Asian economies included in the empirical analysis.

Asian economies (28)
Azerbaijan, Bangladesh, Cambodia, China, Cyprus, Georgia, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kyrgyzstan, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Russian Federation, Singapore, South Korea, Thailand, Türkiye, Uzbekistan, Vietnam.

Table A1 presents the complete list of the 28 Asian economies included in the empirical analysis to ensure absolute transparency and facilitate future replication.