De-risking the transition: Architecting cross-sectoral governance sandboxes for grid-scale renewable energy in developing states

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Abstract: The transition to grid scale renewable energy in developing states remains constrained by fragmented regulatory systems, policy uncertainty, and weak institutional coordination across sectors responsible for energy, environment, finance, and infrastructure. This study examines the role of cross sectoral governance sandboxes as institutional platforms that allow regulators, private investors, and public agencies to test new policy instruments and regulatory approaches within a controlled setting. The study is guided by the Multi-Level Governance framework which explains the interaction of institutions, policy actors, and regulatory authority across multiple layers of government and sectors. A mixed methods research design was adopted which combined survey responses from 280 stakeholders drawn from energy ministries, regulatory agencies, private energy developers, and financial institutions with semi structured interviews and policy document review. Quantitative data were analyzed using Structural Equation Modeling with the aid of SmartPLS while qualitative evidence was examined through thematic analysis. Findings reveal three critical governance failures. Regulatory rigidity continues to block experimental policy learning within energy institutions. Institutional rivalry across sectoral regulators produces fragmented decision making that weakens investor confidence. Policy pilots often remain symbolic exercises with little transition to national energy systems. The study recommends the creation of legally protected experimental regulatory zones for renewable energy projects, the establishment of a central cross sector energy coordination authority, and the adoption of mandatory policy scaling frameworks that convert successful sandbox experiments into enforceable national energy regulations..

Keywords: : governance sandboxes, renewable energy governance, grid scale renewable energy, multi-level governance, regulatory innovation, developing states.

Introduction

Grid-scale renewable energy has become central to global decarbonization and energy security efforts. According to the International Energy Agency (IEA, 2023), renewables accounted for about 30%

of global electricity generation in 2022. However, developing countries receive less than 15% of global renewable energy investment, reflecting persistent structural and institutional constraints..

In Africa, renewable energy development remains limited despite vast natural potential. The International Renewable Energy Agency (IRENA, 2023) reports that Africa contributes only about 2% of global installed renewable energy capacity. This gap is driven more by governance and institutional weaknesses than resource availability.

Nigeria reflects these broader structural challenges. The country has an installed electricity capacity of about 12–13 GW, but actual generation often falls below 5 GW due to infrastructure and operational inefficiencies (World Bank, 2023). Although the Energy Transition Plan provides a policy direction for cleaner energy investment, implementation remains constrained by regulatory uncertainty and weak institutional coordination (Federal Government of Nigeria, 2022).

Investment risk remains a major barrier to renewable energy expansion. Regulatory inconsistency, fragmented institutional arrangements, and weak coordination across agencies increase uncertainty for investors. The World Bank (2023) identifies regulatory risk as one of the most significant barriers to renewable energy investment in Sub-Saharan Africa. In Nigeria, these risks are intensified by overlapping mandates and limited policy learning mechanisms.

Emerging governance approaches such as policy experimentation and regulatory coordination are increasingly proposed as solutions. Policy experimentation allows governments to test regulatory reforms before scaling them nationally, thereby reducing uncertainty and improving learning in complex governance systems (Kemp et al., 1998; He et. al., 2022; Feser et. al., 2024). Regulatory coordination enhances alignment among institutions and reduces duplication in decision-making processes.

Despite these developments, empirical evidence on how regulatory coordination and policy experimentation jointly influence renewable energy investment risk remains limited in Nigeria. Existing studies largely focus on financing constraints, infrastructure deficits, and general policy challenges (Oyedepo, 2012; Adeshina et. al., 2024; Wali et. al., 2026), with limited attention to institutional mechanisms that shape investor confidence and risk reduction.

This study examines de-risking in grid-scale renewable energy investment in Nigeria, focusing on how regulatory coordination and policy experimentation influence investment risk and uncertainty. It also assesses the combined effect of both mechanisms on investor confidence and renewable energy deployment. The study is significant because it provides empirical evidence on governance-based risk reduction in renewable energy systems. It offers practical insights for policymakers, regulators, and investors on how institutional coordination and policy experimentation can be used to improve investment conditions. The findings are expected to support efforts aimed at accelerating renewable energy transition in developing economies.

Methods

Research design

A mixed-methods research design was adopted to examine how regulatory coordination and policy experimentation influence investment risk in grid-scale renewable energy in Nigeria. The design was considered appropriate because it combines measurable empirical evidence with contextual institutional insights, allowing for a more comprehensive understanding of governance processes in the sector.

The quantitative component relied on a survey design to capture stakeholders' perceptions of regulatory coordination, policy experimentation, and investment risk. The qualitative component used in-depth interviews to explore institutional experiences, regulatory interactions, and practical challenges affecting renewable energy investment. This dual approach aligns with the study's conceptual focus on governance mechanisms as key determinants of investment risk.

Population and sample

The population comprised key stakeholders involved in renewable energy governance and investment in Nigeria. These included officials from relevant federal ministries, regulatory agencies, and public institutions, as well as private sector actors such as renewable energy developers and financial institutions.

The study covered institutions such as the Federal Ministry of Power, Federal Ministry of Environment, Nigerian Electricity Regulatory Commission (NERC), Rural Electrification Agency

(REA), Energy Commission of Nigeria (ECN), Nigerian Investment Promotion Commission (NIPC), selected renewable energy firms, and financial institutions. This ensured coverage of both regulatory and market-side actors within the renewable energy ecosystem.

A total of 300 respondents were selected for the quantitative survey using purposive and stratified sampling techniques to ensure representation across regulatory, policy, technical, and investment-related roles. In addition, 30 key informants were purposively selected for qualitative interviews, including senior policymakers, regulatory officials, project developers, energy experts, and financial sector actors with direct involvement in renewable energy investment decisions.

Justification for selection of stakeholder groups

The selection of stakeholder groups was guided by the multi-actor nature of renewable energy governance in Nigeria. Investment outcomes in grid-scale renewable energy are shaped by interactions among policy institutions, regulatory bodies, implementing agencies, investors, and financiers.

Ministries were included because they provide policy direction and strategic oversight in the energy, environment, and financial sectors. Regulatory agencies such as NERC were included due to their central role in licensing, tariff regulation, and compliance enforcement, all of which directly affect investor confidence. Implementation agencies such as REA and ECN were included because they translate policy into operational programmes.

Private renewable energy firms were included as primary project developers, providing insights into regulatory bottlenecks, project execution challenges, and market realities. Financial institutions were included because they assess project bankability and are highly sensitive to regulatory uncertainty and institutional risk.

This structure ensured that the study captured both governance and investment perspectives, strengthening triangulation and improving the validity of findings.

Conceptual and theoretical basis of the method

The study was guided by a conceptual framework that positions regulatory coordination and policy experimentation as key determinants of investment risk in grid-scale renewable energy. Regulatory fragmentation, policy inconsistency, and weak inter-agency collaboration are conceptualized as increasing investment risk, while coordination and experimentation are expected to reduce uncertainty and improve predictability.

The study was also informed by the Multi-Level Governance (MLG) framework, which explains how policy outcomes in complex sectors are shaped by interactions across multiple institutional levels and actors. In the context of renewable energy, this includes coordination between federal ministries, regulatory agencies, implementing bodies, and private sector stakeholders.

The core logic of the framework is that:

regulatory coordination reduces fragmentation and improves policy consistency,

policy experimentation supports learning and reduces uncertainty,

both mechanisms jointly contribute to investment risk reduction.

Data sources

Data were obtained from primary quantitative and qualitative sources. Quantitative data were collected using structured Likert-scale questionnaires administered through electronic platforms and physical distribution across selected institutions. The instrument captured perceptions of regulatory coordination, policy experimentation, institutional effectiveness, and investment risk.

Qualitative data were collected through semi-structured in-depth interviews to explore governance processes, regulatory challenges, coordination dynamics, and investment-related experiences in greater depth.

Data collection procedure

Questionnaire items were developed directly from the study objectives and operational variables derived from the conceptual framework. The instrument captured indicators of regulatory coordination, policy experimentation, and investment risk.

In-depth interview questions were designed to complement the survey by capturing institutional experiences, regulatory interactions, and practical governance challenges not easily captured through structured instruments.

Prior to data collection, respondents were informed about the purpose of the study. Informed

consent was obtained, participation was voluntary, and confidentiality was strictly maintained throughout the process.

Data analysis

Quantitative data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize respondents' perceptions.

Prior to inferential analysis, principal component analysis (PCA) was applied to the observed indicators of regulatory coordination, policy experimentation, and investment risk to generate composite index scores for each construct. These index variables were then used for further analysis.

The relationship between variables was examined using structural equation modelling (SEM) in STATA 17. The analysis was conducted in two stages. First, measurement validity was assessed using factor loadings and standard model fit indices. Second, the structural model was estimated to determine the effects of regulatory coordination and policy experimentation on investment risk.

Model fit was assessed using Chi-square statistics, RMSEA, CFI, TLI, and SRMR. Results were interpreted using standardized coefficients, z-values, and p-values.

Qualitative analysis

Qualitative data from the 30 key informant interviews were transcribed verbatim and analyzed thematically. Key themes included regulatory coordination, institutional fragmentation, policy experimentation, investment risk, and governance effectiveness. These themes were used to explain and contextualize the quantitative results.

Integration of findings

Findings from quantitative and qualitative components were integrated during interpretation. While the survey and SEM results provided statistical relationships among variables, the interview data explained the institutional mechanisms behind these relationships. This ensured triangulation and a more comprehensive understanding of governance effects on investment risk.

Validity and reliability

Instrument validity was ensured through pre-testing with 40 respondents drawn from relevant institutions. The interview guide was also pre-tested with selected experts to ensure clarity and relevance.

Reliability was assessed using Cronbach's alpha, with all constructs exceeding 0.80, indicating strong internal consistency. Construct validity was further supported through the measurement model assessment within the SEM framework.

Ethical considerations

The study adhered to established ethical research standards. Participation was voluntary, informed consent was obtained from all respondents, and confidentiality was guaranteed. Respondents were also assured of anonymity and their right to withdraw from the study at any stage without consequences.

Results

The results in Table 1 present the demographic characteristics of the respondents involved in the study. The gender distribution shows that 59.7% of respondents were male, while 40.3% were female. This indicates a male-dominated sample, which reflects the broader structure of the energy and infrastructure sectors in Nigeria.

The age distribution reveals that 39.0% of respondents were between 30 and 39 years. This is followed by 24.7% within the 40–49 age group and 22.0% below 30 years. Only 14.3% were above 49 years, suggesting that the majority of participants are within the active and mid-career workforce.

In terms of institutional affiliation, 26.3% of respondents were drawn from private renewable energy firms. This is closely followed by 24.0% from government agencies and 19.3% from ministries. Financial institutions accounted for 18.3%, while 12.0% were from the regulatory commission (NERC). This distribution shows balanced representation across policy, regulatory, implementation, and investment actors.

The educational profile indicates that most respondents are highly educated. About 49.7% hold a master's degree, while 30.7% possess a BSc/HND. Respondents with PhDs account for 19.7%, demonstrating a strong presence of advanced expertise within the sample.

The distribution of years of experience shows that 37.0% of respondents have between 6 and 10

years of experience. This is followed by 25.3% with 11–15 years and 22.3% with 1–5 years of experience. Only 15.3% have more than 15 years of experience, indicating a workforce largely composed of mid-level professionals.

Table 1 Frequencies and percentages for the demographic characteristics of respondents

Respondent characteristics	Response category	Frequency	Percentage
Sex	Male	179	59.7
	Female	121	40.3
	Total	300	100.0
Age	Below 30	66	22.0
	30–39	117	39.0
	40–49	74	24.7
	Above 49	43	14.3
	Total	300	100.0
Institutional affiliation	Ministries	58	19.3
	Agencies	72	24.0
	Regulatory Commission (NERC)	36	12.0
	Private renewable firms	79	26.3
	Financial institutions	55	18.3
	Total	300	100.0
Educational qualification	BSc/ HND	92	30.7
	MSc	149	49.7
	PhD	59	19.7
	Total	300	100.0
Years of experience	1–5 years	67	22.3
	6–10 years	111	37.0
	11–15 years	76	25.3
	Above 15 years	46	15.3
	Total	300	100.0

Extent of regulatory and institutional risks affecting renewable energy investment

The findings indicate a consistently high perception of regulatory risk in grid-scale renewable energy investment in Nigeria. Specifically, 70.0% of respondents agreed that regulatory policies change frequently, while 70.7% reported a lack of clear regulatory guidelines. In addition, 73.3% indicated that licensing and approval processes are complex, 67.6% reported unpredictable tariff structures, and 70.7% confirmed inconsistent regulatory decisions. This suggests that regulatory uncertainty is widely experienced across the sector.

The results also show strong evidence of institutional risk. A total of 69.7% of respondents reported poor coordination among institutions, while 71.6% indicated overlapping institutional mandates. Similarly, 69.4% reported inter-agency conflicts that delay projects, 72.0% observed fragmented decision-making processes, and 67.7% confirmed weak institutional capacity. This reflects persistent governance and coordination challenges within the renewable energy ecosystem.

Having examined the indicators individually, the results suggest that regulatory and institutional weaknesses are widely perceived as major constraints affecting investment conditions in Nigeria's renewable energy sector. The high proportion of agreement across most items indicates that these challenges are not isolated but systemic and interconnected in nature.

Qualitative evidence from in-depth interviews further supports these findings.

A senior official from a regulatory agency explained:

"Policies change too often, and investors are constantly trying to adjust to new requirements in licensing

and tariffs." (KII 3)

A private sector developer noted:

"The approval process is not predictable. Sometimes projects are delayed without clear reasons or timelines." (KII 8)

On institutional issues, a government respondent stated:

"Different agencies operate separately, and this lack of coordination slows down project approvals significantly." (KII 5)

A financial sector participant added:

"When institutions are not aligned, it increases uncertainty, and this affects how we assess project risks." (KII 14)

Another private sector developer elaborated:

"In reality, we deal with multiple institutions that do not communicate effectively with each other. Sometimes one agency approves a step, but another agency requests additional documentation for the same process. This repetition not only delays projects but also increases administrative costs significantly." (KII 9)

An energy expert observed:

"There is still weak institutional capacity, and this limits how effectively policies are implemented on the ground." (KII 19)

Another energy expert added:

"Decision-making is not streamlined. Responsibilities overlap in several areas and this creates ambiguity about who has final authority. In some cases, this leads to delays simply because institutions are waiting for each other to act first." (KII 12)

The qualitative evidence buttresses the quantitative results by showing that regulatory instability and institutional fragmentation jointly contribute to heightened investment risk.

Table 2: Frequencies (Percentages) and Mean (Standard deviation) for the extent of regulatory and institutional risks affecting renewable energy investment

Factors affecting renewable energy investment	Frequency (percentage)				Mean (SD)
	Very Low extent	Low extent	High extent	Very high extent	
Regulatory factors					
Frequent changes in regulatory policies	32 (10.7)	58 (19.3)	124 (41.3)	86 (28.7)	2.88 (0.94)
Lack of clear regulatory guidelines	27 (9.0)	61 (20.3)	129 (43.0)	83 (27.7)	2.90 (0.91)
Complex licensing and approval processes	25 (8.3)	55 (18.3)	132 (44.0)	88 (29.3)	2.94 (0.89)
Unpredictable tariff structures	34 (11.3)	63 (21.0)	121 (40.3)	82 (27.3)	2.84 (0.96)
Inconsistent regulatory decisions	29 (9.7)	59 (19.7)	128 (42.7)	84 (28.0)	2.89 (0.92)
Institutional factors					
Poor coordination among institutions	31 (10.3)	60 (20.0)	126 (42.0)	83 (27.7)	2.87 (0.93)
Overlapping institutional mandates	28 (9.3)	57 (19.0)	130 (43.3)	85 (28.3)	2.91 (0.90)
Inter-agency conflicts delaying projects	30 (10.0)	62 (20.7)	125 (41.7)	83 (27.7)	2.87 (0.93)
Fragmented decision-making processes	26 (8.7)	58 (19.3)	131 (43.7)	85 (28.3)	2.92 (0.89)
Weak institutional capacity	33 (11.0)	64 (21.3)	120 (40.0)	83 (27.7)	2.86 (0.95)

Effect of regulatory coordination and policy experimentation on investment risk in grid-scale renewable energy in Nigeria

To be able to do the analysis, we applied the principal component analysis (PCA) on the variables patterning to regulatory coordination, policy experimentation and investment risk to generate one single index variable for each indicator. The descriptive statistics of the questionnaire items used to create each index is attached as Supplementary file I.

The results show that regulatory coordination has a negative and statistically significant effect on investment risk (β = -0.389, z = -6.75, $p < 0.001$; CI: -0.531 to -0.293). This implies that stronger coordination among institutions reduces uncertainty and improves investment conditions. Policy experimentation also has a negative and significant effect (β = -0.271, z = -5.14, $p < 0.001$; CI: -0.412 to -0.184), indicating that mechanisms such as pilot projects and regulatory sandboxes help to lower perceived investment risk.

The overall model fit is acceptable. Although the Chi-square (χ^2) value is marginally significant ($\chi^2 = 3.87$, $p = 0.049$), other fit indices support the model. The root mean square error of approximation (RMSEA = 0.062), Comparative fit index (CFI = 0.961), Tucker–Lewis index (TLI = 0.942), and standardized root mean square residual (SRMR = 0.031) all indicate good fit. These results suggest that the model adequately represents the relationships among the variables.

The model explains 52% of the variation in investment risk ($R^2 = 0.52$), showing moderate to strong explanatory power. This means that regulatory coordination and policy experimentation play a substantial role in shaping investment risk (see Table 3).

Qualitative evidence from in-depth interviews further supports these findings. A senior official from a regulatory agency explained:

"When regulatory processes are better coordinated, investors are not confronted with conflicting directives. It creates a more predictable environment, and that directly reduces the level of risk associated with project execution." (KII 3)

A government respondent stated:

"Different agencies operate separately, but when coordination improves, approvals become faster and more structured. This reduces delays and gives investors more confidence in the system." (KII 5)

A private sector developer noted:

"The approval process becomes easier to navigate when institutions align their requirements. Without that alignment, uncertainty increases, but coordination helps to stabilize expectations." (KII 8)

Another private sector developer elaborated:

"In practice, when agencies begin to share information and streamline their processes, we spend less time dealing with duplication. That reduction in administrative burden directly lowers project risk." (KII 9)

A financial sector participant added:

"When institutions are coordinated, it improves how we assess risk because there is more clarity and consistency in regulatory processes. This makes investment decisions less uncertain." (KII 14)

On policy experimentation, an energy expert observed:

"Pilot projects provide an opportunity to test policies before full implementation. This helps identify potential challenges early and reduces the uncertainty that investors usually face." (KII 19)

Another energy expert added:

"Regulatory sandboxes allow controlled experimentation, and this gives both regulators and investors room to understand what works. It reduces the fear of unexpected policy changes." (KII 12)

An additional private sector respondent emphasized:

"When policies are tested through pilot phases, it builds confidence because investors can see practical outcomes rather than relying on assumptions. This makes long-term planning more reliable." (KII 20)

Table 3: Structural equation model results on effects of regulatory coordination (RC) and policy experimentation (PE) on investment risk (N = 300)

Path / fit measure	Coefficient	Std. Error	z-value	p-value	95% Confidence Interval
RC → IR	-0.389***	0.061	-6.75	0.000	-0.531, -0.293
PE → IR	-0.271***	0.058	-5.14	0.000	-0.412, -0.184
Chi-square (df = 1)	3.87				
Model p-value	0.049				
RMSEA	0.062				
CFI	0.961				
TLI	0.942				
SRMR	0.031				
R^2	0.52				

*** = *significant at 5%*

Combined effect of regulatory coordination and policy experimentation on de-risking grid-scale renewable energy investment in Nigeria

The combined effect of regulatory coordination and policy experimentation on investment risk in grid-scale renewable energy is evident in the overall explanatory power of the model. The results show that both regulatory coordination and policy experimentation jointly explain 52% of the variation in investment risk ($R^2 = 0.52$), indicating a moderate to strong level of explanatory power. This suggests that investment risk in the sector is substantially shaped by the interaction of governance structures and experimental policy approaches operating within the same institutional environment (see Table 3).

The results indicate that the two governance mechanisms operate as a complementary institutional system for reducing investment risk. Regulatory coordination enhances predictability and reduces fragmentation in decision-making processes, while policy experimentation supports learning and reduces uncertainty through controlled policy testing. When operating together within the same governance framework, these mechanisms strengthen investor confidence by improving both institutional coherence and adaptive capacity. However, the model also suggests that a substantial proportion of variation in investment risk is influenced by other contextual and structural factors not captured in the current specification.

Findings from in-depth interviews conducted with key informants indicate that investment risk reduction is strongest where regulatory coordination and policy experimentation operate together as a unified governance approach rather than as separate mechanisms.

A senior official from a regulatory agency noted:

"The real shift happens when coordination across agencies is matched with controlled experimentation. It is the combination that allows us to reduce uncertainty while still adapting policies based on real implementation feedback." (KII 3)

A policy advisor in a federal ministry explained:

"Coordination ensures that government speaks with one voice, but experimentation ensures that we are not locked into rigid frameworks. Together, they create a governance balance that reduces investor hesitation." (KII 6)

A private sector developer observed:

"From our experience, risk is significantly reduced when there is both policy consistency across institutions and room to test how those policies actually work in practice. One without the other is not enough." (KII 9)

A financial analyst stated:

"Investment risk becomes manageable when regulatory clarity is combined with evidence from pilot projects. Coordination gives structure, while experimentation provides assurance that policies are not just theoretical." (KII 12)

An energy commission official added:

"We have seen better investment outcomes where agencies coordinate licensing and approvals while also allowing experimental policy tools like pilot schemes. It reduces uncertainty at multiple levels." (KII 15)

A renewable energy consultant explained:

"What really matters is not just having coordinated institutions or experimental policies, but how both reinforce each other. Coordination reduces fragmentation, while experimentation reduces fear of unknown policy outcomes." (KII 18)

A senior government respondent noted:

"When coordination is weak, experimentation becomes confusing for investors. But when both are aligned, it creates a structured learning environment that supports investment confidence." (KII 21)

A development finance officer stated:

"The combination of institutional alignment and policy testing improves our willingness to finance projects because it signals both stability and adaptability in the system." (KII 24)

A private sector energy developer further remarked:

"We are more comfortable investing when we see that agencies are working together and policies are being tested before full rollout. That combination reduces unexpected policy shocks." (KII 27)

A regulatory economist concluded:

"The strongest de-risking effect comes from the interaction between coordinated governance and experimental policy design. It creates a system where uncertainty is both managed and gradually reduced through learning." (KII 30)

The qualitative evidence demonstrates that investment risk is most effectively reduced when regulatory coordination and policy experimentation function as complementary components of a unified governance system. This buttresses the quantitative result, which shows that both mechanisms jointly explain a substantial proportion of variation in investment risk ($R^2 = 0.52$), highlighting the importance of integrated governance approaches in de-risking renewable energy investment in Nigeria.

Discussion

This study examined the extent of regulatory and institutional risks affecting renewable energy investment, as well as the influence of regulatory coordination and policy experimentation on investment risk in Nigeria. Our result shows that governance-related factors play a central role in shaping investment conditions within the renewable energy sector.

The findings revealed a consistently high perception of regulatory risk, particularly in relation to policy instability, unclear guidelines, complex licensing, and tariff unpredictability. This supports earlier studies which identified regulatory uncertainty as a major barrier to renewable energy investment in developing countries (Painuly, 2001; Poudineh, Sen, & Fattouh, 2018). These studies argue that inconsistent policies and weak regulatory clarity increase transaction costs and discourage long-term investment. However, this contrasts with Polzin et al. (2015), who found that stable and credible policy frameworks can mitigate investment risk even in less developed markets. The implication is that while policy design matters, consistency and credibility remain critical gaps in the Nigerian context.

The study also found strong evidence of institutional risk, particularly weak coordination, overlapping mandates and fragmented decision-making processes. This aligns with Sovacool (2009), who highlighted institutional inefficiencies as key constraints to renewable energy deployment. Similarly, Lema, Berger, and Schmitz (2013) found that weak institutional alignment undermines policy implementation and slows sectoral transformation. In contrast, Newell and Phillips (2016) suggest that institutional diversity can support innovation when effectively coordinated. The present findings indicate that in Nigeria, the lack of coordination limits such benefits and instead contributes to delays and inefficiencies.

Beyond individual factors, the results show that regulatory and institutional risks are interconnected and jointly shape investment conditions. This supports the broader institutional perspective that economic outcomes are influenced by the interaction of multiple governance structures rather than isolated factors (North, 1990; Hall & Soskice, 2001). The findings therefore suggest that fragmented reforms targeting single constraints may not be sufficient to improve investment conditions in the renewable energy sector.

The results further revealed that regulatory coordination has a negative and statistically significant effect on investment risk. This is consistent with Andrews, Beynon, and McDermott (2016), who found that coordinated institutional systems improve policy effectiveness and reduce uncertainty. Similarly, Ostrom (2010) emphasized that coordinated governance enhances collective action and institutional performance in complex systems. The qualitative evidence in this study supports this position, showing that improved alignment among agencies reduces conflicting directives and enhances predictability for investors.

Policy experimentation was also found to significantly reduce investment risk. This finding

supports Rodrik (2008), who argues that experimentation allows policymakers to test and refine reforms in uncertain environments. In the same vein, Sabel and Zeitlin (2012) show that experimental governance promotes learning and adaptability in policy implementation. However, some studies caution that poorly designed experimentation may introduce additional uncertainty (Greenstone, 2009). The present findings suggest that when properly implemented, policy experimentation contributes to reducing uncertainty and improving investor confidence.

The combined effect of regulatory coordination and policy experimentation shows that both factors jointly explain a substantial proportion of variation in investment risk. This supports the complementarities perspective, which emphasizes that governance mechanisms are more effective when they operate together rather than in isolation (Aoki, 2001). Empirical support is also found in Meckling, Kelsey, Biber, and Zysman (2015), who demonstrate that policy mixes combining stability and flexibility are more effective in driving energy investments. The findings therefore indicate that coordinated and adaptive governance systems are critical for de-risking renewable energy investment in Nigeria.

A major strength of this study lies in its mixed-methods design, which enabled triangulation between survey findings, structural equation modelling results, and in-depth interviews. This strengthened the credibility and interpretive depth of the findings. However, some limitations should be acknowledged. The reliance on self-reported survey data may introduce perception bias, while the focus on selected ministries, agencies, and private sector actors may limit generalizability. Future studies may adopt longitudinal designs and comparative cross-country analyses to better understand how governance mechanisms influence renewable energy investment risk over time.

Conclusion

This study examined the extent of regulatory and institutional risks affecting grid-scale renewable energy investment in Nigeria, with emphasis on how regulatory coordination and policy experimentation shape investment risk. Regulatory instability, unclear policy guidelines, complex licensing procedures, and unpredictable tariff structures continue to define the investment environment, while institutional weaknesses such as poor coordination among agencies, overlapping mandates, inter-agency conflicts, and fragmented decision-making further intensify these risks.

Evidence indicates that regulatory coordination reduces investment risk by improving consistency in policy implementation, strengthening inter-agency alignment, and reducing fragmentation in regulatory processes. Policy experimentation contributes by enabling structured learning, testing policy options in controlled environments, and reducing uncertainty associated with implementation outcomes.

The combined governance structure shows a stronger effect, where investment risk is more effectively reduced when coordination mechanisms operate alongside experimental policy approaches. This interaction reflects a system in which institutional alignment provides stability while policy experimentation introduces adaptability, jointly improving predictability for investors in the renewable energy sector.

Attention to renewable energy investment in Nigeria therefore points to the need for governance arrangements that integrate institutional coordination with adaptive policy design. Strengthening regulatory coherence, improving inter-agency collaboration, and expanding structured policy experimentation remain central to reducing investment risk and improving investor confidence in the sector.

References

Adeshina, M. A., Ogunleye, A. M., Suleiman, H. O., Yakub, A. O., Same, N. N., Suleiman, Z. A., & Huh, J.-S. (2024). Frompotential to power: Advancing Nigeria ' s energy sector through renewable integration and policy reform.Sustainability, 16(20), 8803. https://doi.org/10.3390/su16208803

Andrews, R., Beynon, M. J., & McDermott, A. M. (2016). Organizational capability in the public sector: A configurational approach. Journal of Public Administration Research and Theory, 26(2), 239–258. https://doi.org/10.1093/jopart/muv005

Aoki, M. (2001). Toward a comparative institutional analysis. MIT Press.

Federal Government of Nigeria. (2022). Nigeria energy transition plan. Abuja: Energy Transition Office. https://energytransition.gov.ng

Feser, D., Winkler-Portmann, S., Bischoff, T. S., Bauknecht, D., Bizer, K., Führ, M., Heyen, D. A., Proeger, T., von

der Leyen, K., & Vogel, M. (2024). Institutional rules for the up-take of regulatory experiments: A comparative case study. Futures, 156, 103318. https://doi.org/10.1016/j.futures.2024.103318
Greenstone, M. (2009). Toward a culture of persistent regulatory experimentation and evaluation. In D. Moss & J. Cisternino (Eds.), New perspectives on regulation (pp. 111–126). Harvard Kennedy School.
Hall, P. A., & Soskice, D. (2001). Varieties of capitalism: The institutional foundations of comparative advantage. Oxford University Press.
He, A. J., Fan, Y., & Su, R. (2022). Seeking policy solutions in a complex system: Experimentalist governance in China's healthcare reform. Policy Sciences, 55(4), 755–776. https://doi.org/10.1007/s11077-022-09482-2
International Energy Agency. (2023). Renewables 2023: Analysis and forecast to 2028. https://www.iea.org/reports/renewables-2023
International Renewable Energy Agency. (2023). World energy transitions outlook 2023: 1.5°C pathway. https://www.irena.org/publications/2023/Jun/World-Energy-Transitions-Outlook-2023
Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. Technology Analysis & Strategic Management, 10(2), 175–198. https://doi.org/10.1080/09537329808524310
Lema, R., Berger, A., & Schmitz, H. (2013). China's impact on the global wind power industry. Journal of Current Chinese Affairs, 42(1), 37–69. https://doi.org/10.1177/186810261304200103
Meckling, J., Kelsey, N., Biber, E., & Zysman, J. (2015). Winning coalitions for climate policy. Science, 349(6253), 1170–1171. https://doi.org/10.1126/science.aab1336
Newell, P., & Phillips, J. (2016). Neoliberal energy transitions in the South: Kenyan experiences. Geoforum, 74, 39–48. https://doi.org/10.1016/j.geoforum.2016.05.009
North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge University Press.
Ostrom, E. (2010). Beyond markets and states: Polycentric governance of complex economic systems. American Economic Review, 100(3), 641–672. https://doi.org/10.1257/aer.100.3.641
Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: The way forward. Energy, Sustainability and Society, 2(15), 1–17. https://doi.org/10.1186/2192-0567-2-15
Painuly, J. P. (2001). Barriers to renewable energy penetration: A framework for analysis. Renewable Energy, 24(1), 73–89. https://doi.org/10.1016/S0960-1481(00)00186-5
Polzin, F., Migendt, M., Täube, F. A., & von Flotow, P. (2015). Public policy influence on renewable energy investments—A panel data study across OECD countries. Energy Policy, 80, 98–111. https://doi.org/10.1016/j.enpol.2015.01.026
Poudineh, R., Sen, A., & Fattouh, B. (2018). Advancing renewable energy in resource-rich economies of the MENA. Oxford Institute for Energy Studies Paper.
Rodrik, D. (2008). Second-best institutions. American Economic Review Papers & Proceedings, 98(2), 100–104. https://doi.org/10.1257/aer.98.2.100
Sabel, C. F., & Zeitlin, J. (2012). Experimentalist governance. In D. Levi-Faur (Ed.), The Oxford handbook of governance (pp. 169–183). Oxford University Press.
Sovacool, B. K. (2009). The cultural barriers to renewable energy and energy efficiency in the United States. Technology in Society, 31(4), 365–373. https://doi.org/10.1016/j.techsoc.2009.10.009
Wali, H. N., Dutta, T., Umar, M., & Fuad, U. (2026). A critical review of Nigeria's energy sector: Sources, policies and electricity market. Cogent Economics & Finance, 14(1), Article 2639684. https://doi.org/10.1080/23322039.2026.2639684
World Bank. (2023). Nigeria energy sector overview: Power sector recovery and resilience. https://www.worldbank.org/en/country/nigeria