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Country Risk, Financial Development, And Renewable Energy Consumption: Evidence from G20 Countries

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Abstract

Background: The global energy transition toward renewable energy sources remains constrained by complex institutional, financial, and geopolitical barriers, particularly among G20 economies that collectively contribute more than 75% of global CO_2 emissions. Despite recent growth in renewable energy investment, the share of renewable energy in total final energy consumption across G20 countries remains heterogeneous and unevenly distributed, reflecting structural differences in financial system maturity, political risk environments, and fossil energy path dependencies.
Objective: This study analyzes the effects of country risk measured through the International Country Risk Guide (ICRG) composite index and financial development on renewable energy consumption across 18 G20 member countries over 1992–2021 (540 observations).
Method: Employing fixed-effects panel regression as a baseline and Mean Group Estimator (MG) as the primary estimator, the study yields three key findings.
Results: First, financial development exerts a significant negative effect on renewable energy consumption (β = −4.433**), contrary to conventional expectations, confirming the dominance of the financial incumbency hypothesis in the G20 context an entrenched financial system perpetuates fossil fuel financing orientation. Second, composite risk is insignificant, confirming aggregation bias in composite risk indices that conceals individual risk dimension effects. Third, CO2 emissions exert a highly significant negative effect (β = −1.403***) as the only variable consistent across all estimations, confirming carbon lock-in as a universal barrier to energy transition.
Conclusion: The reversal of the financial development coefficient from a statistically insignificant positive estimate in OLS FE (β = 8.328, t = 1.32) to a significant negative estimate in MG (−4.433**) empirically demonstrates the aggregation bias consequences concealed in homogeneous panel estimators.

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INTRODUCTION

The transition from fossil-based energy toward renewable energy is a strategic priority for achieving global climate targets, including the 2050 Net Zero Emissions (NZE) agenda and the Paris Agreement commitment to limit global temperature increases to well below 2°C (IEA, 2023; IPCC, 2021; UNFCCC, 2015). The G20 countries have a particularly important role in this transition because they collectively account for more than 75% of global CO_2 emissions. However, renewable energy consumption remains highly heterogeneous across G20 members. In 2021, renewable energy accounted for approximately 19.1% of global final energy consumption, while its share within the G20 ranged from less than 5% in countries such as Saudi Arabia and Russia to more than 45% in Brazil (IEA, 2022; IRENA, 2023). This variation reflects differences in economic structures, financial systems, institutional conditions, and dependence on fossil-based energy.

Country risk represents one of the institutional factors that may influence renewable energy development because it affects investment uncertainty, financing conditions, and the policy environment. The International Country Risk Guide (ICRG) provides a composite measure of country risk covering political, economic, and financial dimensions. Previous studies indicate that political uncertainty can discourage renewable energy investment by increasing investment risk (Cadoret & Padovano, 2016), while economic and financial conditions may influence investment capacity and the cost of capital (Campiglio et al., 2018). Nevertheless, the use of a composite risk index may conceal differences among individual risk dimensions. When political, economic, and financial risks have different effects on renewable energy consumption, aggregating them into a single index may reduce the ability to identify their respective relationships.

Financial development is another important determinant of renewable energy consumption. Conventional financial development theory suggests that deeper and more efficient financial systems can facilitate renewable energy investment by improving access to capital and reducing financing constraints (Shahbaz et al., 2021). However, this relationship may not be uniform across countries. The financial incumbency hypothesis argues that established financial systems can become structurally connected to existing fossil-fuel industries through long-term lending relationships, investment portfolios, financial expertise, and institutional arrangements (Campiglio et al., 2018). Consequently, financial development may not necessarily accelerate renewable energy transition when financial institutions remain strongly embedded in fossil-based economic structures. This possibility is particularly relevant for G20 economies, where financial systems range from rapidly developing markets to highly mature systems with long-established fossil-energy financing structures.

Existing empirical evidence provides mixed findings regarding the relationship between financial development and renewable energy consumption. Studies focusing primarily on developing and emerging economies generally report that financial deepening promotes renewable energy consumption (Paramati et al., 2021). In contrast, evidence from more financially developed economies suggests that political, economic, and financial risks may influence renewable energy consumption through different channels (Hondroyiannis et al., 2024). These differences indicate that the relationship between financial development and renewable energy may depend on the structural characteristics of the financial system. At the same time, limited attention has been given to whether the conventional positive relationship remains valid when countries with substantially different levels of financial development and fossil-fuel dependence are analyzed within a heterogeneous panel framework.

A further methodological issue concerns the treatment of heterogeneity across countries. Conventional homogeneous panel estimators, such as fixed-effects models, impose common slope coefficients across cross-sectional units. This assumption can be problematic when countries differ substantially in their institutional structures, financial systems, energy policies, and historical dependence on fossil fuels. Pesaran & Smith (1995) demonstrate that imposing slope homogeneity in heterogeneous panels may generate aggregation bias and potentially distort the direction and magnitude of estimated relationships. The Mean Group (MG) estimator addresses this problem by allowing country-specific coefficients before obtaining the average effect across countries. Despite the relevance of this approach, empirical research on renewable energy consumption in the G20 has rarely combined the financial incumbency perspective with a heterogeneous panel estimator to examine whether the relationship between financial development and renewable energy differs from the results obtained using homogeneous estimators.

Based on these gaps, this study examines the relationship between country risk, financial development, and renewable energy consumption in 18 G20 countries over the period 1992–2021. The study specifically addresses whether the ICRG composite risk index provides sufficient information for explaining renewable energy consumption and whether financial development promotes or constrains renewable energy consumption in a highly heterogeneous G20 setting. The analysis employs the OLS Fixed Effects estimator as a baseline and the Mean Group estimator as the primary approach to explicitly account for slope heterogeneity across countries.

This study contributes to the literature in three ways. First, it provides empirical evidence on the financial incumbency hypothesis in the G20 by examining whether financial development continues to support renewable energy consumption when country-level heterogeneity is explicitly considered. Second, it evaluates the potential aggregation bias associated with the use of the ICRG composite risk index and highlights the importance of considering the distinct dimensions of country risk. Third, by comparing homogeneous and heterogeneous panel estimates, the study demonstrates the methodological importance of accounting for cross-country differences when analyzing the determinants of renewable energy consumption. The findings are expected to provide empirical implications for the design of financial and energy policies aimed at redirecting financial resources toward renewable energy and reducing structural dependence on fossil-based financing.

METHODS

This study used balanced panel data from 18 G20 countries, excluding Saudi Arabia because its renewable energy (hereafter NRE) consumption data were almost zero throughout the period, covering 1992–2021 and resulting in 540 observations (N = 18, T = 30). This period was selected to maximize the temporal depth required by the Mean Group Estimator to produce consistent estimates (Pesaran & Smith, 1995). It is acknowledged that excluding Saudi Arabia, as one of the world's largest oil-producing economies with a unique fossil-dominant financial system, may introduce sample-selection bias by omitting an extreme case of financial incumbency. This limitation is explicitly addressed in the Research Limitations section (Heckman, 1979).

The dependent variable is renewable energy consumption (renewable), measured as a percentage of total final energy consumption and sourced from the World Development Indicators (WDI) of the World Bank. This variable includes all NRE sources, such as hydropower, wind, solar, biomass, and geothermal energy, and therefore comprehensively represents the renewable energy mix.

The main independent variables consist of two groups. The first is composite risk (r_comp), based on the ICRG aggregate index, which assigns a 50% weight to political risk (0–100) and 25% each to economic risk (0–50) and financial risk (0–50), resulting in a total score of 0–100, where higher values indicate more stable conditions. The data were obtained from the University of Pennsylvania online library portal. The second is financial development (fd), measured using the IMF Financial Development Index (Svirydzenka ,2016), which incorporates the depth, accessibility, and efficiency of financial institutions and financial markets into a single integrated index (0–1).

The control variables include CO2 emissions per capita (co2e, tons) from WDI, used as a proxy for fossil-dependence intensity; the human capital index (hc) from the Penn World Table, referring to Psacharopoulos (1994), used as a proxy for technology adoption capacity; GDP per capita in natural logarithms (lngdp, constant 2015 USD) from WDI; and economic openness (open = (exports + imports)/GDP × 100) from WDI, used as a proxy for international trade integration.

Four diagnostic tests were performed before the main estimation. First, the Pesaran & Yamagata (2008) slope heterogeneity test was used to test the hypothesis H_0: $\beta_i = \beta$ (slope homogeneity). Rejection of H_0 justifies the use of MG over OLS FE. Second, the cross-sectional dependence (CSD) test used four statistics simultaneously: CD Pesaran (2015), CDw (Juodis & Reese), CDw+, and CD* Pesaran (2021), to identify the presence of global common factors affecting all countries simultaneously. Third, the stationarity tests used IPS Im et al. (2003) and PESCADF Pesaran (2007), both of which were selected because they are robust to strong CSD. Fourth, the multicollinearity test used the Variance Inflation Factor (VIF), with a threshold of VIF < 10.

Strong cross-sectional dependence detected through the CDw+ and CD* statistics was addressed through two complementary approaches: (1) the Mean Group Estimator, which produces consistent estimates in heterogeneous panels, even in the presence of common factors, by allowing full slope heterogeneity (Pesaran & Smith, 1995); and (2) the use of panel unit root tests (IPS and PESCADF) that are robust to cross-sectional dependence (Pesaran, 2007). Although augmented estimators such as CCEMG Pesaran (2006) and AMG Eberhardt & Bond (2009) would provide explicit corrections for common factors, their application is reserved as a follow-up robustness-test agenda, given the current study's focus on the MG-versus-OLS-FE comparison (Eberhardt & Teal, 2011).

This study uses two complementary estimators. First, the OLS Fixed Effects panel model is used as a baseline:

$$renewit = \alpha_1 + \beta_1 r\_comp_{it} + \beta_2 fd_{it} + \beta_3 co2eit + \beta_4 HC_{it} + \beta_5 lngdp_{it} + \beta_6 Open_{it} + \varepsilon_{it}$$

where α1 represents country fixed effects that absorb time-invariant unobserved characteristics. OLS FE is recognized as having a critical limitation: the assumption of slope homogeneity (β_i = β for all i), which, when violated, results in aggregation bias and inconsistent estimates, even in large samples (Robertson & Symons, 1992).

Second, the Mean Group Estimator (Pesaran & Smith, 1995) is used as the main estimator. This estimator estimates equation (1) separately for each country i and then takes the arithmetic mean of the coefficients: β_MG = (1/N) Σi β̂_i. By allowing full heterogeneity in slopes and intercepts, MG produces consistent estimates for sufficiently large N and T without requiring uniformity in the order of integration among variables (Eberhardt & Teal, 2011). Estimation was conducted using the xtmg command with the robust mg option in Stata 17.

RESULTS AND DISCUSSION

Results

Diagnostic Test Results

Table 1 presents the results of the diagnostic test. The Pesaran-Yamagata slope heterogeneity test rejected the slope homogeneity H0 very significantly (p = 0.000), confirming that the key OLS FE assumption was not met in this data. This is the main empirical justification for why MG is not OLS FE which is used as an inferential estimator.

Four CSD statistics consistently detect very strong cross-sectional dependencies. CDw+ = 379.12 and CD* = 4.16, both significant at the level of 1%, confirming the existence of strong global common factors affecting all 18 G20 countries simultaneously reflecting global energy shocks, international financial crises, and shared global climate commitments.

The stationarity test identified a mixture of I(0) and I(1): the renew, co2e, hc, and open variables are I (1) stationary after the first difference, while r_comp, fd, and lngdp are I (0). This integration mixture is not a problem for MG which does not require uniformity of integration orders, but requires attention to the potential for spurious regression which is mitigated through verification of residual stationarity. All VIF values were below threshold 10, confirming there were no serious multicollinearity problems.

Table 1

Summary of Diagnostic Test Results

Diagnostic Tests	Statistics	p-value	Conclusion
Slope Heterogeneity (Delta)	Significant	0.000***	Slope heterogeneous
CD (Pesaran, 2015)	0.97	0.333	Weak CSD
CDw (Juodis & Reese)	−2.68	0.007**	There is a CSD
CDw+ (Fan et al.)	379.12	0.000***	CSD strong
CD* (Pesaran, 2021)	4.16	0.000***	CSD strong
Stationarity (IPS & PESCADF)	Mix I(0)/I(1)	–	Valid MG
Maximum VIF	< 10 all variables	–	No problem

Source: Processed data. ***p<0.01, **p<0.05, *p<0.10. 3 out of 4 significant CSD stats → There is CSD

Comparison of OLS FE Results and Mean Group Estimator

Table 2 presents the results of the OLS Fixed Effects (column 1) and Mean Group Estimator (column 2) estimates side by side to facilitate direct comparisons and demonstrate the empirical consequences of aggregation bias.

Table 2

OLS Fixed Effects and Mean Group Estimator Estimation Results (Model 1)

Variable	OLS Fixed Effects	Mean Group Estimator

	Coef. (t-stat)	Coef. (t-stat)
Composite Risk (r_comp)	−0.008 (−0.08)	0.001 (0.03)
Financial Development (fd)	8.328 (1.32)	−4.433** (−2.02)
CO2 Emissions (co2e)	−1.871*** (−4.13)	−1.403*** (−3.86)
Human Capital (HC)	0.117 (0.004)	3.916 (1.23)
GDP per capita (lngdp)	-3.768* (−1.95)	0.450 (0.73)
Economic Openness (open)	0.061 (0.80)	0.005 (0.22)
Observation / Country	540 / 18	540 / 18

Note: t-statistics in parentheses. ***p<0.01, **p<0.05, *p<0.10. Dependent variable: renew (% of total final energy). Higher r_comp value = lower risk/more stable condition (ICRG scale 0–100). Coefficient values use period (.) as decimal separator. Source: research data processing results.

Discussion

Financial Incumbency Hypothesis: Key Findings

The most significant and most original finding in this study was the systematic reversal of the financial development sign (fd) from a statistically insignificant positive estimate in the OLS FE (β = 8.328, t = 1.32) to a significant negative estimate in MG (−4.433**, t = −2.02). This sign reversal is not a statistical artifact but rather a proper empirical manifestation of aggregation bias. Estimators that impose slope homogeneity on heterogeneous panels produce inconsistent estimates and can even fundamentally reverse the direction of influence (Robertson & Symons, 1992). This finding stands in contrast to studies such as Paramati et al. (2021), which identified a positive association between financial development and renewable energy consumption.

The divergence can be attributed to sample composition: these studies predominantly draw on developing and emerging market samples where financial systems are still growing and have not yet become structurally entrenched with fossil energy infrastructure. In contrast, the G20 sample in the present study includes highly developed financial systems (United States, United Kingdom, Germany, Japan) characterized by deep fossil-financing path dependencies, consistent with the financial incumbency hypothesis (Hondroyiannis et al., 2024). These results underscore the conditionality of the fd–NRE relationship: positive in contexts of nascent financial development, but negative in contexts of advanced financial system consolidation with fossil industries.

The MG coefficient −4.433** means that every 1 unit increase in the Financial Development Index is associated with a decrease in NRE consumption by 4.433 percent after controlling for all control variables and heterogeneity between countries. This confirms the validity of the financial incumbency hypothesis in the context of the G20: a highly developed financial system that is reflected in the depth of capital markets, credit accessibility, and high intermediation efficiency. In the context of the G20, it has been deeply consolidated with the existing fossil energy industry infrastructure, so that instead of channeling capital to the NRE sector, which is more environmentally productive, it maintains the orientation of conventional financing.

The mechanism of financial incumbency works through three main channels identified by (Battiston et al., 2017). First, historical portfolio concentration: G20 financial institutions have highly concentrated credit portfolios in the fossil energy sector after decades of financing, so massive reallocation to renewable energy will trigger significant mark-to-market losses. Second, asymmetry of information and expertise: financial institutions have deep expertise in assessing the risks of fossil assets but relatively lack of experience in assessing the risks of NRE projects, resulting in a disproportionately high-risk premium for NRE projects. Third, prudential regulation that is not climate-neutral: the Basel III/IV framework sets a risk weight based on historical data dominated by fossil asset performance, effectively providing a competitive advantage for fossil financing (Campiglio, 2016).

These findings correct the conclusions of Paramati et al. (2021) and Shahbaz et al. (2021) who found a positive association in a sample of developing countries, and confirm the conditionality identified by (Hondroyiannis et al., 2024). The fd-NRE relationship is sample-specific. Positive relations apply to developing countries with financial systems that are still growing and have not been consolidated with fossils, but have turned negative in the G20 where the financial system is already very established and consolidated. Firm policy implications: the development of the G20 financial sector must be accompanied by binding green regulatory instruments such as green taxonomy, sustainable finance framework, banking climate stress testing, and fiscal incentives for green bonds so that developing financial capacity can be directed to financing for the energy transition.

Composite Risk Bias Aggregation

Composite risk (r_comp) had no significant effect in either OLS FE (−0.008, t = −0.08) or MG (0.001, t = 0.03). The consistent insignificance in these two estimators makes an important methodological contribution to the literature: the use of a single composite risk index is insufficient to identify the influence of state risks on NRE consumption. Importantly, however, statistical insignificance alone is not sufficient grounds to conclude that the composite index is categorically inadequate as a construct. The insignificance observed here is more precisely interpreted as evidence of dimensionality collapse: the three-dimensional risk information (political, economic, financial) is compressed into a single scalar index whose weighting scheme (50% political, 25% economic, 25% financial) was not derived empirically from NRE determinants. When component dimensions exert heterogeneous effects on NRE, their algebraic summation within the composite index causes mutual neutralization of signals, rendering the resulting coefficient statistically undetectable (Erb et al., 1996). The appropriate methodological conclusion is therefore that future research should adopt dimensional decomposition of ICRG components, not that risk indices are inherently irrelevant to NRE outcomes.

The insignificance of composite risk reflects the aggregation problem inherent in the construction of the ICRG index as identified by (Erb et al., 1996)Erb. The composite index assigns 50% weight to political risk and 25% to economic and financial risk respectively. When the three risk dimensions have different directions and magnitudes of influence on NRE, as evidenced when the dimensions were analyzed individually in previous studies (Hondroyiannis et al., 2024). Combining in a single number causes different effects to negate each other and do not produce statistically detectable net signals. These findings provide a strong empirical justification for future research to adopt a risk-per-dimensional decomposition approach rather than relying on a single composite index.

CO2 Emissions as a Universal Barrier

CO2 (co2e) emissions are the only variable that exhibits negative and very significant perfect consistency at the level of 1% in both estimators (OLS FE: −1.871***, MG: −1.403***) of identical magnitudes. This consistency reflects two things. First, the effect of carbon lock-in on NRE transition barriers is robust to the choice of estimation method, different from fd which is sensitive to slope homogeneity assumptions. Second, the effect of CO2 emissions is homogeneous between countries, an increase in per capita emissions of 1 ton is related to a consistent decrease in NRE consumption by 1.403 percent in all 18 G20 countries.

These findings underscore the urgency of credible carbon pricing mechanisms as the most effective structural decarbonization instruments. The consistency of the negative influence of co2e confirms that deeper fossil dependencies are systematically hampering the NRE transition and that the only way to break this chain is through instruments that fundamentally alter structural incentives, not through incremental policies.

Contributions to International Scientific Discourse

This research resulted in three substantive contributions to the international scientific discourse on the determinants of the renewable energy transition. The first contribution is theoretical-empirical: this study provides consistent panel evidence on the applicability of the financial incumbency hypothesis in the G20 economy using heterogeneous estimators (MGs) that are methodologically superior to the dominant homogeneous estimators in the previous literature. Previous literature that has found the positive influence of financial development on NRE consumption is generally sourced from a sample of developing countries with financial systems that have not been consolidated with fossil energy infrastructure (Shahbaz et al., 2021). This study proves that the relationship is non-linear and sample-dependent: in G20 economies whose financial systems have reached an advanced stage of development and are structurally attached to the fossil industry, the direction of influence is reversed significantly (β = −4.433**). These findings extend the scope of financial incumbency theory to the realm of heterogeneous panel econometrics and strengthen the conditionality argument identified by Hondroyiannis et al. (2024) in the context of the OECD, while providing an empirical basis for the design of green finance regulations in countries with advanced financial systems.

The second contribution is methodological: this study provides the first empirical evidence of aggregation bias in the use of the ICRG composite risk index to predict NRE consumption in the G20 sample. Consistent composite risk insignificance in both estimators (OLS FE: −0.008, t = −0.08; MG: 0.001, t = 0.03) does not reflect the absence of the influence of state risk on NRE, but is a consequence of the aggregation of risk dimensions that have a heterogeneous direction and amount of influence so that they neutralize each other in a single index (Erb et al., 1996). This methodological contribution is relevant for the international community of researchers and policymakers who widely use the ICRG composite index as a proxy for state risk in the study of NRE investment determinants. The implications are operational: multilateral institutions such as the International Renewable Energy Agency and the Green Climate Fund that use aggregate risk metrics in the selection and de-risking process of NRE investments need to adopt a risk-by-dimensional decomposition approach so that the designed investment guarantee instruments can target the actual barrier mechanisms (IRENA, 2023).

The third contribution is cross-contextual: the consistency of the negative influence of CO2 emissions as a robust carbon lock-in proxy for estimator selection and insensitive to heterogeneity between G20 countries provides cross-cultural empirical evidence of the universality of structural barriers to the NRE transition. This consistency is significant internationally because the G20 sample covers a very broad spectrum of development, spanning advanced industrialized countries such as the United States, Japan, and Germany to large developing countries such as India, Brazil, and Indonesia, with very diverse energy policy traditions and institutional legacies. The fact that carbon lock-in operates consistently across these contexts indicates that these barriers are systemic and cannot be overcome through incremental policy approaches (Unruh, 2000). The international relevance of these findings directly supports the urgency of accelerating the implementation of a coordinated carbon pricing mechanism at the G20 level as recommended by the IEA (2023) and in line with the commitments of Just Energy Transition Partnerships (JETPs) that are being implemented in Indonesia, India, Vietnam, and South Africa, where an understanding of the structural rigidity of carbon lock-in is a prerequisite for the design of effective transition instruments.

Overall, the findings of this study contribute to the development of a richer analytical framework for understanding the determinants of NRE transition in institutionally diverse contexts. The heterogeneity of the coefficients between countries recorded in the MG estimate reflects path-dependent variations in institutional capacity, energy regulatory legacy, and the degree of consolidation of the financial system with fossil infrastructure in each country. Understanding the source of this heterogeneity has direct implications for the international scientific community, namely that one-size-fits-all models that ignore the specific institutional and historical context of each country will result in policy recommendations that are not on target (North, 1990). Thus, this research not only produces original empirical findings, but also sets a research agenda for international scientists to develop analytical approaches that are more sensitive to institutional heterogeneity in designing sustainable and equitable energy transition strategies.

Research Limitations

This research has several limitations that need to be explicitly acknowledged as part of academic integrity and to determine the limits of the validity of the findings. First, methodologically, the MG used did not incorporate explicit corrections to the significantly detected strong cross-sectional dependence (CDw+ = 379.12, $p < 0.001$). The existence of strong global common factors such as international energy price shocks, global financial crises, and multilateral climate agreements has the potential to cause the estimated MG coefficient to be biased if these factors are not explicitly filtered (Pesaran, 2006). The application of Common Correlated Effects Mean Group (CCEMG Pesaran (2006)) and Augmented Mean Group (AMG

Eberhardt & Bond (2009)) estimators represents a critical priority for follow-up research, as these estimators explicitly remove common factor influences through cross-sectional mean augmentation, producing more efficient and consistent coefficients under strong CSD conditions. Future studies replicating this analysis should adopt CCEMG and AMG as primary estimators rather than robustness checks, given the severity of the CSD detected (CDw+ = 379.12) which approaches the upper bounds of what standard MG can reliably accommodate (Eberhardt & Teal, 2011).

Second, in terms of sample coverage, Saudi Arabia's exclusion due to the absence of NRE consumption data throughout the observation period is a limitation that needs to be noted, considering that Saudi Arabia represents one of the largest fossil-based economies and financial systems with unique characteristics among G20 members. Furthermore, although the G20 accounts for more than 75 percent of global CO2 emissions, generalizing the findings of this study to countries outside the G20 sample, especially the least developed countries (LDCs) and small island developing states (SIDS) requires a high degree of precision. The economic structure, institutional capacity, and financial system conditions in the group of countries are fundamentally different from the G20 economy which is used as the basis for estimation. In fact, the group of countries that are most vulnerable to the impacts of climate change but have the greatest limitations in accessing NRE financing is a very relevant research subject for the just energy transition agenda at the global level, and further research that specifically examines the determinants of NRE consumption in these groups of countries is urgently needed.

Third, from a conceptual perspective, this study tested state risk through the ICRG composite index and concluded the existence of aggregation bias, but the research design did not include simultaneous testing of the decomposition of the three dimensions of risk (political, economic, and financial) in a single integrated model specification. This limitation is a consequence of a deliberate design to focus the analysis on methodological questions regarding the validity of composite indices, but the implication is that the specific transmission mechanism of each dimension of risk to NRE consumption in the context of the G20 has not been definitively identified. The study by Hondroyiannis et al. (2024) that tested all three dimensions simultaneously in the OECD sample is an important methodological precedent, but replication with the G20 sample using MG or CCEMG has not been carried out and is a significant research gap. Fourth, the use of the IMF's Financial Development Index as a measure of financial development, although comprehensive in covering the dimensions of depth, accessibility, and efficiency of financial institutions and markets (Svirydzenka, 2016), does not allow the identification of specific transmission channels of financial incumbent barriers. Whether the dominance of fossil finance is sourced from commercial banking, capital markets (bonds and equities), or certain structured financial instruments is an empirical question that is highly relevant to the design of targeted green finance regulations, and requires more granular financing data at the instrument level as a follow-up research agenda.

CONCLUSION

This study examines the determinants of renewable energy consumption in 18 G20 countries over the period 1992–2021 using OLS Fixed Effects as a baseline and the Mean Group (MG) estimator as the primary approach. The results confirm that financial development has a significant negative effect on renewable energy consumption in the MG estimation, providing empirical support for the financial incumbency hypothesis. This finding indicates that more advanced financial systems may remain structurally connected to fossil-based financing, thereby constraining the expansion of renewable energy. The study also finds that the ICRG composite country risk index has no significant effect on renewable energy consumption, suggesting that aggregating political, economic, and financial risk dimensions into a single index may obscure their individual effects. In contrast, CO_2 emissions have a consistently significant negative effect across both estimators, indicating that fossil-energy dependence represents a persistent structural barrier to renewable energy transition.

These findings highlight the importance of considering cross-country heterogeneity when assessing the determinants of renewable energy consumption. The comparison between OLS Fixed Effects and MG estimates demonstrates that imposing homogeneous slope coefficients can produce substantially different conclusions, particularly for financial development. Therefore, G20 policymakers should complement financial sector development with policies that redirect capital toward renewable energy, including green finance frameworks, climate-oriented financial regulation, and mechanisms that reduce fossil-fuel financing dependence. Future research should employ estimators that explicitly account for strong cross-sectional dependence, such as CCEMG or AMG, and examine the individual political, economic, and financial dimensions of country risk to identify more specific mechanisms underlying the renewable energy transition.

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AUTHOR CONTRIBUTION STATEMENT

Wahyu Nugroho: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft. Rossanto Dwi Handoyo: Supervision, Validation, Funding Acquisition. Both authors have read and approved the final version of the manuscript. The authors stated that there was no conflict of interest.

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