TOWARDS NET-ZERO ENERGY 2060:
Fiscal Vulnerability and Energy Transition in Nigeria

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ABSTRACT

Nigeria's journey towards net-zero energy emissions by 2060 is emblematic of the contemporary global narrative. Moreover, the interplay between fiscal dynamics and energy transition strategies plays a major role in a prosperous economy and a sustainable future. Specifically, grounded in the Porter-Drewello energy transition framework, this research investigates the nexus between fiscal vulnerability and energy transition in Nigeria. Employing the quantile regression methodology and vector autoregressive models, the research dissects the impact of fiscal vulnerability on energy transition, scrutinizing quarterly data from 2000q1 to 2021q4. The findings delineate that fiscal vulnerability exerts a significant negative effect on energy transition, particularly at median and higher quantiles. Additionally, the interplay between fiscal vulnerability and institutional quality is explored, emphasizing the role of institutional quality as a catalyst for renewable energy *integration in the quest for energy transition. Key policy recommendations of the study underscore the role of strong fiscal institutions, renewable energy investments, energy efficiency, and institutional frameworks in mitigating the negative effects of fiscal vulnerability on energy transition.*

Keywords: Energy Transition, Fiscal Vulnerability, Climate Change, Environment, Sustainability

JEL classification: H12, O13, Q48

1. Introduction

In the current age of climate change amid other global challenges, the call to attain net-zero energy emissions by 2060 stands as a clarion call that resonates across borders and disciplines. The energy sector is a key contributor to climate change, accounting for more than two-thirds of global greenhouse gas emissions (IEA, 2020). Hence, ongoing global action on climate change through stabilization of emissions at levels compatible with the internationally-agreed 2°C temperature target would have major implications for the energy sector (Bletsas et al., 2022; Dimnwobi et al., 2022). This has paved the way for the drive towards transiting from pollutant fossil fuels to cleaner energy options, ushering a fundamental transformation of the energy industry worldwide on a pathway to complete decarbonization (Zlatinov, 2020; Emmanuel et al., 2024). The resultant energy transition is a continuing process requiring long-term energy strategies and planning capacity to support interventions with a clear potential to accelerate the achievement of SDG7 and that are aligned with the Paris Agreement and NDCs targets (Porter & Hardin, 2020; Onuoha et al., 2023; UNDP, 2023).

While energy transition intentions remain laudable, the reality of the global decarbonization agenda will be disruptive and difficult to implement. The World Bank (2023) highlights three key barriers preventing countries from accelerating their energy transition: prohibitively high upfront capital costs of clean energy projects, high cost of capital that distorts investment choices away from renewables, and weak energy sector fundamentals, especially institutional capacities. In particular, apart from the cost implications, global energy transition means that the finances of several countries will be affected by an inability to exploit some resources and natural assets, which may have to be devalued or retired before the end of their useful life cycles (UNDP, 2023; World Bank, 2023). This will disrupt traditional revenue sources, such as exports of fossil fuels, with higher fiscal sustainability risks (Ibekilo et al., 2023). Moreover, several low-income and vulnerable countries simply cannot afford to increase public green investment and may have more pressing needs competing for their scarce resources (Ekesiobi, et al., 2024a; Dimnwobi et al., 2023; Jakob et al., 2019).

The evolution of traditional macroeconomic goals to incorporate new ecological realities assigns a specific role to macroeconomic policy. However, for fiscal policy in particular, the low-carbon economy transition poses challenges in terms of providing financial resources to fund expensive green energy investments as well as tackle the potential adverse public revenue effects (Roy et al., 2013; Maarof et al., 2023). Thus, while fiscal policy is instrumental in enabling the economy to achieve progress in a variety of ways, including price stability, economic growth, income redistribution and reduction in unemployment, an unstable and unsustainable fiscal environment has dire consequences for energy transition and environmental sustainability (Jamil et al., 2022; Maduka et al., 2022). To preclude fiscal uncertainties, policymakers implement fiscal policy as shock absorbers and stabilizers to counterbalance macroeconomic variations using countercyclical revenue and expenditure measures (Catalano & Forni, 2022). However, failure to prosecute fiscal intentions manifests in recurring and persistent fiscal imbalances, usually leading to susceptibility to unexpected fiscal shocks and their attendant effects on the economy (Ekpo, 2023; Tule et al., 2017). This situation of fiscal vulnerability describes the exposure of an economy to the possibility of failure to meet its aggregate fiscal policy objectives with implications on macroeconomic risks, threats to longer-term fiscal sustainability, and structural or institutional weaknesses affecting the future design and implementation of fiscal policy (Friday, 2023; Hemming & Petrie, 2000). The existence of well-entrenched fiscal rules and a medium-term framework can be a source of great support to provide control over public expenditure during a budget cycle as well as provide the latitude to be able to respond to shocks (Damane, 2022; Doran et al., 2023).

In synthesis, the convergence of fiscal vulnerability and energy transition forms an intellectual and practical crucible wherein the aspirations of ecological sustainability and economic viability intertwine. The intricate interplay between fiscal vulnerability and energy transition constitutes a pivotal nexus within the realm of sustainable economic development (Guo, 2022; Mesagan et al., 2024a). Fiscal vulnerabilities, stemming from inadequate fiscal institutions and unstable financial frameworks, can exert substantial constraints on the endeavour to transition towards sustainable energy sources. The allocation of financial resources towards energy transition initiatives becomes precarious in the presence of fiscal vulnerabilities, potentially impeding the realization of renewable energy adoption targets (WEF, 2023). Robust fiscal governance and transparent financial mechanisms are imperative to mitigate these constraints, creating an environment conducive to the swift and effective deployment of sustainable energy infrastructure. In tandem, energy transition, with its imperative to mitigate climate change and secure future energy needs, necessitates fiscal stability to ensure a steady flow of resources for technology deployment, research, and infrastructural advancement (Yergin, 2022). Recognizing this symbiotic relationship underscores the critical role of fiscal policy in fostering a harmonious evolution towards a net-zero energy landscape.

On the basis of the aforementioned discussions, the complex nexus between fiscal vulnerability and energy transition in Nigeria provides an opportunity for fiscal and energy policy deepening. Decades of fiscal development in the nation have been inextricably tied to petrodollar from the oil sector, leaving the fiscal space heavily reliant on oil revenue (Ekesobi et al., 2024b). Nigeria's susceptibility to global oil price fluctuations has rendered its fiscal position precarious (Agu & Ogbeide-Osaretin, 2017). Before the COVID-19 pandemic, over 80% of Nigeria’s foreign reserves were oil-derived, severely constraining the nation's fiscal manoeuvrability. The reliance on oil is evident in the fact that the oil sector contributed 50% of fiscal revenues, leaving budgets vulnerable to oil price shocks. The nation's fiscal instability is further underscored by its total government revenue, which plummeted to an average of 7.0% of GDP between 2016 and 2020 (Ekpo, 2023). Exacerbating this, Nigeria's debt-to-GDP ratio doubled from 17.4% in 2011 to 36.6% in 2021, potentially trapping the nation in a debt spiral (World Bank, 2022). Escalating debt servicing, with debt service-to-revenue ratio in 2023 at 73.5%, according to the Debt Management Office (DMO), hampered investments in critical areas like energy transition. Concurrently, the slow pace of clean energy system investments, with only about 800 million USD allocated from an expected annual 17.7 billion USD, can be attributed to fiscal constraints. This fiscal vulnerability jeopardizes Nigeria's commitment to the global energy transition and climate goals. As part of the Nigeria Energy Transition Plan (NETP), nearly $1.9 trillion is required, demanding substantial fiscal investments. However, Nigeria's Transition Readiness score of 43.1 casts doubt on its ability to achieve energy transition targets and net-zero global energy ambitions (World Economic Forum, 2022). Amidst these challenges, an investigation into the relationship between fiscal vulnerability and energy transition is imperative.

A growing body of research has been conducted to determine the impact of fiscal policy or specific fiscal instruments on energy transition (Mesagan et al., 2024b; Doran et al., 2023; Maarof et al., 2023; Bletsas et al., 2022; Jamil et al., 2022; Catalano & Forni, 2022; Zlatinov, 2020; Agu & Ogbeide-Osaretin, 2017; Roy et al., 2013). Many of these research conclusions point to the need for empirical attention to additional fiscal policy factors and dimensions not adequately discussed in the literature. It is not surprising then that the impact of fiscal vulnerability on energy transition has piqued the interest of this study. Based on this premise, the research question of the study queries how does fiscal vulnerability affects energy transition in Nigeria?

In a bid to provide evidence-based answers to the research question, this study makes important contributions to the literature. First, this study is a first-of-its-kind attempt to analyse the environmental implications of the effect of fiscal vulnerability on energy transition. This is pertinent in the wake of the aftermath of the fiscal and energy shocks from the COVID-19 pandemic and the Russia-Ukranie war, respectively. Second, the focus on Nigeria – the largest economy in Africa – with its vast natural resources, and one of the world's largest oil and gas producers, is imperative.

Notably, Nigeria, along with six other countries, accounts for 40% of the globe's oil production and they are responsible for approximately 65% of the gas flared worldwide (World Bank, 2021). Such practices contribute to climatic contamination and result in significant economic costs, estimated at around 1% of post-GNP (WHO, 2018; Dada & Ajide, 2021; Maduka et al., 2022). Third, most studies have utilized CO2 emissions and ecological footprint (EF) as indicators of energy transition since environmental pollution declines as renewable energy adoption improves (Bilgili et al., 2022; Sadiq et al., 2022). However, both metrics provide for just a demand-side study of environmental strain. This strategy ignores the ability of natural resources to cope with anthropogenic stresses on water, soil, and air ecosystems. To sidestep these shortcomings, this study employs the load capacity factor (LCF), which incorporates both biocapacity and EF, making it possible to evaluate environment pollution from both the demand and supply sides. Also, for robustness and comparative purposes, the study simultaneously estimates energy transition using the conventional ratio of renewable to non-renewable energy consumption as a proxy for energy transition.

Given the widespread presence of fragile institutions in Nigeria, consideration of institutional quality is crucial in comprehending the potential influence of fiscal vulnerability on energy transition in the country. Overlooking this factor might result in an underestimated assessment of the actual impact of fiscal vulnerability on energy transition in the economy, potentially impeding Nigeria's endeavours to achieve net zero by 2060. For estimation purposes, this study employed the quantile vector autoregressive (QVAR) models among other analytic techniques for several key reasons, namely: they allow us to explore how fiscal vulnerability impacts energy transition across different quantiles, accommodating potential variations in the relationship. The QVAR is also robust to outliers commonly found in economic data. Moreover, it does not assume a specific error distribution, offering flexibility. This is crucial as the impact of fiscal vulnerability on energy transition may not be linear, and QVAR can capture nonlinear effects. Finally, our research contributes to the existing body of knowledge by providing scholars, policymakers and policy enthusiasts with a novel perspective on the environmental repercussions of the fiscal vulnerability-energy transition nexus. The research will elucidate how fiscal instability hampers sustainable energy investments and impacts the nation's readiness for clean energy transition. Such insights are pivotal for devising informed policies that align fiscal stability with the imperative of sustainable energy transition, contributing to Nigeria's journey towards net-zero energy by 2060.

The rest of this paper is structured as follows. Section 2 provides stylized and literature assessments of the subject matter. Section 3 details the data set, model, and technique, and section 4 presents and discusses the empirical outcomes. The paper is wrapped up in section 5.

2. Stylized Assessments and Literature Discourse

2.1 Fiscal development and energy transition investment in Nigeria

We present stylized information regarding fiscal development and energy transition indicators for Nigeria in this study segment. Without a doubt, a plethora of literature has established the crucial role of fiscal engagement in providing basic public necessities and driving economic development in any economy (Adekunle et al., 2022). Therefore, financing clean energy system investment to guarantee access to modern energy for national development is not out of the scope of fiscal policy. The significance of fiscal policy for fiscal responsibilities across nations perhaps accounts for the growth and development parameter gap. To a considerable degree, the observable fiscal policy gauges determine a country's net receipt, fiscal surplus, or deficit. Similarly, fiscal policy encapsulates a nation's revenue, expenditure and debt. Chandia et al. (2022) emphasized that fiscal development is aimed at achieving a balance between the country's earnings and spending, making adjustments through public debt in the event of a deficit fiscal regime.

The fiscal development of Nigeria over several decades has hinged on crude oil export and the oil sector (Ude & Ekesiobi, 2015; Madichie et al., 2014). In fact, Adekunle et al. (2022) noted that the size of the Nigerian public sector and trade balance is driven by crude oil revenue. For instance, more than 90% of the nation's foreign reserve comes from oil exports, with less than 10% of foreign receipts from the non-oil sector (World Bank, 2022). Due to the excessive reliance on the oil sector, Nigeria's fiscal space is limited (World Bank, 2022). Prior to the COVID-19 outburst, the oil sector provided 50% of general fiscal revenues, and, like the external positions, the budgets of both federal and state governments were highly vulnerable to oil price fluctuations. Moreover, following the 2015 oil shock, the nation's already poor total government revenue plummeted to an average of 7.0% of GDP between 2016 and 2020, ranking among the smallest in the world (World

Bank, 2022). In terms of tax and non-tax revenue as % GDP, in 2020, the tax revenue-to-GDP ratio was 5.5% from 6.0% in 2019, while the non-tax revenue-to-GDP ratio was 3.1% for the same year with 64.5% representing 2.1% of the non-tax revenue-to GDP coming from oil rents and royalties (OECD, 2022). The share of tax and non-tax revenue to Nigeria's GDP remains the lowest compared to the average of 31 African countries from 2020 to 2022 (OECD, 2022). Attesting to Nigeria's fiscal instability and vulnerability, the World Bank (2022) emphasized that Nigeria's fiscal condition became increasingly hazardous in 2020 and 2021, as the total government deficit averaged 5.6% of GDP, exceeding the 4% statutory cap stipulated in the Fiscal Responsibility Act of 2007.

Figure 1 depicts the fiscal position of the country showing that the fiscal position of Nigeria remained unstable over the years, characterized by deficits and surpluses. It is clearly observed that after the major decline in the nation's fiscal position between 2008 and 2009, occasioned by the global financial crisis, the country's financial position has remained unstable, with a deficit financial position recorded in 2020 and 2021. Due to declining commodity prices, revenues and the staggering financial position, the Federal Government found it difficult to maintain basic spending (World Bank, 2022). In Figure 2, Nigeria's debt-to-GDP trend is presented to determine the size of the country's debt in relation to the country's size.

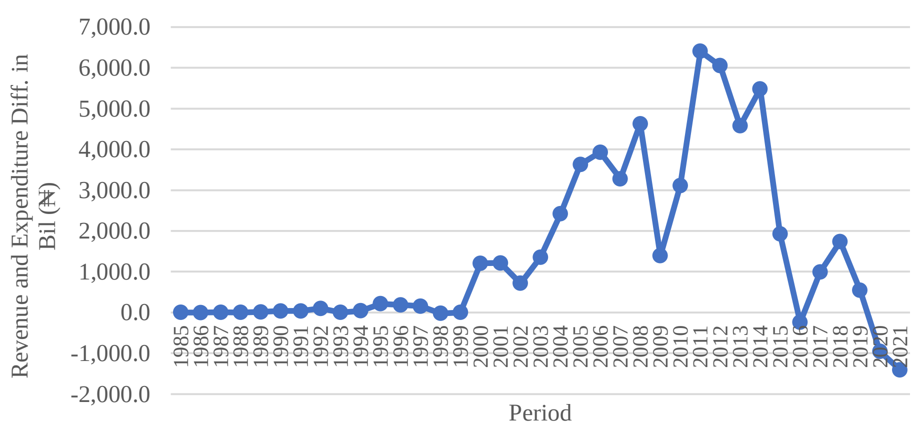

Figure 1. Nigeria's Fiscal Position

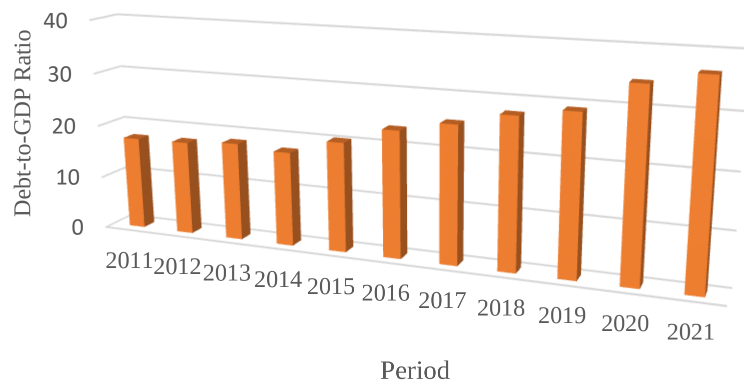

Figure 2. Debt-to-GDP Ratio in Nigeria

The fluctuations in the nation's financial position, as depicted in Figure 1, have exposed Nigeria's fiscal development to a debt trap as the debt-to-GDP size continued to grow. Connecting the scenarios in Figures 1 and 2, in 2011, the country's financial position started plummeting, and the debt-to-GDP size began to expand, denoting that within the period, the country was fiscally trapped. Therefore, based on Figure 2, the debt-to-GDP ratio increased from 17.4% in 2011 to about 36.6% in 2021, showing that the debt vulnerability of the country had doubled in a decade. Furthermore, we present the state of debt financing with the surge in national debt in Figure 3.

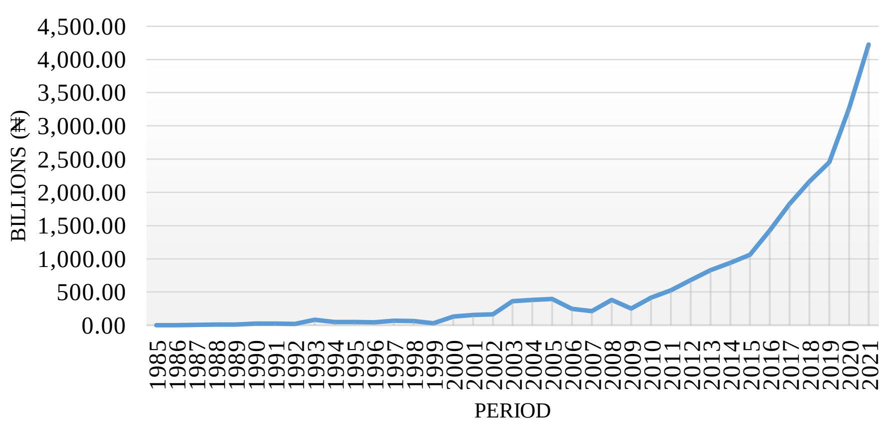

Figure 3. Debt Servicing in Nigeria

Figure 3 shows that debt servicing in Nigeria follows an upward trend, which denotes a surge in the amount of money the government spends on debt services, both domestic and foreign. The surge in debt services gives the government the resources to invest in social infrastructure like clean energy systems that will transition. In Figure 4, we present the debt servicing-to-revenue ratio to capture the cost of borrowing.

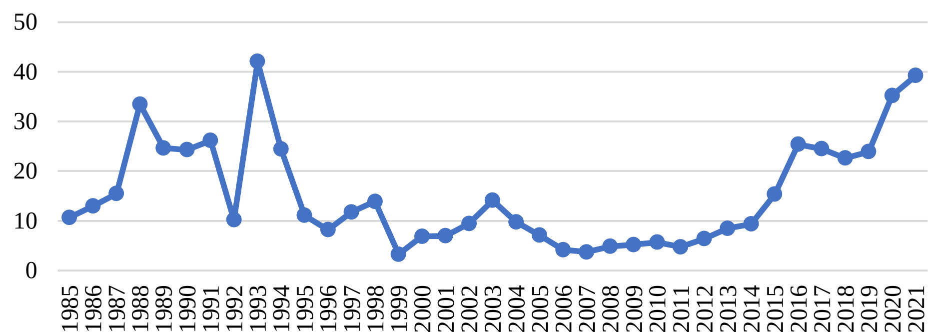

Figure 4. Debt Service-to-Revenue Ratio in Nigeria

The trend in Figure 4 follows the pattern of movements in Figures 1-3. The debt-service-to-revenue ratio of the country is on the rise, with the ratio moving from the lowest point of 3.2% in 1999 to about 40% in 2021. Therefore, as debt servicing commitments consume a greater share of government revenue, there is less capacity to devote cash for other critical areas, such as government services infrastructure development, which includes financing energy transition projects. This fiscal challenge occasioned by excessive debt has exposed the nation to fiscal distress.

Furthermore, energy system investment to accelerate the energy transition agenda of the nation and its attainment of the global commitment remains very poor (Climate Policy Initiative, 2022). The clean energy system investment in Nigeria between 2019 and 2020 against the expected investment commitment is presented in Figure 5. The expected annual investment was about 17.7 billion USD, but only about 800 million USD has been spent on clean energy systems to accelerate the energy transition in Nigeria. This slow pace of investment in the clean energy system is perhaps not unconnected with the nation's fiscal crisis because a significant portion of

Nigeria's income is being channeled towards repayment of debt stock. However, according to Climate Policy Initiative (2022), even out of the 800 million USD spent on the energy system, 55% of the financing came from multilateral development finance institutions (DFIs), 20% flowed from bilateral DFIs, and 19% funding flowed from government, financed with debt.

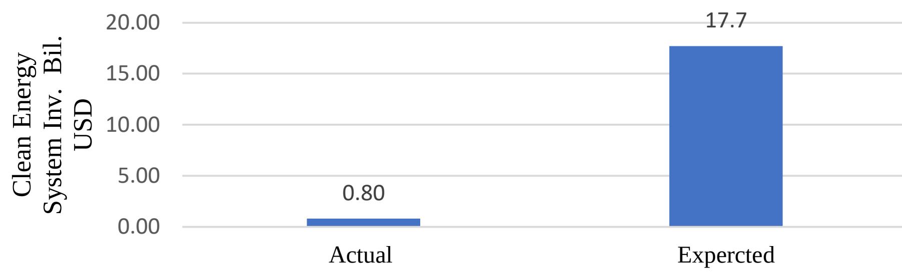

Figure 5. Clean Energy System Investment in Nigeria

2.2 Literature review

The prominent theories that provide a theoretical perspective of this study are the fiscal expenditure and energy ladder theory. These two theories provide perspectives that are linked to fiscal vulnerability and energy transition. The fiscal expenditure theory argues for the role of public expenditure in financing public goods and stabilizing the macroeconomic environment (Musa, 2021). Similarly, Ubi and Inyang (2018) posit that the primary goal of fiscal expenditure is to steer the macroeconomic environment to enhance people's living standards. This theory is famously connected to Wagner's hypothesis, credited to Adolph Wagner in 1886. The central argument of the hypothesis is that fiscal spending and economic development go hand in hand and that, as a nation's economy grows, so does its public spending (Adekunle et al., 2022). This implies that through fiscal expenditure, the government is able to invest in social infrastructure, such as energy systems, to cater for the needs of the economy as it expands. However, the income of the government is not always sufficient to meet the fiscal responsibilities of the state, necessitating deficit financing (Ubi and Inyang, 2018). This deficit financing fiscal expenditure can stabilize the macroeconomic environment and improve household living standards in the short run, but over the long run, economies can become vulnerable to a debt trap (Agu et al., 2015). Consequently, debt servicing becomes a competitor with public infrastructure spending as a result of the debt trap.

This theory is relevant to the theme of this study because, over the decades, the debt financing fiscal expenditure approach has remained central in Nigeria's fiscal spending. This debt financing option has triggered debt accumulation, with debt-to-GDP size reaching about 40% in 2022 (World Bank, 2022). With the size of the debt, fiscal expenditure is not constrained because government earnings are largely diverted to finance and service debt, thereby engendering fiscal vulnerability. Moreover, because finances are now diverted towards debt funding, less public funds will be available to fund energy transition supportive projects, which can deter the commitment of the nation towards reaching net zero by the 2060 national target.

The energy ladder theory on its part, posits that households transition from traditional and unclean energy sources to cleaner energy sources as their economic status improves (Van der Kroon, 2013). This implies that as households' incomes increase, the choice of energy sources improves from fossil sources to cleaner sources for cooking, lighting and transportation. John (2022) emphasized that the prevailing macroeconomic condition determines households' incomes. This means that unstable macroeconomic conditions occasioned by fiscal crisis and instability can pin down households' incomes, lowering the chances of transiting to cleaner energy. Contrariwise, a stable macroeconomic environment that is not characterized by fiscal burden can enhance people's incomes, thereby accelerating their transition to cleaner fuels. The fiscal expenditure and energy ladder theories provide relevant perspectives to the present study. Additionally, following the framework of the Porter-Drewello energy transition (Porter, 1990, 2000, 2008; Drewello, 2022) that opined that energy transition across nations is contingent on endowment, macroeconomic competitiveness and microeconomic competitiveness, the fiscal expenditure and energy ladder theories provide understanding of the macroeconomic and microeconomic competitiveness that is critical in driving energy transition.

Viewed through the prism of the empirical literature, the transition to sustainable energy sources is a complex process influenced by many factors, among which fiscal policy and vulnerability stand out as pivotal. This review delves into the intricate relationship between these fiscal dimensions and energy transition, drawing insights from a plethora of academic studies. The first strand of studies has as focal point the relationship between fiscal policy and energy transition, with varying perspectives on its impact. Several scholars have underscored the positive influence of fiscal policy in advancing energy transition. For instance, Rasoulinezhad et al. (2020) highlighted that geopolitical risk, exchange rate, and financial openness can accelerate energy transition in countries like Russia. Bardazzi et al. (2015) emphasized that appropriate fiscal policies, particularly those altering relative prices, can significantly influence the industrial energy mix. Furthermore, Ponta et al. (2018) found that feed-in tariff policies are effective in fostering the sustainability transition of the energy sector, leading to increased investments and positive impacts on unemployment rates.

On the other hand, some studies have presented a more nuanced view. Azhgaliyeva et al. (2020) identified several policy instruments that effectively reduce energy intensity, including standards, labelling, government direct investment, strategic planning, and fiscal measures. However, the effectiveness of these instruments may vary across countries and contexts. Sung and Park (2018) revealed that while government and market forces directly promote the transition to renewable energy, the traditional energy sector can negatively affect this transition. In the context of developing countries, Murshed (2020) suggested that trade liberalization policies can effectively facilitate renewable energy transition in low-income countries. However, these policies might prolong the transition period in middle-income countries. This underscores the need for tailored fiscal policies that consider the unique economic and social contexts of individual countries. The global perspective on energy transition also highlights the role of policy interdependence. Sattich et al. (2021) discussed the patterns of policy interdependence in the field of energy policy, suggesting potential avenues for renewed cooperation, especially between major players like the EU and China.

For the second strand of studies examining the nexus between fiscal vulnerabilities and the trajectory of energy transition, although scanty in the literature, such research endeavours are garnering attention in contemporary academic discourse. The fiscal health of a country, often gauged by several key indicators such as budget deficits, current account deficits, public debt, and structural or institutional weaknesses, not only reflects the economic stability of a nation but also plays a pivotal role in its ability to invest in and transition to sustainable energy sources. This interplay is especially crucial in the context of global efforts to combat climate change while ensuring economic stability. Onuoha et al. (2023) examined the sub-Saharan African context, emphasizing the instrumental role of governance quality in channelling public debt towards renewable energy consumption. Their findings resonate with the model proposed by Efthimiadis and Tsintzos (2023), which advocates for an implicit debt servicing standstill combined with policies promoting renewable energy. Such a synergy, they argue, can catalyse positive economic growth while ensuring debt sustainability.

However, the landscape of fiscal vulnerabilities and energy transition is not uniformly positive. Ayele and Mutyaba (2021) offer a cautionary perspective, discussing the ramifications of Chinese investments in electricity generation in sub-Saharan Africa. They argue that such investments have inadvertently exacerbated the debt burden of host countries, with a disproportionate allocation not directed towards modern renewable energy sources. This sentiment is echoed by Andreolli and Abdychev (2016), who highlight the fiscal challenges and potential risks associated with large public investments in energy projects, using a hydropower plant in Lesotho as a case study.

Furthermore, the intricate linkage between public debt, renewable electricity output, and CO_2 emissions in emerging economies has been analysed by Zeraibi et al. (2023), shedding light on the potential environmental and economic outcomes of such relationships. The uncertainty surrounding the relationship between fiscal indicators and energy transition is further elucidated by Kemfert and Schäfer (2012). They underscore the challenges inherent in financing energy transitions, particularly during periods of financial market instability. Their research suggests that the availability of private capital and the associated risks of innovation funding in constrained fiscal environments can significantly influence a country's energy transition trajectory. This view is complemented by the insights of Buiter and Lago (2001), who explored the indebtedness dynamics of transition economies, emphasizing both the challenges and potential solutions in the context of energy transition. While the existing literature provides some insights into the relationship between fiscal policy, fiscal vulnerability, and energy transition, there appears to be a paucity of research specifically focusing on countries like Nigeria, which grapple with unique fiscal challenges and energy transition goals. Moreover, the interplay of international sustainability commitments and fiscal vulnerabilities in shaping energy transition in developing countries remains underexplored.

In synthesizing the literature, fiscal policies and vulnerabilities emerge as instrumental in shaping energy transitions. However, their impact is modulated by a nation's broader economic, political, and social milieu. As countries, especially those like Nigeria, navigate the labyrinthine path to sustainable energy transitions, an astute understanding of these fiscal dimensions becomes indispensable.

3. Theoretical Framework and Empirical Strategy

3.1 Porter-Drewello's energy transition framework

The theoretical framework for this paper is anchored on the Porter-Drewello energy transition framework (Porter, 1990, 2000, 2008; Drewello, 2022). Porter-Drewello's tripartite framework hypothesizes that the disparities in energy transition across nations are contingent on three levels of determinants: endowment, macroeconomic competitiveness and microeconomic competitiveness. Endowments refer to the geographical, population and natural resource attributes, as well as the climate conditions, land area, and historical legacy that form the foundation for prosperity within a given region. However, as averred by Porter (2008), real competitiveness emerges from the productive utilization of these endowments.

Microeconomic competitiveness depends on the enhancement of microeconomic capability and the refinement of local competition. The pivotal determinants for local competitiveness encompass the nature of the business environment, the intricacy of business environments and strategy, and the condition of cluster development.

The third level determinant, macroeconomic competitiveness, comprises prudent fiscal and monetary policy, effective public institutions, and the advancement of human and social development through robust education and healthcare systems. In accordance with Porter's assertion, macroeconomic competitiveness establishes the overarching framework for the emergence of local competitiveness, yet does not guarantee its attainment due to constraints imposed by the fiscal position of the state.

The government's fiscal position is a function of its budget constraint. According to Romer (2012), government budget constraints can be stated as follows:

$$\int_{t=0}^{\infty} e^{-R_t} G_t dt \leq -D_0 + \int_{t=0}^{\infty} e^{-R_t} T_t dt \qquad (1)$$

where: G_t refers to government real purchases, T_t refers to taxes at time t, D_0 is debt stock at time 0, R_t denotes $\int_{\tau=0}^{t} r_\tau d\tau$, where r_τ is the real interest rate at time τ. This implies that the value of a unit of output at time t discounted back to time 0 is e^{-R_t} .

Equation (1) shows that the present value of government spending on goods and services, including energy transition investments, must not exceed the sum of its real wealth and the present value of taxes. If the real interest rate is consistently positive, then a constant but positive value of D would fulfil the budget constraint. In other words, the government is always indebted. Alternatively, if the growth rate of D is lower than the real interest rate, then a policy where D continuously increases would also satisfy the budget constraint.

Suppose we define the budget deficit as the rate of change of the stock of debt, which is determined by the difference between government spending and revenues, along with the real interest on its debt.

$$\dot{D}_t = G_t - T_t + r_t D_t \qquad (2)$$

where: r_t is the real interest rate at time t and $\dot{D}_t = D_t - D_{t-1}$

Suppose $g_t = \frac{Y_t}{Y_{t-1}}, d_t = \frac{D_t}{P_t Y_t}, \delta_t = \frac{G_t - T_t}{Y_t}, \omega_t = \frac{P_t}{P_{t-1}}, r_t = i_t - \omega_t$

where: ω = rate of inflation, PY = nominal GDP, Y = real GDP, P = price level, δ =primary balance as a ratio of GDP

Following Stoian (2011), Equation (2) becomes:

$$\delta_t = \frac{i - [(1+\omega)(1+g) - 1]}{(1+\omega)(1+g)} d_{t-1} \qquad (3)$$

Contextually, primary balance refers to the difference between a government's total revenue (excluding borrowing) and its outlay not related to interest. According to the IMF (2021), the objective of government is debt sustainability, thereby ensuring that $d_t = d_{t-1}$. Suppose we allow a small variation of $\omega.g$ Equation (3) yields:

$$\delta_t^* = \frac{i - \omega - g}{(1+\omega)(1+g)} d_{t-1} \qquad (4)$$

Equation (4) is the primary balance required to stabilize public debt. We refer to this as a fiscal rule. In other words, a non-vulnerable fiscal policy is achieved when this fiscal rule equals the current primary balance (that is, δ_t^* $= \delta$), or when $\delta_t^* < \delta$.

Invariably, in the view of the Porter-Drewello framework, increased investment in energy transition or achieving a set target in energy transition will require that Equation (4) holds over the range of period to which the target applies.

3.2 Econometric procedure

3.2.1 *Model Specification*

The estimation technique adopted in this paper is the quantile regression developed by Koenker and Bassett (1978). Quantile regression extends the traditional linear regression framework by allowing us to estimate the conditional quantiles rather than just the conditional mean of the dependent variable, given the independent variables as in the case of traditional regression models. In quantile regression, we estimate the conditional quantiles by minimizing a weighted absolute loss function. The weights reflect the relative importance assigned to different parts of the distribution. This approach allows us to estimate the conditional quantiles without making any assumptions about the error distribution. Quantile regression offers several advantages over traditional regression techniques. For instance, it provides robustness to outliers and is less sensitive to violations of the normality assumption. Moreover, quantile regression allows us to analyse the effects of covariates at specific quantiles, enabling us to capture the heterogeneity in response across different parts of the distribution.

The quantile regression model aims to estimate the q^{th} quantile of m_t, given a set of explanatory variables n_t, as:

$$Q_q(m_t / n_t) = n_t \phi(q) \tag{5}$$

where: the parameter vector ϕ gives the marginal effect of the corresponding explanatory variables, $\phi(q)$ highlights the different parameter vector at each respective quantile q of the distribution.

Equation (5) shows that the focus is not on the conditional mean, but on the whole conditional distribution of m_t. This distribution, characterized by its quantiles $q \in (0,1)$, seeks to explain changes in the q^{th} quantile of the yt-distribution by changes in the explanatory variables.

Following Koenker and Bassett (1978) and Furno and Vistocco (2018), the estimate for the parameter vector is given as:

$$Q_q(m_t / n_t) = \hat{\phi}(q) = \arg \min_{\phi(q)} \sum_t \alpha_q \left[m_t - n_t(\phi(q)) \right] \tag{6}$$

In Equation (6), the function, α_q, is defined for $\psi_t \equiv m_t - n_t(\phi(q))$ as $\alpha_q[\psi_t] = (q - I_{\psi_t} < 0)\psi_t$ such that $I_{\psi_t = 0} = 1$ if $\psi_t < 0$, otherwise, $I_{\psi_t < 0} = 0$

Note that quantile regression is a nonlinear estimation procedure. As noted by Chandia et al. (2022), nonlinear regression estimations are more appropriate for fiscal policy estimations due to the recognition that the relationship between fiscal policy and economic outcomes is often complex and nonlinear. Nonlinear regression allows for more flexible modelling, accommodating nonlinear relationships between variables. This is particularly important when examining the effects of fiscal policy, as the impact may vary across different levels of fiscal vulnerability, economic conditions, or policy regimes. Nonlinear regression estimations can capture threshold effects, where the impact of fiscal policy changes significantly at certain points or ranges of the independent variable. It can also account for interactions and nonlinear interactions between variables that may influence the effects of fiscal policy on the economy.

To estimate Equation (5), we apply quantile regression to a p^{th}-order vector autoregression (VAR) in line with Cecchetti and Li (2008) and Chavleishvili et al. (2021). Suppose $y_t = (y_{1t}, y_{2t}, ..., y_{zt})'$ is a vector of z variables while $q = (q_1, q_2, ..., q_z)'$ is a vector of quantile. The VAR model for q is given as:

$$Q_q = (y_t / y_{t-1}, ..., y_{t-p}) = \theta(q) + \sum_{i=1}^{p} \Omega_i(q) y_{t-1} \tag{7}$$

$\Omega(q)$ and $\theta(q)$ are defined as:

$$\Omega(q) = \begin{pmatrix} \phi_{i,11}(q_1) & \dots & \phi_{i,1z}(q_1) \\ \phi_{i,21}(q_2) & \dots & \phi_{i,2z}(q_2) \\ \vdots & & \vdots \\ \phi_{i,z1}(q_z) & \dots & \phi_{i,zz}(q_z) \end{pmatrix} \quad \text{and} \quad \theta(q) = \begin{pmatrix} \theta_1(q_1) \\ \theta_2(q_2) \\ \vdots \\ \theta_z(q_z) \end{pmatrix}$$

The quantile VAR (QVAR) allows us to estimate the impulse response function indicating the effect of fiscal vulnerability shocks on energy transition.

3.2.2 *Description of Variables*

Table 1 summarizes the description of the variables, including the descriptive statistics. All variables except the effective interest rate (which cannot have a trend) are measured as log deviations from quadratic time trends. Energy transition measures (ET and ET_A) entered the model as dependent variables, fiscal vulnerability (FVI) is the predictor variable and INV, PCI, Y, RD and INT are the covariates. All variables were tested for the presence of unit root in their log deviation form, and the result (not presented here) shows that the data are stationary. The construction of FVI using principal component analysis is shown in the appendix to allow us focus on the main results.

Table 1. Variable Description

Variable	Variable Description	Mean	Min.	Max.
Energy transition (*ET*)	ET is measured as a ratio of renewable energy to total energy consumption.	0.405	0.022	0.802
Load factor capacity (*ET_A*)	This is an alternative measure of energy transition that measures energy transition through environmental impacts	0.021	0.003	0.071
Fiscal vulnerability index (*FVI*)	FVI measures a country's susceptibility to fiscal risks and shocks. Although it can be measured using fiscal rule, in this study, we constructed the index using principal component analysis.	0.009	0.001	0.029
Gross investment (*INV*)	INV controls the private sector financing side of the energy transition. It is measured as the sum of gross fixed capital formation and inventory adjustment	1.290	0.892	2.003
Per capita income (*PCI*)	PCI captures the personal income of energy users. It is a control variable for household investment in energy transition	0.992	0.201	1.003
Real output (*y*)	This is a measure of real economic activity adjusted for inflationary effect	3.092	1.190	4.422
Variable	Variable Description	Mean	Min.	Max.
Research & Development (*RD*)	This is a measure of technological advancement in the energy ecosystem. It is proxied by real capital spending by Nigeria's central government	2.129	1.886	3.199
Effective interest rate (*INT*)	INT controls for monetary policy effect. It is measured as 1-year Treasury bill	12.343	5.39	18.87

Source: Authors' computation.

4. Results

This section presents the estimation outcomes. We estimate vector autoregressive models at the quantiles of the conditional distribution of measures of energy transition or green energy and discuss the findings of our results. First, the impulse response results are presented to examine the impact of fiscal vulnerability shocks on green energy. This is followed by QVAR estimates.

4.1 Impact of fiscal vulnerability shocks on energy transition

In this section, we utilize quantile regression to estimate vector autoregressive models, specifically focusing on the impact of fiscal vulnerability on energy transition. We use quarterly data from 2000q1 to 2021q4. Our baseline set of variables consists of the energy transition, *ET*, measured as the ratio of renewable energy to total energy consumption, fiscal vulnerability index, *FVI*, gross investment, *INV*, per capita income, *PCI*, real output, *Y*, research and development, *RD*, measured as real capital spending, and effective interest rate, *INT*, measured as one-year treasury bill rate. While the effective interest rate controls for monetary policy effect, gross investment controls for private sector financing side of energy transition.

The estimation of VAR parameters involves conducting equation-by-equation quantile regressions, as explained in the methodology section. The variables are measured at the medians of their conditional distributions on the left-hand sides of the estimation equations. However, the effects on energy transition are evaluated at different quantiles of its conditional distribution. This approach allows us to determine whether the impacts of fiscal vulnerability vary depending on whether the energy transition is relatively low or high.

In order to maintain brevity, we present the results for three specific quantiles of energy transition levels: q = (0.1, 0.5, 0.9). These quantiles serve as benchmark cases to examine the impact of fiscal vulnerability on energy transition. For q = 0.1, the energy transition is situated in the lowest 10% of its conditional distribution. At q = 0.5, we assess the effects of fiscal vulnerability at the median level of the energy transition, which closely aligns with its mean. Finally, at q = 0.9, we estimate the effects of fiscal vulnerability when the energy transition level is predicted to be high, representing the highest 10% of its conditional distribution.

We have specifically selected these quantiles to enhance the clarity of our presentations and to emphasize the most intriguing aspects of the discussion. It is crucial to acknowledge that these quantile values serve as illustrative examples representing different segments of the green energy distribution. Nevertheless, it is worth noting that the overall results remain robust regardless of the selection of alternative quantiles.

The findings are presented in Figure 6, where the solid black line represents the observed changes in the transition to green energy. The red line corresponds to the lower quantile, while the green line represents the upper quantile. This visual depiction illustrates instances in our dataset where the realization of the transition path is closely aligned with the 0.1 or 0.9 conditional quantile forecast. These occurrences highlight the episodes of fiscal shocks that significantly influenced the progress of the green transition, either surpassing or falling below its projected conditional mean forecast.

Next, we examine the effects of fiscal vulnerability at different quantiles. To accomplish this, we estimate the reduced form VAR equations for a specific quantile, denoted as q, and calculate impulse responses by orthogonalizing the residual covariance matrix using a Cholesky decomposition. This approach allows us to apply a standard recursive identification scheme. The fiscal vulnerability index variable takes precedence in the ordering, followed by other covariates.

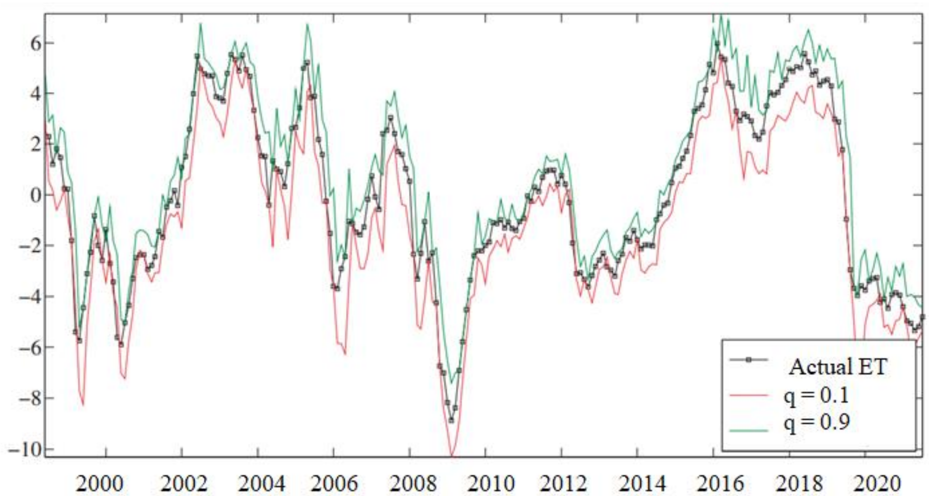

Figure 6. ET versus one-step-ahead quantile forecasts

4.2 Impulse response functions

Figure 7 illustrates the orthogonalized impulse responses of green energy and fiscal vulnerability derived from the VAR equations estimated at different quantiles of green energy in our model. Specifically, it examines the response to a positive 1% shock in fiscal vulnerability (at the median level). The shaded areas represent bootstrapped 95% confidence intervals. The figure demonstrates that an increase in fiscal vulnerability typically leads to a negative response in the green energy transition. Moreover, the response is statistically significant and persists for several quarters following the shock.

The figure further shows that during the shock period, the impact response is approximately consistent across all quantiles of the green energy transition. However, notable differences arise in terms of the maximum response of green energy. At the lowest quantile (q = 0.1) of green energy transition, fiscal vulnerability induces a moderate effect on the energy transition trajectory. Initially, there is an immediate decline followed by a moderate recovery that offsets the impact. In contrast, at the median or highest quantile of the green energy transition path (q = 0.5 and q = 0.9), the negative shock persists for an extended duration, unless there is a shift in the fiscal regime.

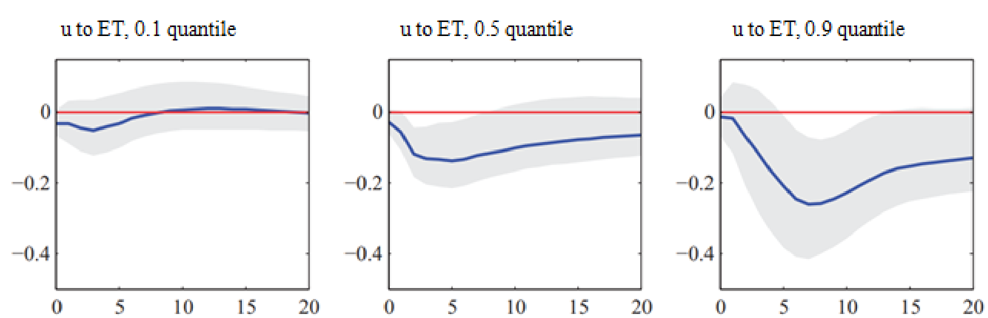

Figure 7. Impulse response of the impact of fiscal vulnerability on energy transition

Figure 8 shows the results for a broader range of conditional green energy quantiles. Again, for easy readability we condense the information in the impulse responses by computing the extreme values of the point-wise ratios of green energy to fiscal vulnerability responses, and the cumulative response ratios.

Both measures allow very similar interpretations. The result shows that at the lower quantile of the conditional distribution of green energy, the fiscal vulnerability effect appears smaller relative to the median and maximum quantiles.

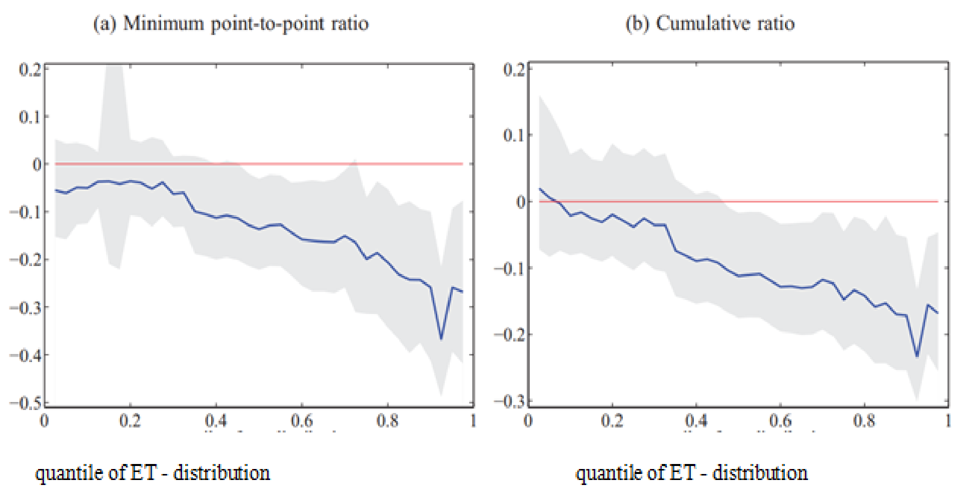

Figure 8. ET ratios at different quantiles of the green energy distribution

These results highlight the significance of considering nonlinear effects when examining fiscal vulnerability. If an estimation approach solely focused on average effects was used instead of the one proposed here, the results would closely align with what we observe at the median, consequently underestimating the impact of fiscal vulnerability shocks on ET. Additionally, we provide quantitative measures to assess the disparity in green energy responses across different quantiles.

Figure 9 displays histograms representing the bootstrapped distributions of the minimum point-wise and cumulative ratios between the green energy response and the fiscal vulnerability response. In the first row of the figure, we compare the 0.9 quantile of green energy with the 0.1 quantile. The second row, on the other hand, compares the 0.975 and 0.025 quantiles.

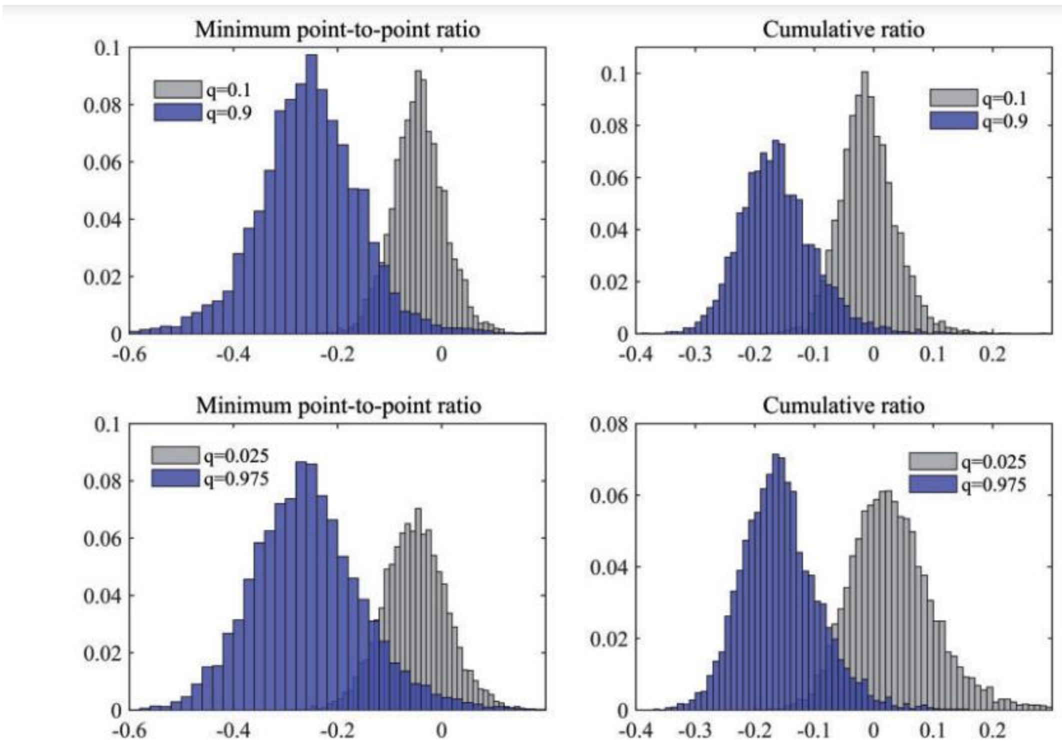

Figure 9. Histograms of quantile-specific ET ratios

The results of the impulse function, minimum point-to-point ratio and cumulative ratio when fiscal vulnerability is interacted with institutional quality are shown in Figure 10. The findings obtained show that the impact of fiscal vulnerability shock is moderated when interacted with institutional quality. This suggests that institutional quality ensures that green energy investment is not muted when there is fiscal crisis.

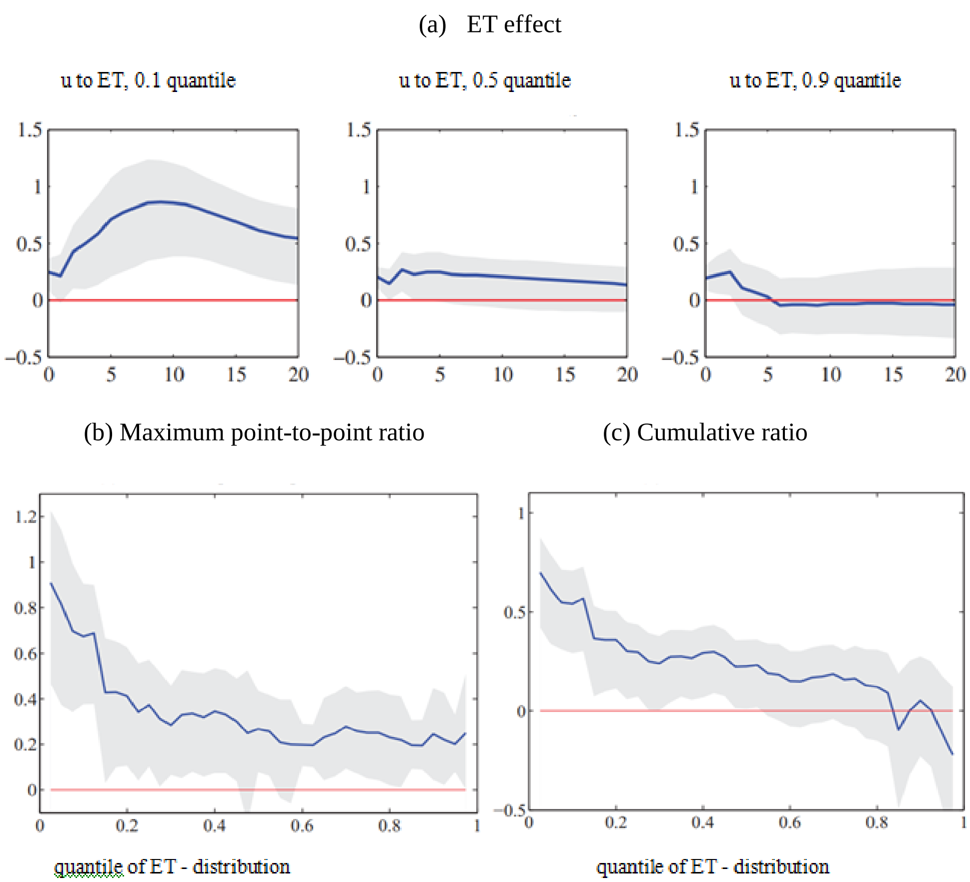

Figure 10. Impulse response of the impact of the interaction of fiscal vulnerability and institutional quality on energy transition, and ET ratios at different quantiles of the green energy distribution

4.3 Alternative measurements of ET

We have observed significant nonlinearities in the impacts of fiscal vulnerability across different quantiles of the conditional distribution of green energy transition. In our analysis, green energy transition is defined as the ratio of renewable energy consumption to total energy. However, it is worth noting that our main finding remains robust even when using an alternative measure of energy transition, such as the load capacity factor.

Figure 11 illustrates the cumulative ratio among different quantiles of green energy for the alternative specification. In this scenario, the ratio of green energy response is more significant for the lower quantiles of the conditional distribution compared to the median or higher quantiles. This finding reaffirms the qualitative result of nonlinear fiscal vulnerability effects.

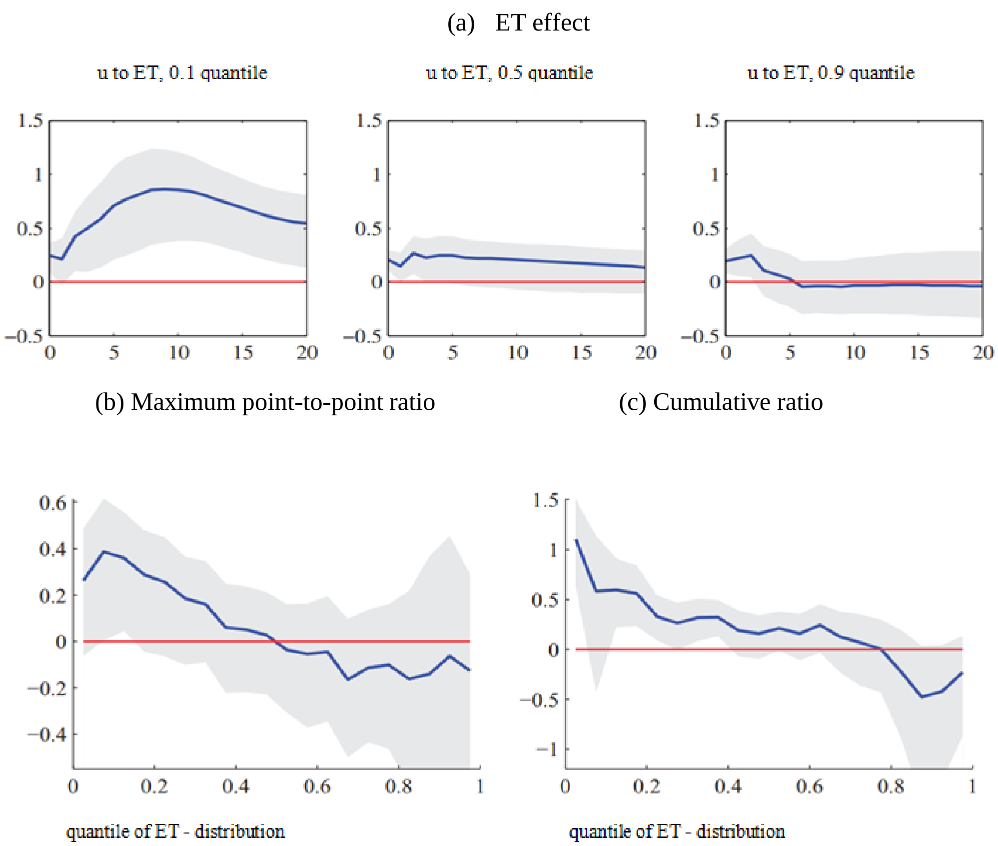

Figure 11. Impulse response of the impact of fiscal vulnerability on ET using alternative measure (11(a)), and ET ratios at different quantiles of the green energy distribution (11(a),(b))

4.4 QVAR Estimates of the impact of fiscal vulnerability on energy vulnerability

The results obtained from the quantile regression analysis indicate that fiscal vulnerability has a statistically significant negative impact on energy transition, particularly at the median and maximum quantiles. Specifically, at the q = 0.1 quantile, an increase of one unit in fiscal vulnerability is estimated to result in a decrease of 0.052 units in the ratio of renewable to total energy consumption. However, the impact of fiscal vulnerability is not statistically significant at the first quantile. Similarly, at the q = 0.5 quantile, the negative coefficient of -0.081 suggests that an increase of one unit in fiscal vulnerability is associated with a decrease in the energy transition ratio. This relationship was found to be statistically significant at a 5% significance level. Finally, at the q = 0.9 quantile, the coefficient of -0.094 indicates that an increase of one unit in fiscal vulnerability leads to a reduction in the ratio of renewable to total energy consumption.

Table 2. Impact of Fiscal Vulnerability on Energy Transition

Dependent Variable: Renewable Energy as a Ratio of Total Energy Consumption						
qth quantile	0.1		0.5		0.9	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
FVI	-0.052	0.049	-0.081***	0.027	-0.094***	0.031
FVI*IQI	0.084**	0.040	0.085***	0.032	0.090***	0.029
PCI	0.074***	0.026	0.053	0.053	0.034*	0.018
K	0.08***	0.029	0.094***	0.028	0.105***	0.035
INV	0.300***	0.038	0.367***	0.039	0.445***	0.051
INT	-0.351***	0.088	-0.447***	0.099	-0.537***	0.122
Y	0.711	0.508	0.506*	0.309	0.489	0.319
RD	0.068***	0.011	0.081**	0.033	0.109***	0.016
IQI	0.060***	0.023	0.056***	0.020	0.048**	0.021

These results show that the impact of fiscal vulnerability energy transition varies across various quantiles. The results also provide empirical evidence supporting the hypothesis that higher levels of fiscal vulnerability exert a constraining effect on energy transition. The negative coefficients indicate that as fiscal vulnerability increases, the adoption and utilization of renewable energy sources decrease, underscoring the significance of addressing fiscal vulnerabilities to promote sustainable energy practices.

For instance, Chishti et al. (2021) conducted a study on the impact of fiscal policy on renewable energy investments and found expansionary fiscal is associated with increase in investments in renewable energy projects.

Given that fiscal vulnerability is a constraining factor in the fiscal space, this finding corroborates the results that we obtained. However, Sun et al. (2022) found a dissenting result. Their findings suggest that factors beyond fiscal vulnerability, such as policy support, technological advancements, and institutional quality, may play a more prominent role in driving sustainable energy practices.

The interaction between fiscal vulnerability and institutional quality adds an additional dimension to the analysis. Considering the coefficients obtained across the quantiles for this interaction term, which are positive rather than negative as observed in the case of fiscal vulnerability without interaction, it indicates that as the joint influence of fiscal vulnerability and institutional quality increases, the adoption and utilization of renewable energy sources also increase, emphasising the importance of institutional quality in promoting sustainable energy practices.

Also, using an alternative measure of energy transition, which is reflective of environmental sustainability rather than energy consumption, the result shows that fiscal vulnerability reduces environmental sustainability. The results obtained from the quantile regression analysis provide insights into the impact of fiscal vulnerability on energy transition, as measured by the load capacity factor (LCF). The negative estimates (-0.019, -0.031, and -0.012) for the q = 0.1, q = 0.5, and q = 0.9, respectively, indicate that higher levels of fiscal vulnerability are associated with a decrease in the LCF, reflecting an impediment to environmental sustainability through slack in energy transition. Again, these findings highlight the importance of addressing fiscal vulnerabilities to promote a transition to sustainable energy practices. The negative coefficients suggest that fiscal vulnerabilities act as barriers to the adoption and utilization of renewable energy sources, hindering progress towards a more environmentally sustainable energy system.

Again, using an alternative measure, the interaction between fiscal vulnerability and energy transition moderated the negative impact of fiscal vulnerability on energy transition. The positive interaction effect aligns with the notion that when institutional quality is high, it can potentially mitigate the negative impact of fiscal vulnerability on energy transition. Institutional quality encompasses factors such as governance, regulatory frameworks, and policy effectiveness, which can create an enabling environment for renewable energy investments and initiatives. Therefore, when a fiscal vulnerability is coupled with favourable institutional quality, it can act as a catalyst for energy transition, facilitating the adoption and utilization of renewable energy sources. However, it is crucial to note that the joint effect of fiscal vulnerability and institutional quality may vary depending on contextual factors and specific institutional frameworks.

Table 3. Impact of Fiscal Vulnerability on Energy Transition

Dependent Variable: Load Capacity Factor						
qth quantile	0.1		0.5		0.9	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
FVI	-0.019***	0.007	-0.031***	0.010	-0.012***	0.004
FVI*IQ1	0.090***	0.021	0.043**	0.020	0.018***	0.004
PCI	0.073	0.091	0.030***	0.010	0.067	0.050
K	0.085***	0.029	0.007***	0.002	0.078***	0.011
INV	0.157**	0.071	0.047***	0.005	0.146	0.253
INT	-0.017***	0.006	-0.006***	0.001	-0.017***	0.004
Y	0.029	0.030	0.021	0.013	0.008*	0.004
RD	0.089***	0.023	0.006***	0.001	0.007***	0.002
IQI	0.049***	0.064	0.011***	0.004	-0.140**	-0.063

Note: *,**,and *** refer to 10%, 5% and 1% significance level
Source: Authors' computation.

In terms of policy and theoretical implications, the negative impact of fiscal vulnerability on energy transition and environmental sustainability suggests that policymakers need to address and mitigate fiscal vulnerabilities to promote sustainable energy practices. This can be achieved through the strengthening of fiscal institutions. Improving fiscal governance and transparency can help reduce fiscal vulnerabilities and create a more stable environment for energy transition initiatives. This includes measures like effective budgetary management, debt control, and fiscal risk assessment.

This study also crystallizes the importance of fostering renewable energy investments. Policymakers should prioritize renewable energy investments to reduce reliance on fossil fuels, promote energy diversification and guarantee energy security. This can be achieved through financial incentives, supportive regulatory frameworks, and targeted subsidies for renewable energy projects.

Also, emphasizing energy efficiency can help offset the negative impact of fiscal vulnerabilities on energy transition. Policies that promote energy-efficient technologies, building codes, and consumer awareness can contribute to a more sustainable energy landscape.

Moreso, the finding that institutional frameworks moderate the effect of fiscal vulnerability on energy transition highlights the importance of supportive governance structures in promoting sustainable investment and the shift to green energy. This implies that economic factors do not solely determine the impact of fiscal vulnerability on energy transition but is also influenced by the institutional context. Thus, the findings support the theoretical proposition of institutional economists, which emphasizes that institutional frameworks, such as regulatory policies, legal systems, and governance structures, play a crucial role in shaping economic development or the effectiveness of economic policies. Future research can delve deeper into understanding the specific mechanisms through which institutions moderate this relationship.

5. Policy Recommendations and Conclusion

This paper employed Porter-Drewello's energy transition framework and quantile regression analysis to investigate the impact of fiscal vulnerability on energy transition. The study used quarterly data from 2000q1 to 2021q4 and assessed the effect of fiscal vulnerability on energy transition at different quantiles. The findings reveal that higher levels of fiscal vulnerability significantly hinder energy transition, as measured by the ratio of renewable energy to total energy consumption. The negative coefficients indicate that as fiscal vulnerability increases, the adoption and utilization of renewable energy sources decrease. Moreover, the interaction between fiscal vulnerability and institutional quality emerges as a significant factor, suggesting that favourable institutional quality can mitigate the negative impact of fiscal vulnerability on energy transition. An alternative measure of energy transition, the load capacity factor, also confirms the inhibitory effect of fiscal vulnerability on environmental sustainability.

The research findings underscore the urgent need for policy interventions to address fiscal vulnerabilities and facilitate a successful energy transition in Nigeria. Policymakers should prioritize fiscal reforms that enhance revenue diversification, reduce the country's dependence on oil revenue, and strengthen the fiscal base. This could involve implementing effective fiscal rules, improving tax collection mechanisms, and promoting non-oil revenue sources. Furthermore, improving institutional quality is essential. Enhancing governance, regulatory frameworks, and policy effectiveness can create an enabling environment for renewable energy investments and initiatives. Collaboration between government agencies, the private sector, and international organizations is crucial to mobilize resources and the expertise necessary for sustainable energy practices. Investments in clean energy systems should be bolstered through strategic financial mechanisms. Policies that incentivize private sector participation and direct investments towards clean energy projects will accelerate the transition to a sustainable energy system. Additionally, a comprehensive national energy transition plan, backed by robust fiscal provisions, will facilitate the achievement of net-zero energy goals.

While this study modestly contributes to our understanding of the relationship between fiscal vulnerability and energy transition in Nigeria, there are areas for improvement and further exploration. Several limitations deserve acknowledgement. First, the accuracy of findings might be influenced by data gaps, inconsistencies, or potential measurement errors in underlying variables. Second, the study's focus on the impact of fiscal vulnerability on energy transition omits potential reverse causality or bidirectional relationships. Future investigations could employ dynamic models or instrumental variable methods to address endogeneity concerns and establish causation more robustly. Third, the research predominantly employs a quantitative approach emphasizing statistical relationships, potentially missing qualitative aspects like policy challenges, social acceptance, and technological limitations. Combining quantitative analysis with qualitative methods such as case studies and interviews could allow a deeper grasp of energy transition complexities. Future research opportunities in this domain could expand and refine the current study in various ways. Examining the role of policy interventions in mitigating the impact of fiscal vulnerability on energy transition could provide valuable insights. Evaluating mechanisms like carbon pricing, renewable energy subsidies, and fiscal reforms could guide effective policy design. Assessing regional heterogeneities within Nigeria might unveil divergent energy transition and fiscal vulnerability dynamics. By integrating a long-term perspective, the research could uncover nonlinear trends and unexpected developments, offering a more comprehensive evaluation of pathways towards net-zero energy by 2060.

In conclusion, the study sheds light on the intricate relationship between fiscal vulnerability and energy transition in Nigeria. The research findings confirm that fiscal vulnerabilities act as formidable barriers to adopting and utilizing renewable energy sources, hindering the country's progress towards sustainable energy practices. The negative impact of fiscal vulnerability on energy transition is further moderated by institutional quality, emphasizing the crucial role of effective governance and policy frameworks. The implications of these findings are significant as Nigeria seeks to transition towards net-zero energy by 2060. Addressing fiscal vulnerabilities and bolstering institutional quality are imperative steps to enable a successful energy transition. The study underscores the necessity for comprehensive and integrated policy measures that align fiscal reforms with sustainable energy objectives. Through the combination of fiscal resilience with favourable institutional conditions, Nigeria can navigate the challenges of energy transition and pave the way for a more sustainable and environmentally-conscious future.

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APPENDIX

Constructing Fiscal Vulnerability Index using Principal Component Analysis (PCA)

The Principal component analysis (PCA) is a statistical technique used to reduce the dimensionality of a dataset while preserving the most important information. It involves transforming a set of variables that are correlated into a smaller number of uncorrelated variables. Following relevant literature, the following variables were selected for constructing the PCA.

Debt-to-GDP ratio (DGR): DGR was computed by dividing the nominal public debt in year t with the nominal GDP in year t. The higher the DGR, the greater the risk of default fiscal sustainability crises.

Fiscal deficit-GDP ratio (FGR): This is the ratio of actual fiscal deficit to nominal GDP. As noted by Sun et al. (2022), fiscal deficits can weaken a country's fiscal position, leading to increased borrowing and debt accumulation.

Revenue growth (RG): The ability of an economy to meet its fiscal obligations is largely contingent on its capacity to grow its revenue over time so as to match revenue with expenditure. Revenue growth, measured as percentage increase in revenue, is supported by revenue diversification. Revenue concentration, especially on a volatile revenue stream can make a nation more susceptible to economic fluctuations and shocks.

External effect (EE): This is captured using exchange rate volatility. This variable assesses the external vulnerabilities of an economy, such as exposure to international trade, and external headwinds, which can have implications for the fiscal balance. The standard deviation approach to computing exchange rate volatility was adopted.

To compute the index, we start by standardizing the variables. This ensures that the variables have a mean of zero and a standard deviation of one. This is important as it ensures that variables with different scales do not dominate the analysis. This is followed by assignment of weights based on their relative importance, the computation of the covariance matrix, eigenvectors and eigenvalues. Next, the principal component is selected based on a threshold or using a scree plot, which shows the eigenvalues against the number of components. Finally, the selected eigenvectors (principal components) are used to transform the original dataset into a new dataset called the FVI. The FVI provides a snapshot of a country's fiscal vulnerability level.

The result of the PCA is shown in Table A.1. The eigenvalues are 2.162, 0.892, 0.674 and 0.271 for PC 1, PC 2, PC 3, and PC 4 respectively. The eigenvalues represent the amount of variance explained by each PC. Larger eigenvalues indicate

PCs that explain a larger proportion of the variance in the data. A significant drop in eigenvalue after a certain PC suggests that the subsequent PCs explain less variance and may not be as important.

The proportion of variance explained by each PC is 0.541, 0.223, 0.169 and 0.068 for PC 1, PC 2, PC 3, and PC 4 respectively. The proportion of eigenvalues indicates the relative importance of each PC in capturing the variability in the data. PCs with higher proportions of variance are considered more influential. Only PC1 has an eigenvalue greater than 1 (that is, 2.162). Following Kaiser's criterion, only PCs with eigenvalues greater than one are considered. The mean FVI obtained is 0.404 with maximum and minimum values of 3.235 and -2.077 respectively.

Table A.1 PCA for FVI

Eigenvalues: (Sum = 4, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.162384	1.270306	0.5406	2.162384	0.5406
2	0.892078	0.217928	0.2230	3.054462	0.7636
3	0.674150	0.402762	0.1685	3.728612	0.9322
4	0.271388	---	0.0678	4.000000	1.0000

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3	PC 4
DGR	0.603718	-0.075324	-0.298423	0.735387
FGR	-0.515816	-0.488994	0.437430	0.550885
RG	0.456077	0.273413	0.846895	-0.002739
EE	-0.401812	0.824898	-0.048648	0.394619

Ordinary correlations:

	DGR	FGR	RG	EE
DGR	1.000000			
FGR	-0.618584	1.000000		
RG	0.406096	-0.378638	1.000000	
EE	-0.491439	0.132990	-0.223143	1.000000