PROBLEMY EKOROZWOJU/ PROBLEMS OF SUSTAINABLE DEVELOPMENT

SUBMITTED: 4.03.2026, ACCEPTED: 9.04.2026, PUBLISHED ON-LINE: 1.07.2026
2026, 21(2): 361-392, DOI: https://doi.org/10.35784/preko.9305

Financial Inclusion, Energy Access, and Poverty Reduction in BRICS Plus Economies

Włączenie finansowe, dostęp do energii i redukcja ubóstwa w gospodarkach BRICS Plus

Xiaowan Xu

Jinan Vocational College of Nursing, Finance Department，Jinan 250102, Shandong, China
E-mail: echo.shanjing@163.com, ORCID: 0009-0003-1424-2713

Abstract
Expanding financial systems and energy infrastructure is widely assumed to reduce poverty, yet evidence on how these systems interact remains limited. This study investigates whether financial inclusion and energy access independently and jointly influence poverty reduction in BRICS Plus economies. Using a balanced annual panel dataset covering ten emerging economies across the Middle East, Africa, Asia, and Latin America over the period 2004–2023, the analysis employs two-way fixed effects with Driscoll–Kraay and Panel-Corrected Standard Errors to address heteroskedasticity and cross-sectional dependence. Poverty reduction is proxied by household final consumption expenditure per capita, while financial inclusion is measured through a principal component index and energy access by electricity access rates. The results show that energy access and financial inclusion individually exhibit negative associations with household welfare, suggesting that infrastructure expansion and financial deepening do not automatically translate into improved living standards when affordability constraints, tariffs, and financial costs are present. However, the interaction between financial inclusion and energy access is positive and highly significant, indicating strong complementarity. Financial systems enable households to convert electricity access into productive activities that enhance income and consumption. The interaction effect is particularly strong in lower-middle-income economies, while it weakens in higher-income contexts where financial and energy systems are already mature. The complementarity also declines during the COVID period, highlighting the vulnerability of development channels to global shocks. The study contributes to the literature by providing new evidence that the poverty effects of energy access depend critically on financial system inclusiveness. The findings underscore the importance of integrated finance–energy policies for advancing inclusive growth and sustainable development in emerging economies.

Key words: BRICS economies, energy access, financial inclusion, poverty reduction, Sustainable development goals

Streszczenie
Powszechnie zakłada się, że rozwój systemów finansowych i infrastruktury energetycznej prowadzi do redukcji ubóstwa, jednak dowody na interakcje między tymi systemami pozostają ograniczone. Niniejszy artykuł ma na celu zbadanie, czy włączenie finansowe i dostęp do energii niezależnie i łącznie wpływają na redukcję ubóstwa w gospodarkach BRICS Plus. Wykorzystując zbilansowany roczny zestaw danych panelowych obejmujący dziesięć gospodarek wschodzących na Bliskim Wschodzie, w Afryce, Azji i Ameryce Łacińskiej w latach 2004–2023, analiza wykorzystuje dwukierunkowe efekty stałe z modelem Driscolla–Kraaya i błędami standardowymi skorygowanymi panelowo, aby uwzględnić heteroskedastyczność i zależność przekrojową. Redukcję ubóstwa przybliżają ostateczne wydatki konsumpcyjne gospodarstw domowych na mieszkańca, podczas gdy włączenie finansowe mierzy się za pomocą indeksu głównych składowych, a dostęp do energii – stawkami za energię elektryczną. Wyniki pokazują, że dostęp do energii i włączenie finansowe indywidualnie wykazują negatywne korelacje z dobrobytem gospodarstw domowych, co sugeruje, że rozbudowa infrastruktury i pogłębienie sytuacji finansowej nie przekładają się automatycznie na poprawę poziomu życia w przypadku ograniczeń w dostępności, taryf i kosztów

finansowych. Jednakże interakcja między włączeniem finansowym a dostępem do energii jest pozytywna i wysoce istotna, co wskazuje na silną komplementarność. Systemy finansowe umożliwiają gospodarstwom domowym przekształcanie dostępu do energii elektrycznej w działalność produkcyjną, która zwiększa dochody i konsumpcję. Efekt interakcji jest szczególnie silny w gospodarkach o niższych średnich dochodach, natomiast słabnie w krajach o wyższych dochodach, gdzie systemy finansowe i energetyczne są już rozwinięte. Komplementarność maleje również w okresie pandemii COVID-19, co uwydatnia wrażliwość kanałów rozwoju na globalne wstrząsy. Artykuł stanowi wkład do literatury naukowej, dostarczając nowych dowodów na to, że wpływ dostępu do energii na ubóstwo zależy w decydującym stopniu od inkluzywności systemu finansowego. Wyniki podkreślają znaczenie zintegrowanej polityki finansowo-energetycznej dla wspierania inkluzywnego wzrostu i zrównoważonego rozwoju w gospodarkach wschodzących.

Słowa kluczowe: gospodarki BRICS, dostęp do energii, włączenie finansowe, redukcja ubóstwa, Cele zrównoważonego rozwoju

1. Introduction

Poverty reduction remains central to the global sustainable development agenda, yet progress continues to be uneven in many emerging economies where rapid economic expansion coexists with persistent deprivation. In such contexts, the ability of households to maintain and expand consumption, withstand economic shocks, and participate in productive activities is shaped not only by income growth but also by access to enabling systems that expand opportunity and reduce vulnerability. Two of the most critical systems in this regard are inclusive financial systems and modern energy infrastructure. Inclusive finance provides households and firms with access to savings, payment platforms, credit, and risk-management tools that facilitate economic participation, while reliable and affordable energy access supports productivity, health, education, and livelihood diversification. These systems are therefore central to achieving Sustainable Development Goal (SDG) 1 on poverty eradication and SDG 7 on affordable and clean energy, while also reinforcing SDG 8 on inclusive economic growth and SDG 10 on reduced inequalities.

Development finance theory emphasises that inclusive financial systems enhance the allocation of capital, strengthen risk sharing, and facilitate productive investment, thereby promoting broad-based economic participation (Demirgüç-Kunt et al., 2017). Inclusive growth perspectives further highlight that the development value of finance lies not merely in raising aggregate output but in expanding participation and improving welfare outcomes across different segments of society (Hay et al., 2020). Empirical evidence supports this view. Financial inclusion has been shown to reduce extreme poverty by enabling households to manage risks, smooth consumption, and invest in income-generating activities (Saha and Qin, 2023). The welfare benefits of financial access are also shaped by institutional and policy environments, as macroeconomic volatility and weak financial infrastructure can limit the extent to which financial systems translate into inclusive development outcomes (Davoodi, 2021). Distributional considerations are equally important, since financial inclusion tends to produce stronger poverty-reduction effects when services are effectively targeted toward disadvantaged populations such as rural households, women, and low-income groups (Okolo-Obasi et al., 2025; Kumar and Jie, 2023). Nevertheless, substantial regional variation persists, reflecting differences in financial system depth, institutional capacity, and access to financial infrastructure (Olayiwola and Akinbobola, 2022; Tadesse Tulu, 2023).

At the same time, the energy–poverty nexus literature demonstrates that access to modern energy services is a fundamental determinant of welfare and socio-economic development. Energy poverty constrains productive activities, exacerbates health risks, reinforces gender inequalities, and restricts educational attainment, thereby limiting progress toward broader development objectives (Barkat et al., 2023; Acheampong et al., 2024). Improvements in electricity access and cleaner energy sources have been shown to enhance human development outcomes by improving education and health indicators and reducing income inequality (Barkat et al., 2023), while also supporting employment creation and economic growth (Acheampong et al., 2024). However, the welfare effects of energy access depend not only on the availability of infrastructure but also on households' capacity to afford and sustain modern energy use. Financial inclusion plays an important role in this regard by easing liquidity constraints and enabling households to invest in modern energy technologies. Evidence indicates that financially included households experience significantly lower levels of energy poverty, largely because access to financial services enables them to finance electricity connections and adopt cleaner energy technologies (Sen et al., 2023; Kar and Bali, 2023). Related studies also show that households without access to financial resources often remain dependent on traditional biomass energy due to the upfront costs associated with cleaner energy technologies (Wei et al., 2025).

From a sustainable development perspective, poverty reduction cannot be effectively addressed through isolated sectoral interventions. Sustainable welfare improvements require integrated systems that simultaneously strengthen economic capabilities, social inclusion, and access to essential infrastructure. Financial inclusion expands households' capacity to mobilise resources, manage risks, and participate in economic activities, while modern energy access enhances productivity, human capital formation, and health outcomes. When these systems operate together, they create reinforcing development pathways that support long-term welfare improvements rather than short-term poverty alleviation. Within the SDG framework, this interaction reflects the structural linkages between SDG 1 (No Poverty), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 10 (Reduced Inequalities). Understanding how financial systems and energy infrastructure jointly shape welfare outcomes is therefore critical for designing integrated policies capable of delivering sustainable and inclusive development.

Despite growing interest in the individual roles of financial inclusion and energy access in reducing poverty, much of the empirical literature examines these factors separately or within region-specific contexts. Studies on financial inclusion frequently focus on poverty, inequality, or growth outcomes without incorporating energy constraints, while energy access studies often analyse welfare outcomes without accounting for households' financial capacity to adopt and sustain modern energy services. As a result, the potential complementarity between financial systems and energy infrastructure remains insufficiently explored, particularly within large and heterogeneous emerging economy groupings such as the BRICS bloc. Given the substantial variation across BRICS and BRICS Plus economies in financial development, energy infrastructure, and socio-economic conditions, examining the interaction between financial inclusion and energy access provides an important opportunity to understand how these systems jointly influence welfare outcomes.

Against this background, the broad objective of this study is to examine how financial inclusion and energy access interact to influence poverty reduction in BRICS economies. Specifically, the study seeks to examine the effect of financial inclusion on poverty reduction in BRICS economies, assess the effect of energy access on poverty reduction in BRICS economies, and analyse whether financial inclusion conditions the poverty-reducing effect of energy access in BRICS economies. These objectives give rise to three key research questions: what is the effect of financial inclusion on poverty reduction in BRICS economies; how does energy access affect poverty reduction in BRICS economies; and does financial inclusion condition the effect of energy access on poverty reduction in BRICS economies?

The study contributes to the literature in several ways. First, it advances the emerging scholarship on the finance–energy–poverty nexus by explicitly modelling the interaction between financial inclusion and energy access, thereby providing empirical evidence on whether these systems operate as complementary drivers of welfare improvement. Second, by focusing on BRICS Plus economies characterised by diverse development trajectories, financial structures, and energy systems, the analysis provides insights into how structural heterogeneity shapes the welfare implications of finance and energy policies. Finally, the study contributes to sustainable development scholarship by examining how financial systems and energy infrastructure jointly influence welfare outcomes, offering evidence on integrated policy pathways toward achieving SDG 1 and SDG 7 while supporting broader inclusive growth and inequality reduction objectives in emerging economies.

2. Literature review outline

2.1. Conceptual and theoretical framework

2.1.1. Development finance and inclusive growth perspectives

Development finance theory emphasises the central role of financial systems in fostering inclusive growth and reducing poverty by expanding access to formal financial services for households and firms traditionally excluded from the financial sector. At its core, the theory posits that efficient and inclusive financial systems enhance the allocation of capital, improve risk sharing, and facilitate productive investment, thereby supporting broad-based economic participation (Demirgüç-Kunt et al., 2017). These propositions speak directly to SDG 1 (No Poverty) by highlighting finance as a mechanism for reducing vulnerability and persistent poverty, and to SDG 8 (Decent Work and Economic Growth) through the channels of investment, productivity, and employment-linked income generation. Beyond growth, inclusive growth perspectives emphasise that the development value of finance is realised when financial expansion broadens participation and strengthens household wellbeing, rather than simply raising aggregate output (Hay et al., 2020). This focus on distributional outcomes aligns with SDG 10 (Reduced Inequalities), which foregrounds the need for development processes that expand opportunities for disadvantaged groups.

Empirical evidence reinforces the argument that the welfare consequences of financial inclusion depend on the type and quality of financial services available. Savings accounts and digital payment systems are consistently associated with positive welfare outcomes, particularly through improved transaction efficiency, consumption smoothing, and risk management, while the effects of credit access remain mixed and context dependent (Demirgüç-Kunt et al., 2017). These mechanisms are central to the poverty and vulnerability objectives embedded in SDG 1, as they enable households to manage shocks and stabilise consumption. At the same time, the degree to which these benefits materialise is shaped by macroeconomic conditions. Procyclical fiscal and monetary policies can undermine inclusive growth by amplifying economic volatility and disproportionately harming vulnerable groups (Davoodi, 2021), thereby weakening progress toward SDG 1 and SDG 10 and constraining the stability needed for sustained advancement under SDG 8.

The poverty-related impacts of financial inclusion operate through multiple interrelated transmission channels. Access to formal financial services enables households to invest in income-generating activities, manage shocks, and integrate into formal economic systems, thereby reducing vulnerability and persistent poverty traps (Saha and Qin, 2023). Cross-country evidence from 156 economies demonstrates that financial inclusion significantly reduces extreme poverty, with stronger effects observed in developing regions (Saha and Qin, 2023). These findings underscore the contribution of inclusive financial systems to advancing SDG 1, while also supporting SDG 8 through the creation of conditions that allow households to participate more effectively in economic activities. However, the literature also emphasises that distributional design matters. Poverty reduction gains are larger when financial services are directed toward disadvantaged groups, including rural households, women, and low-income populations (Okolo-Obasi et al., 2025), and when financial service provision is equitably distributed across the population (Kumar and Jie, 2023). This evidence connects strongly to SDG 10 and, where gender-targeted inclusion is emphasised, contributes to SDG 5 (Gender Equality) through improved financial agency and economic participation among women.

From a structural perspective, financial inclusion supports poverty reduction by improving resource allocation and fostering technological change rather than simply increasing savings rates (Levine, 2021). By easing credit and liquidity constraints, inclusive finance enhances productivity and sustainability, particularly for small and medium-sized enterprises (Jacob-Udeme, 2024). This emphasis on productive transformation situates financial inclusion within broader pathways to SDG 8, where decent work and inclusive economic growth depend on expanding opportunities for enterprise development and employment creation. However, the literature highlights significant regional and institutional heterogeneity. In Sub-Saharan Africa, inclusive growth has reduced poverty, yet the magnitude depends on the depth and functionality of the financial sector (Olayiwola and Akinbobola, 2022). Persistent constraints such as low account ownership and limited rural outreach continue to weaken the reach and effectiveness of financial inclusion initiatives (Tadesse Tulu, 2023). These limitations indicate that progress toward SDG 1 and SDG 10 requires more than expansion of nominal access; it requires institutional and structural environments that enable broad, reliable, and meaningful utilisation of financial services.

Overall, development finance and inclusive growth perspectives provide a framework for interpreting financial inclusion not only as an instrument for economic participation but also as a distribution-sensitive pathway to welfare improvement. Within the SDG framework, the core implication is that financial inclusion contributes to poverty reduction most effectively when it is paired with stable macroeconomic environments and institutional arrangements that ensure equitable access and effective use. This establishes the conceptual foundation for examining how financial inclusion interacts with other development inputs, notably energy access, in shaping welfare outcomes across emerging economies.

2.1.2. Energy–poverty nexus and welfare transmission channels

The energy–poverty nexus framework conceptualises energy access as a multidimensional determinant of welfare, extending beyond physical availability to encompass affordability, reliability, and quality of supply. Energy poverty constrains human development by limiting productive activities, exacerbating health risks, reinforcing gender inequalities, and restricting educational attainment. These conceptual claims align centrally with SDG 7 (Affordable and Clean Energy) and reinforce the interlinkages between energy access and poverty outcomes under SDG 1, while extending to human capability goals such as SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education). A growing body of empirical literature confirms that improved access to modern energy services is a critical driver of socio-economic development and poverty reduction in developing and emerging economies (Barkat et al., 2023; Acheampong et al., 2024). Importantly, this literature frames energy poverty not merely as an infrastructure deficit but as a structural constraint that limits inclusive development and undermines welfare sustainability.

Large-scale cross-country studies provide robust evidence of the welfare transmission channels linking energy access to broader development outcomes. Analysis of 109 developing countries shows that enhanced energy access contributes to improved human development outcomes through reductions in income inequality and improvements in education and health indicators (Barkat et al., 2023). Panel evidence from 98 countries further demonstrates that electricity access and cleaner energy sources promote employment creation, gender parity in education, and overall economic growth (Acheampong et al., 2024). These findings demonstrate how energy access advances SDG 7 while simultaneously strengthening the inclusive growth objectives of SDG 8, reducing inequalities under SDG 10, and supporting progress toward SDG 4 and SDG 3 through education and health pathways.

The literature also highlights that the welfare impacts of energy access are shaped by financial capacity, suggesting that energy and finance interact in ways that can either reinforce or weaken poverty reduction. Financial inclusion improves households' capacity to afford and invest in modern energy services, thereby reducing both acute and chronic forms of energy poverty. Household-level evidence indicates that financially included households experience between 13 and 33 per cent lower rates of acute and severe energy poverty compared to financially excluded households (Sen et al., 2023). Cross-country studies in Sub-Saharan Africa similarly confirm that access to financial services significantly lowers energy poverty by easing liquidity constraints and enabling energy-related investments (Kar and Bali, 2023). These mechanisms highlight how financial inclusion supports SDG 7 not only through energy affordability but also through the capacity to sustain modern energy use over time, while reinforcing SDG 1 by reducing energy-driven deprivation and vulnerability.

The welfare implications of reduced energy poverty extend to broader dimensions of multidimensional poverty. Improved energy access supported by inclusive financial systems enhances health outcomes, reduces time poverty, and expands opportunities for microenterprise development (Manko and Watkins, 2022). These channels align with SDG 3 and SDG 8, while reductions in time poverty and gendered burdens of energy deprivation speak to SDG 5 in contexts where women bear disproportionate costs of biomass collection and exposure to indoor air pollution. Complementary evidence shows an inverse relationship between renewable energy utilisation and poverty, implying that cleaner energy transitions can strengthen economic conditions when supported by appropriate financial and institutional frameworks (Li and Qamruzzaman, 2023). This perspective connects to the broader sustainability agenda where SDG 7 interacts with structural transformation and resilience objectives. Recent studies further identify financial inclusion, renewable energy deployment, human capital, and global integration as key determinants of energy poverty reduction (Khan et al., 2023), reinforcing the importance of integrated policy systems in advancing SDG-linked welfare outcomes.

Taken together, the theoretical and empirical literature highlights the interconnected nature of financial inclusion, energy access, and poverty reduction. Energy access improves welfare through productivity, health, and human capital channels, yet these benefits depend on households' capacity to afford, sustain, and productively utilise energy services. Financial inclusion strengthens this capacity by easing liquidity constraints and enabling investment in energy technologies. Within the SDG framework, this interdependence suggests that sustained progress toward SDG 1 and SDG 7 is more likely when financial and energy systems are developed as complementary pillars of inclusive development, with broader co-benefits for SDG 8, SDG 10, and human development outcomes embedded in SDG 3 and SDG 4.

2.2. Financial inclusion and poverty reduction in BRICS economies

2.2.1. Financial access, digital finance, and household welfare

The literature increasingly recognises financial inclusion as a critical mechanism for poverty reduction and household welfare improvement in BRICS economies, operating through income stabilisation, consumption smoothing, entrepreneurship, and enhanced financial resilience. These mechanisms directly contribute to the objectives of Sustainable Development Goal 1 (No Poverty) by improving households' capacity to manage income volatility and maintain consumption. At the same time, expanded access to financial services facilitates economic participation and productive investment, reinforcing SDG 8 (Decent Work and Economic Growth) and SDG 10 (Reduced Inequalities) through broader inclusion in formal financial systems.

Cross-country evidence provides strong support for this relationship. Using data from 156 countries, Saha and Qin (2023) show that financial inclusion significantly reduces extreme poverty, with effects that are particularly pronounced in developing economies. Their findings suggest that formal financial access enables poor households to participate more effectively in economic activities, reduces transaction costs, and improves market integration, thereby mitigating income volatility and vulnerability. These outcomes highlight the role of inclusive financial systems in supporting the achievement of SDG 1 while strengthening resilience in the face of economic shocks.

Within BRICS economies, digital finance has emerged as a particularly influential dimension of financial inclusion. Digital financial inclusion expands access to financial services by lowering entry barriers, reducing costs, and improving outreach to previously excluded populations. Empirical studies demonstrate that digital financial inclusion is positively associated with household well-being and poverty reduction, with stronger effects observed among lower-income and less-educated households (Du et al., 2023). Similarly, Lin and Zhang (2023) find that digital finance enhances fairness in income distribution, increases household consumption, and contributes to poverty reduction through improved financial participation. Evidence from Sodokin et al. (2023) further shows that digital finance promotes household investment in physical assets and improves financial practices, reinforcing its role in strengthening long-term welfare outcomes. These dynamics also align with SDG 9 (Industry, Innovation and Infrastructure), as digital financial platforms represent technological innovations that broaden access to financial services.

Recent evidence also highlights the importance of financial access in enabling welfare-enhancing energy investments, particularly for poor households facing liquidity constraints. Wei et al. (2025) demonstrate that the adoption of clean cooking technologies is critically shaped by households' access to finance, as high upfront costs associated with modern cooking solutions such as LPG stoves, electric cookers, and biogas systems pose significant barriers, especially in rural and informal settings. Their findings show that households lacking access to formal or semi-formal financial mechanisms are unable to smooth consumption or mobilise capital for energy investments, thereby remaining dependent on traditional biomass. Conversely, households with stable income streams or informal savings mechanisms exhibit a significantly higher likelihood of adopting clean cooking technologies, suggesting that financial access improves welfare not only through direct income effects but also by relaxing credit constraints that impede productive and health-enhancing investments (Wei et al., 2025). These insights demonstrate how financial inclusion can facilitate progress toward SDG 7 (Affordable and Clean Energy) alongside SDG 1, by enabling households to invest in cleaner and more efficient energy technologies.

A growing strand of the literature focuses on specific welfare transmission channels linking financial inclusion to household outcomes. Song et al. (2024) demonstrate that digital inclusive finance significantly smooths household consumption volatility, primarily by promoting entrepreneurship and reducing income instability. This stabilising effect becomes especially important during periods of economic or health-related shocks. In line with this, Liu et al. (2024) show that digital financial inclusion improves consumption smoothing during health shocks, highlighting its role in enhancing household resilience. At the micro level, Xie and Chen (2024) provide evidence that digital financial literacy promotes household entrepreneurship, with particularly strong effects in rural and underdeveloped regions where traditional financial services are limited. These channels collectively support SDG 8 by promoting entrepreneurship and economic participation while reinforcing SDG 1 through improved household welfare.

These findings are reinforced by earlier work emphasising the importance of financial and digital literacy in translating access into meaningful welfare gains. Lyons et al. (2019) argue that financial inclusion yields stronger poverty-reducing effects when accompanied by adequate financial capability, which enables households to make informed decisions, manage risks, and utilise financial products effectively. However, the literature also cautions against unqualified optimism. Yue et al. (2022) note that expanded credit access through digital platforms may increase household debt risks if not properly regulated, suggesting that the welfare effects of digital finance depend critically on institutional safeguards and responsible financial product design. Moreover, the concentration of empirical evidence in China and selected developing regions raises concerns about the generalisability of these findings across all BRICS economies, underscoring the need for broader comparative analyses.

2.2.2. Distributional effects and heterogeneity in poverty outcomes

Despite strong aggregate evidence, the poverty-reducing effects of financial inclusion are far from uniform across BRICS economies. A substantial body of research documents pronounced heterogeneity in outcomes across income groups, gender, and institutional contexts. Park and Mercado (2018) find that financial inclusion is associated with significantly lower poverty levels in high- and middle-high-income economies, while the relationship is weak or insignificant in low-income settings, underscoring the importance of structural and institutional conditions in shaping inclusion outcomes. Such disparities highlight the relevance of SDG 10, which emphasises reducing inequalities within and between countries.

Gender, income, and spatial disparities further condition these effects. Saha and Qin (2023) show that unequal access to financial services generates differential poverty impacts, with women and poorer households often benefiting less from financial inclusion initiatives. Recent evidence by Wei et al. (2025) reinforces this distributional perspective by demonstrating pronounced heterogeneity in access to clean cooking energy across income groups, gender, and locations. Their findings indicate that poorer and rural households face the greatest barriers to energy transitions, not due to the absence of technology, but because of unequal financial capacity that prevents low-income households from moving away from traditional biomass fuels. Female-headed households are shown to be particularly vulnerable, given their disproportionate exposure to time poverty and health risks associated with polluting cooking methods (Wei et al., 2025). These insights highlight how financial exclusion operates alongside energy deprivation to reinforce persistent poverty traps, thereby linking the literature to SDG 5 (Gender Equality) and SDG 7 (Affordable and Clean Energy).

At the BRICS level, institutional quality emerges as a critical moderating factor. Onatunji (2025) demonstrates that financial inclusion contributes to income inequality reduction in BRICS economies, but the strength of this effect depends on the quality of institutions that facilitate equitable access and effective use of financial services. Complementary evidence from Pandey (2023) suggests that financial inclusion enhances human development outcomes, particularly for women, reinforcing its potential role in addressing gender-based welfare disparities. These findings further illustrate the intersection between financial inclusion and the broader goals of SDG 5, SDG 8, and SDG 10.

Other studies caution that financial inclusion may disproportionately favour wealthier households if structural inequalities are left unaddressed. Ndlovu and Toerien (2020) show that the benefits of financial inclusion tend to be higher at the upper end of the wealth distribution and very limited among the poorest households. This distributional bias reflects persistent constraints such as discriminatory lending practices, low usage intensity among disadvantaged groups, and gaps in financial and digital literacy. Wei et al. (2025) further show that climate vulnerability amplifies these inequalities, as households exposed to climatic shocks without financial buffers are more likely to revert to polluting fuels following income disruptions. Such reversals erode prior welfare gains and entrench poverty, illustrating how financial exclusion interacts with environmental vulnerability to produce persistent heterogeneity in poverty outcomes.

Taken together, the literature suggests that financial inclusion in BRICS economies generates meaningful welfare gains, but these gains are highly context dependent. Unequal access to finance, limited intensity of use, climate exposure, and institutional weaknesses constrain the inclusiveness of financial systems and weaken their poverty-reducing potential. As such, expanding financial access alone is insufficient. Effective poverty reduction requires targeted and well-regulated inclusion strategies that address structural and gender inequalities, strengthen institutional capacity, and enhance households' financial resilience in the face of environmental and economic shocks.

2.3. Energy access, energy poverty and socio-economic outcomes

2.3.1. Electricity access, clean cooking, and living standards

Energy access is widely conceptualised as a foundational component of development because it shapes basic living conditions and human capabilities through health, education, and time-use pathways (Rao and Pachauri, 2017). These relationships directly align with SDG 7, which seeks universal access to affordable, reliable, and modern energy services, while simultaneously reinforcing broader development goals including SDG 3, SDG 4, and SDG 5.

Empirical evidence links electricity access to measurable improvements in population health outcomes. Byaro et al. (2024) show that electricity access is associated with reductions in infant, child, and maternal mortality across different population quantiles in Sub-Saharan Africa. Parallel evidence from the clean cooking literature demonstrates that reliance on traditional biomass fuels is closely connected to multidimensional deprivation. Wei et al. (2025) show that limited access to clean cooking energy is a core driver of multidimensional poverty due to the health, productivity, and time burdens associated with biomass dependence.

Beyond health outcomes, energy access affects time allocation and household decision-making in ways that shape welfare trajectories. Belmin et al. (2021) find that improved energy access yields time savings and health improvements and is associated with changes in women's reproductive choices that contribute to declining birth rates. These outcomes highlight the broader welfare implications of energy access for gender equality, human capital development, and inclusive growth.

However, the literature consistently cautions that welfare gains from energy access depend not only on infrastructure availability but also on affordability and reliability. Wei et al. (2025) argue that affordability constraints often prevent poor households from fully benefiting from electricity infrastructure. As such, energy poverty is increasingly conceptualised as the inability to sustain modern energy use at levels consistent with basic welfare needs rather than simply the absence of electricity connections.

2.4. Nexus between financial inclusion, energy access and poverty reduction

2.4.1. Complementarities between finance and energy access

An emerging body of literature conceptualises financial inclusion and energy access as mutually reinforcing pathways through which poverty reduction can be achieved. Inclusive financial systems shape households' capacity to access, afford, and sustain modern energy use, while improved energy access enhances the productivity and welfare returns to financial participation. These complementarities illustrate the integrated nature of SDG 1, SDG 7, and SDG 8, which collectively emphasise the importance of inclusive economic systems and universal energy access for sustainable development.

Financial inclusion lowers affordability barriers to modern energy uptake by relaxing liquidity constraints. Evidence from energy-poor countries shows that access to financial services significantly reduces energy poverty by enabling households to mobilise capital for electricity connections and cleaner cooking solutions (Kar and Bali Swain, 2024). Similarly, Said and Acheampong (2023) demonstrate that financial inclusion contributes to improved energy access across Sub-Saharan African countries.

Digital financial inclusion further strengthens these complementarities by expanding the reach and flexibility of financial services. Wang and Fu (2022) find that digital financial inclusion mitigates poverty vulnerability by improving agricultural productivity and stimulating entrepreneurial activities, which in turn increase households' ability to afford modern energy services. Complementary studies show that electricity access can reinforce financial participation by improving educational opportunities and economic productivity (Acheampong et al., 2024).

Nevertheless, the literature also highlights uneven benefits and distributional concerns. Financial services often disproportionately benefit wealthier households if inclusion strategies are not carefully targeted (Ndlovu and Toerien, 2020). This underscores the importance of context-sensitive financial and energy policies capable of addressing structural inequalities while supporting inclusive development outcomes.

3. Materials and methods

3.1. Research design

This study employs a quantitative panel research design to investigate the relationship between financial inclusion, energy access, and poverty reduction across BRICS Plus economies. The panel framework is particularly suitable for analysing macroeconomic relationships that evolve over time while differing across countries. By combining cross-sectional and time-series dimensions, the approach allows the analysis to capture both temporal dynamics and cross-country heterogeneity in welfare outcomes, financial systems, and energy infrastructure development. It also enables the control of unobserved country-specific factors, such as institutional quality, structural economic characteristics, and long-standing policy environments, that may influence poverty dynamics but remain relatively stable over time.

The research design further facilitates the estimation of relationships between key development indicators while accounting for the complex interactions that often characterise macroeconomic and infrastructure-driven development processes. In particular, the study goes beyond assessing the independent effects of financial inclusion and energy access by explicitly examining their joint influence on household welfare. To achieve this, an interaction term between financial inclusion and energy access is incorporated into the empirical model. This specification allows the analysis to test whether the welfare implications of expanded energy access depend on the availability and depth of financial systems. The underlying premise is that households and firms are more likely to translate energy infrastructure into productive and consumption-enhancing activities when they have access to formal financial services that facilitate credit access, savings mobilisation, and efficient payment mechanisms.

The panel research design also allows the study to evaluate structural heterogeneity across countries at different stages of economic development. By incorporating income-group disaggregation and regime-specific estimations, the design makes it possible to assess whether the finance–energy–poverty relationship varies across development contexts and macroeconomic conditions. This is particularly important in the BRICS Plus setting, where countries differ substantially in terms of financial sector maturity, energy infrastructure coverage, and welfare conditions.

Conceptually, the study is closely aligned with the global sustainable development agenda. The analysis directly relates to Sustainable Development Goal 1 (No Poverty) by examining the determinants of household welfare, and to Sustainable Development Goal 7 (Affordable and Clean Energy) through the focus on access to modern energy services. At the same time, the research contributes to the broader discourse on inclusive development captured in Sustainable Development Goal 8 (Decent Work and Economic Growth) and Sustainable Development Goal 10 (Reduced Inequalities), given the central roles of financial systems, infrastructure provision, and macroeconomic stability in promoting equitable and sustained improvements in living standards.

3.2. Data sources, scope of study, and variable measurement

The empirical analysis employs a balanced annual panel dataset covering ten BRICS Plus economies over the period 2004–2023. The BRICS Plus sample reflects substantial heterogeneity in economic structure and development levels. Specifically, the group comprises two High-Income Countries, namely Saudi Arabia and the United Arab Emirates; five Upper-Middle-Income Countries, namely Brazil, China, Iran, Russia, and South Africa; and three Lower-Middle-Income Countries, namely Egypt, Ethiopia, and India. This income-based diversity provides a suitable framework for examining how financial inclusion and energy access interact to influence poverty reduction across different stages of economic development. The classification is particularly relevant for assessing structural heterogeneity in financial systems, infrastructure quality, institutional capacity, and welfare outcomes.

The sample period permits a structured comparison between the pre-COVID era (2004–2019) and the COVID period (2020–2023), allowing the study to capture potential structural disruptions in welfare, energy access, and financial systems within and across income groups. All data are sourced from internationally harmonised and methodologically consistent databases, including the World Development Indicators, the Global Findex Database, the International Energy Agency, and the United Nations Human Development Reports. The selection of variables aligns explicitly with the study's objective, titled *Financial Inclusion, Energy Access, and Poverty Reduction in BRICS Plus Economies*, and with the Sustainable Development Goals framework.

Poverty reduction is proxied by household final consumption expenditure per capita. This measure reflects improvements in living standards and welfare and serves as an inverse proxy for poverty due to the absence of consistent poverty headcount and poverty gap data across the full sample. Higher consumption per capita signals welfare improvement and poverty alleviation, directly aligning with SDG 1 on ending poverty and SDG 10 on reducing inequalities.

Financial inclusion is measured using a composite index constructed through Principal Component Analysis. The index combines automated teller machines per 100,000 adults and commercial bank branches per 100,000 adults. These indicators capture physical access to financial services and the breadth of formal financial infrastructure. The indicators are standardised prior to PCA, and the first principal component is retained and normalised between 0 and 1. Financial inclusion supports SDG 1 by enhancing economic resilience, SDG 8 by promoting inclusive economic participation, and SDG 9 through strengthening financial infrastructure.

Energy access is proxied by access to electricity as a percentage of the population, capturing the availability of modern energy services necessary for productive activity and household welfare. Access to electricity directly aligns with SDG 7 on affordable and clean energy and indirectly supports SDG 1 and SDG 8 through productivity and income effects. The interaction term (FI_EN), constructed as the product of financial inclusion and energy access, captures complementarities between financial systems and energy infrastructure. This interaction reflects

integrated progress toward SDGs 1, 7, 8, and 9 by examining whether financial development enhances the poverty-reducing impact of energy access.
The control variables account for macroeconomic and structural determinants of welfare. GDP per capita captures the level of economic development and aligns with SDG 8. Education, measured by mean years of schooling, reflects human capital accumulation consistent with SDG 4 on quality education and SDG 8 on productive employment. Urbanisation captures demographic transition and infrastructure concentration, linking to SDG 11 on sustainable cities and SDG 9 on infrastructure development. Inflation represents macroeconomic stability, supporting SDG 8 by preserving purchasing power and economic stability. Trade openness captures integration into global markets, aligning with SDG 8 and SDG 17 on global partnerships.
A detailed description of all variables, measurement approaches, data sources, and associated SDGs is presented in Table 1.

Table 1. Variables description, measurement and sources, source: Author's compilation

Variable	Description	Measurement / Proxy	Data Source	SDG Linked
Poverty Reduction (POV)	Extent of poverty reduction	Households and NPISHs Final consumption expenditure per capita (constant 2015 US$)	World Bank, WDI	SDG 1 (No Poverty); SDG 10 (Reduced Inequalities)
Financial Inclusion (FI_Index)	Captures overall access to and usage of financial services	PCA of ATM density (per 100,000 adults) and Commercial bank branches (per 100,000 adults); first principal component normalised (0–1)	World Bank, WDI	SDG 1; SDG 8 (Decent Work and Economic Growth); SDG 9 (Industry, Innovation and Infrastructure)
Energy Access (EN_ACC)	Availability of modern energy services	Access to electricity (% of population)	World Bank, WDI	SDG 7 (Affordable and Clean Energy); SDG 1; SDG 8
FI_EN	Complementarity between finance and energy	Product of Financial Inclusion Index and Energy Access	Computed by author	SDG 1; SDG 7; SDG 8; SDG 9
Economic Growth (GDPPC)	Level of economic development	GDP per capita (constant US$)	World Bank, WDI	SDG 8
Education (EDU)	Human capital development	Mean Years of Schooling	United Nations Human Development Reports	SDG 4 (Quality Education); SDG 8
Urbanisation (URB)	Population concentration and structural transformation	Urban population (% of total population)	World Bank, WDI	SDG 11 (Sustainable Cities and Communities); SDG 9
Inflation (INF)	Macroeconomic stability	Annual percentage change in CPI; computed as ln(CPI_it) − ln(CPI_it−1)	World Bank, WDI	SDG 8
Trade Openness (OPEN)	Degree of integration into global markets	Trade (% of GDP)	World Bank, WDI	SDG 8; SDG 17 (Partnerships for the Goals)

3.3. Justification of country selection

The selection of BRICS Plus economies is guided by a combination of institutional relevance, macroeconomic comparability, and data integrity considerations. The BRICS Plus grouping comprises ten large and strategically influential emerging and energy-producing economies that play significant roles in global output, trade, energy markets, and development finance. The sample includes Saudi Arabia and the United Arab Emirates as High-Income Countries; Brazil, China, Iran, Russia, and South Africa as Upper-Middle-Income Countries; and Egypt, Ethiopia, and India as Lower-Middle-Income Countries. This composition ensures representation across different stages of economic development while maintaining comparable macroeconomic scale and structural significance within the global economy.
A key selection criterion is the availability of consistent and comparable annual data for poverty-related welfare measures, financial inclusion indicators, energy access, and macroeconomic controls over the period 2004–2023. The requirement of a balanced panel structure is central to the econometric strategy, particularly for fixed-effects estimation and robust covariance correction. Ensuring that each country has complete data for the full sample period enhances comparability, reduces potential biases arising from unbalanced panels, and supports reliable sub-sample estimation for the pre-COVID and COVID periods.

The income-based diversity of the BRICS Plus economies provides an appropriate empirical framework for analysing how financial inclusion and energy access interact to influence poverty reduction across different development contexts. High-income economies typically exhibit advanced financial systems and near-universal energy access, while lower-middle-income economies often face infrastructure gaps and financial exclusion constraints. Upper-middle-income economies occupy an intermediate position characterised by rapid structural transformation. This variation allows the study to capture heterogeneity in financial depth, infrastructure quality, institutional capacity, and welfare outcomes. By incorporating countries at different income levels, the analysis can assess whether the complementarity between financial inclusion and energy access is stronger in certain structural environments, thereby addressing cross-country heterogeneity explicitly rather than assuming uniform effects.

At the same time, recent geopolitical developments necessitate careful consideration of Russia's inclusion in the empirical analysis. The Russia–Ukraine conflict has generated substantial economic disruptions, including financial sanctions, restrictions on cross-border transactions, volatility in energy exports, and shifts in capital flows. These disruptions raise legitimate concerns regarding macroeconomic stability, measurement reliability, and comparability of financial and trade data during the conflict period. In view of these considerations, Russia is excluded from the main estimations to prevent potential distortion of parameter estimates arising from conflict-related structural breaks and data uncertainty. However, Russia is incorporated in separate robustness checks to evaluate whether its inclusion materially alters the results.

The Russia–Ukraine conflict is treated analytically as an exogenous geopolitical shock affecting global energy markets, financial systems, and trade networks. The conflict has implications for energy prices, supply chains, inflationary pressures, and financial integration, all of which can indirectly influence poverty dynamics in interconnected economies. By acknowledging the conflict as an external shock, the study recognises its potential to affect financial inclusion through sanctions-induced financial fragmentation, energy access through supply disruptions and price volatility, and poverty outcomes through inflation and income shocks. This contextual framing strengthens the interpretative clarity of the results and ensures that structural disruptions are explicitly accounted for in the empirical strategy.

3.4. Empirical model specification

To examine the effects of financial inclusion and energy access on poverty reduction, the study specifies two related panel models capturing both individual and joint effects. The baseline specification estimates the direct contributions of financial inclusion and energy access to poverty reduction while controlling for macroeconomic conditions:

$$Pov_{it} = \alpha + \beta_1 FI_{it} + \beta_2 ENERGY\_ACC_{it} + \beta_3 GDPPC_{it} + \beta_4 INF_{it} + \beta_5 OPEN_{it} + \beta_6 URB_{it} + \beta_7 EDU_{it} + \mu_i + \lambda_t + \varepsilon_{it}.$$

To test whether financial inclusion enhances the poverty-reducing impact of energy access, an interaction term is introduced:

$$Pov_{it} = \alpha + \beta_1 FI_{it} + \beta_2 ENERGY\_ACC_{it} + \beta_3 (FI_{it} \times EA_{it}) + \beta_4 GDPPC_{it} + \beta_5 INF_{it} + \beta_6 OPEN_{it} + \beta_7 URB_{it} + \beta_8 EDU_{it} + \mu_i + \lambda_t + \varepsilon_{it}.$$

In the interaction model, $\beta_3$captures the complementary effect between financial inclusion and energy access. A negative and statistically significant coefficient is interpreted as evidence that higher financial inclusion strengthens the poverty-reducing impact of energy access. The inclusion of country fixed effects (μ_i)accounts for unobserved time-invariant heterogeneity, while time effects (λ_t)control for common shocks and global trends affecting all BRICS economies.

3.5. Diagnostic and pre-estimation tests

Prior to model estimation, a series of diagnostic tests were conducted to assess multicollinearity, cross-sectional dependence, and heteroskedasticity. These tests provide guidance on the appropriate estimation strategy and the reliability of statistical inference.

Multicollinearity was examined using the Variance Inflation Factor. The mean VIF is 7.21, which falls below the conventional threshold of 10 and suggests that multicollinearity is not severe in the model. The highest VIF values are observed for lnURB at 16.72 and lnGDPPC at 13.74, indicating relatively strong linear association between urbanisation and income levels. This pattern reflects the structural interdependence commonly observed in developing and emerging economies, where economic expansion is closely linked to urban concentration. lnEDU records a VIF of 7.60, indicating moderate collinearity. Energy access shows a VIF of 5.61, trade openness 3.20, and the financial inclusion index 2.41, all within acceptable limits. Inflation exhibits the lowest VIF at 1.17, suggesting minimal linear dependence with other regressors. Overall, although development-related variables display some degree of co-movement, the magnitude does not appear sufficiently large to distort coefficient stability or invalidate inference.

Cross-sectional dependence was evaluated using Pesaran's CD test. The test statistic of 1.084 with a probability value of 0.2784 indicates that the null hypothesis of cross-sectional independence cannot be rejected at conventional significance levels. The average absolute off-diagonal correlation of 0.345 suggests moderate contemporaneous correlation across cross-sectional units. However, this level is not statistically significant and does not indicate the dominance of pervasive common shocks. The result supports the use of standard panel estimation techniques without immediate correction for cross-sectional dependence.

Heteroskedasticity was assessed using the Breusch–Pagan/Cook–Weisberg test. The test yields a chi-square statistic of 12.51 with a probability value of 0.0004. The null hypothesis of constant variance is therefore rejected at the 1 per cent level, indicating the presence of heteroskedasticity in the residuals of the baseline specification. This finding implies that conventional standard errors may be biased, and robust or heteroskedasticity-consistent standard errors are required to ensure valid statistical inference.

Taken together, the diagnostics reveal moderate but manageable multicollinearity, no statistically significant cross-sectional dependence, and clear evidence of heteroskedasticity. These results justify the adoption of robust inference procedures in subsequent estimations to enhance reliability and econometric consistency.

3.6. Estimation techniques

Given the structure of the panel, comprising ten BRICS Plus economies observed over a relatively long-time horizon, the empirical analysis adopts a two-way fixed-effects estimator as the baseline specification. The BRICS Plus grouping expands beyond the original five members and reflects substantial structural diversity in income levels, institutional quality, and development trajectories. The two-way fixed-effects framework controls for unobserved country-specific, time-invariant characteristics as well as common time shocks that may simultaneously influence poverty, financial inclusion, energy access, and other macroeconomic conditions across the sample.

The empirical strategy proceeds in two stages. First, a baseline model is estimated to assess the direct effects of energy access and financial inclusion on poverty. Second, an interaction model is estimated by introducing the multiplicative term between financial inclusion and energy access (FI_EN). This interaction specification evaluates whether financial inclusion conditions the poverty-reducing impact of energy access. The inclusion of the interaction term allows for the possibility that improvements in energy access may generate stronger poverty-reduction effects in economies where financial systems are deeper and more inclusive, thereby capturing complementarity between infrastructure and financial development.

Although Pesaran's cross-sectional dependence test does not reject the null hypothesis of independence at conventional levels, the average cross-sectional correlation of 0.345 suggests moderate co-movement among the BRICS Plus economies. Furthermore, the Breusch–Pagan/Cook–Weisberg test confirms the presence of heteroskedasticity. These diagnostic results indicate that conventional fixed-effects standard errors would be inappropriate and could lead to biased inference.

Accordingly, the baseline fixed-effects estimates are reported with Driscoll–Kraay standard errors. This approach provides robustness to heteroskedasticity, serial correlation, and general forms of cross-sectional dependence. It is particularly suitable for macro-panel data with a limited cross-sectional dimension such as the present sample of ten countries. By correcting the variance–covariance matrix non-parametrically, Driscoll–Kraay ensures that statistical significance is not overstated due to residual temporal or cross-sectional correlation.

To assess the stability of inference under an alternative covariance estimator, Panel-Corrected Standard Errors are additionally reported as a robustness check. PCSE adjusts the estimated variance–covariance matrix for heteroskedasticity and contemporaneous correlation across panels without imposing a fully specified parametric structure on the error process. In small-N macro panels, PCSE provides a conservative and transparent correction that complements the Driscoll–Kraay approach. Consistency in coefficient signs and statistical significance across Driscoll–Kraay and PCSE estimates strengthens confidence that the results are not sensitive to a particular method of variance correction.

Beyond the pooled BRICS Plus analysis, a disaggregated estimation is conducted based on income classification. The sample is categorised into high-income countries, upper-middle-income countries, and lower-middle-income countries using the World Bank's classification. This income-based stratification allows for the examination of heterogeneity in the poverty effects of energy access, financial inclusion, and their interaction. Given differences in institutional capacity, financial depth, and infrastructure quality across income groups, the magnitude and significance of the interaction effect may vary systematically. Estimating the models separately for each income category provides insight into whether the complementarity between financial inclusion and energy access is stronger in certain development contexts.

Finally, in line with the study's emphasis on structural shifts during the pandemic, both the baseline and interaction models are estimated separately for the pre-COVID period from 2004 to 2019 and the COVID era from 2020 to 2023 using the same fixed-effects framework with Driscoll–Kraay and PCSE corrections. This sub-sample analysis enables a direct assessment of whether the poverty effects of energy access, financial inclusion, and their complementarity differ across distinct macroeconomic regimes within the BRICS Plus.

4. Results and discussion

4.1. Presentation of results

4.1.1. Descriptive statistics

Table 2 presents descriptive statistics for the full sample and for income-disaggregated sub-samples: Upper-Middle-Income Countries (UMICs), Lower-Middle-Income Countries (LMICs), and High-Income Countries (HICs). The poverty proxy (POV), measured by household final consumption expenditure per capita aligns with SDG 1 and displays substantial dispersion across the BRICS Plus economies, indicating marked inequality in welfare conditions within the bloc. The full-sample mean is 6,016.23, accompanied by a very large standard deviation of 7,095.90, and an extensive range from 357.06 to 38,678.10. This spread implies that average welfare improvements are unevenly distributed across countries, with some economies exhibiting consumption levels consistent with relatively low poverty exposure, while others remain characterised by pronounced deprivation and limited household purchasing capacity. From a poverty-reduction perspective, the magnitude of dispersion suggests that BRICS Plus cannot be treated as a uniform development group, and that aggregate estimates may conceal important distributional and structural differences in welfare dynamics.

The income-disaggregated statistics reveal a clear development gradient in welfare. High-Income Countries record by far the highest average POV at 16,541.86, reflecting stronger consumption capacity and comparatively lower poverty intensity. Upper-Middle-Income Countries follow with a mean of 3,857.83, indicating intermediate welfare conditions consistent with economies undergoing structural transformation but still facing notable welfare gaps. Lower-Middle-Income Countries report the lowest mean at 2,596.50, reinforcing the presence of deeper poverty challenges, weaker consumption resilience, and greater vulnerability to adverse macroeconomic and energy shocks. The large within-group variation among LMICs, reflected in the wide range from 357.06 to 12,791.10, further indicates that even among lower-middle-income economies, welfare conditions are highly uneven. This heterogeneity matters for inference because it implies that the welfare returns to financial inclusion and energy access are likely to differ across income groups due to differences in baseline deprivation, institutional capacity, and the ability of households to translate access improvements into sustained consumption gains.

The poverty proxy (POV), measured by household final consumption expenditure per capita, displays substantial dispersion across the BRICS Plus economies, indicating marked inequality in welfare conditions within the bloc. The full-sample mean is 6,016.23, accompanied by a very large standard deviation of 7,095.90, and an extensive range from 357.06 to 38,678.10. This spread implies that average welfare improvements are unevenly distributed across countries, with some economies exhibiting consumption levels consistent with relatively low poverty exposure, while others remain characterised by pronounced deprivation and limited household purchasing capacity. From a poverty-reduction perspective, the magnitude of dispersion suggests that BRICS Plus cannot be treated as a uniform development group, and that aggregate estimates may conceal important distributional and structural differences in welfare dynamics.

The income-disaggregated statistics reveal a clear development gradient in welfare. High-Income Countries record by far the highest average POV at 16,541.86, reflecting stronger consumption capacity and comparatively lower poverty intensity. Upper-Middle-Income Countries follow with a mean of 3,857.83, indicating intermediate welfare conditions consistent with economies undergoing structural transformation but still facing notable welfare gaps. Lower-Middle-Income Countries report the lowest mean at 2,596.50, reinforcing the presence of deeper poverty challenges, weaker consumption resilience, and greater vulnerability to adverse macroeconomic and energy shocks. The large within-group variation among LMICs, reflected in the wide range from 357.06 to 12,791.10, further indicates that even among lower-middle-income economies, welfare conditions are highly uneven. This heterogeneity matters for inference because it implies that the welfare returns to financial inclusion and energy access are likely to differ across income groups due to differences in baseline deprivation, institutional capacity, and the ability of households to translate access improvements into sustained consumption gains.

Energy access (EN_ACC), aligned with SDG 7 and closely linked to welfare improvements under SDG 1, is high on average (89.89 per cent) but varies markedly across income categories. HICs exhibit near-universal access (mean 100.00, negligible dispersion), UMICs also show high access (96.32), while LMICs lag behind substantially (72.46) with a wide spread from 14.00 to 100.00. The extreme lower bound highlights persistent energy deprivation pockets within LMICs, reinforcing the study's motivation to evaluate the welfare consequences of expanding electricity access, and the extent to which such gains are conditioned by the inclusiveness of financial systems.

Financial inclusion (FI_Index), constructed from financial access infrastructure and linked to SDG 1, SDG 8, and SDG 9, shows systematic differences across income groups. The full-sample mean is 0.32, with UMICs exhibiting the highest average inclusion (0.46), HICs a moderate level (0.28), and LMICs the lowest (0.13). The low mean and narrow range in LMICs (0.00–0.28) indicate limited financial penetration, which is central to the study's interaction hypothesis: if energy access enables productivity and welfare gains, those gains may be constrained where households and firms face barriers to savings, credit, payments, and risk management. This provides a strong descriptive rationale for estimating an interaction term between energy access and financial inclusion (FI_EN) in the main models.

The macroeconomic controls also display economically meaningful heterogeneity. GDP per capita (GDPPC), linked to SDG 8, averages 11,043.04 in the full sample but ranges from 267.92 to 56,630.00. HICs report a mean of 34,392.29, UMICs 7,256.73, and LMICs 1,787.39. Trade openness (TRADE/OPEN), linked to SDG 8 and SDG 17, averages 59.50 but is considerably higher in HICs (113.75), reflecting stronger integration into global markets. Urbanisation (URB), associated with SDG 11 and SDG 9, shows a clear gradient from LMICs (31.25) to UMICs (69.77) and HICs (83.30), suggesting differing settlement structures and infrastructure concentration. Education (EDU), aligned with SDG 4 and SDG 8, also varies sharply, with LMICs averaging 5.35 years compared with UMICs (9.46) and HICs (10.25). Inflation (INF), a macroeconomic stability indicator relevant for SDG 8, is highest among LMICs (12.01), implying stronger price pressures and potential welfare erosion channels that may weaken poverty-reduction gains from both finance and energy access.

Overall, Table 2 confirms substantial cross-country and cross-income heterogeneity in welfare, infrastructure, and financial depth. This reinforces the study's decision to complement pooled estimations with income-disaggregated models to examine whether the finance–energy complementarity in poverty reduction differs across stages of development.

Table 2. Descriptive statistics, source: Author's computation

Variable	Full Sample	UMICs	LMICs	HICs
POV	6016.23 (7095.90) [357.06–38678.10]	3857.83 (1275.06) [1087.30–5952.93]	2596.50 (3371.33) [357.06–12791.10]	16541.86 (9593.49) [5779.67–38678.10]
EN_ACC	89.89 (20.54) [14.00–100.00]	96.32 (6.15) [80.60–100.00]	72.46 (30.19) [14.00–100.00]	100.00 (0.02) [99.90–100.00]
FI_INDEX	0.32 (0.21) [0.00–1.00]	0.46 (0.21) [0.09–1.00]	0.13 (0.09) [0.00–0.28]	0.28 (0.05) [0.17–0.35]
GDPPC	11043.04 (13172.46) [267.92–56630.00]	7256.73 (2077.35) [3127.86–12484.16]	1787.39 (1212.01) [267.92–4111.31]	34392.29 (12019.45) [20577.50–56630.00]
INF	9.00 (9.28) [-2.08–44.58]	8.90 (9.48) [-0.73–44.58]	12.01 (8.97) [3.33–44.36]	4.74 (7.57) [-2.08–33.33]
TRADE	59.50 (36.10) [20.60–199.05]	44.97 (11.13) [22.11–65.97]	47.54 (16.32) [20.60–91.13]	113.75 (46.40) [47.53–199.05]
URB	60.92 (22.29) [15.76–87.62]	69.77 (11.16) [41.76–87.62]	31.25 (9.93) [15.76–42.97]	83.30 (1.31) [80.75–85.67]
EDU	8.38 (2.93) [1.78–12.99]	9.46 (2.01) [5.98–12.41]	5.35 (2.63) [1.78–10.14]	10.25 (1.51) [7.52–12.99]

Notes: Values are reported as mean, standard deviation in braces, with minimum and maximum values in square brackets. All variables are defined in Table 1. The full sample combines all countries over the study period.

4.1.2. Correlation analysis

Tables 3 to 6 present pairwise correlations, offering preliminary insights into the direction and strength of linear co-movements among the key variables. For the full sample (Table 3), lnPOV is positively correlated with lnGDPPC (0.765), lnURB (0.640), and lnTRADE (0.596). These positive associations are consistent with the use of household consumption as an inverse poverty proxy, where higher income, greater urbanisation, and stronger market integration coincide with higher consumption levels. lnPOV is also positively correlated with lnEN_ACC (0.242) and FI_Index (0.213), which is consistent with the notion that improvements in electricity access and financial inclusion are associated with welfare gains.

However, the correlation matrix also signals potential co-movement among regressors. lnGDPPC correlates strongly with lnURB (0.909) and lnEDU (0.797), while lnURB and lnEDU are also highly correlated (0.872). This pattern is economically intuitive, reflecting the joint evolution of structural transformation, human capital, and income growth. It also provides a basis for the multicollinearity checks undertaken in the diagnostic stage and motivates careful inference using robust covariance estimators in subsequent regression analysis.

The income-group correlation matrices reveal important heterogeneity consistent with the study's conceptual focus. In HICs (Table 4), lnPOV is strongly correlated with lnGDPPC (0.938), indicating that income dynamics are closely mirrored in household consumption. In UMICs (Table 5), lnPOV is positively associated with FI_Index (0.557) and lnGDPPC (0.846), while trade openness is negatively correlated with lnPOV (-0.516), suggesting that increased integration may not translate uniformly into household welfare within this group, potentially reflecting distributional issues or exposure to external shocks. In LMICs (Table 6), lnPOV is strongly negatively correlated with FI_Index (-0.655), which may indicate that in lower-income contexts, improvements in financial inclusion are more tightly associated with welfare gains, potentially because marginal benefits of access to finance are higher where baseline exclusion is severe. Notably, LMICs also display extremely high correlations among lnGDPPC, lnURB, lnEDU, and lnEN_ACC (often above 0.90), indicating strong structural co-movement that reinforces the importance of controlling for time-invariant heterogeneity and applying robust inference procedures.

While correlations do not imply causality, the matrices offer two key implications for the econometric design. First, the direction of associations is broadly consistent with the study's hypothesis that energy access and financial inclusion are welfare-enhancing. Second, the observed co-movement among development-related controls strengthens the case for fixed effects and robust standard errors, and for focusing on interaction effects to test whether financial inclusion strengthens the welfare returns to energy access.

Table 3. Correlation analysis for the full sample, source: Author's computation

	lnPOV	lnEN_ACC	FI_Index	lnGDPPC	INF	lnTRADE	lnURB	lnEDU
lnPOV	1.000							
lnEN_ACC	0.242	1.000						
FI_Index	0.213	0.391	1.000					
lnGDPPC	0.765	0.712	0.382	1.000				
INF	-0.201	-0.208	0.054	-0.301	1.000			
lnTRADE	0.596	0.002	-0.240	0.458	-0.127	1.000		
lnURB	0.640	0.786	0.596	0.909	-0.216	0.197	1.000	
lnEDU	0.499	0.846	0.492	0.797	-0.192	0.243	0.872	1.000

Table 4. Correlation analysis for high-income countries, source: Author's computation

	lnPOV	lnEN_ACC	FI_Index	lnGDPPC	INF	lnTRADE	lnURB	lnEDU
lnPOV	1.000							
lnEN_ACC	0.133	1.000						
FI_Index	0.463	-0.163	1.000					
lnGDPPC	0.938	0.208	0.496	1.000				
INF	0.539	0.076	-0.097	0.418	1.000			
lnTRADE	0.630	0.305	0.290	0.802	0.092	1.000		
lnURB	0.415	-0.003	0.596	0.453	-0.372	0.423	1.000	
lnEDU	0.347	-0.028	0.516	0.348	-0.338	0.285	0.972	1.000

Table 5. Correlation analysis for upper middle-income countries, source: Author's computation

	lnPOV	lnEN_ACC	FI_Index	lnGDPPC	INF	lnTRADE	lnURB	lnEDU
lnPOV	1.000							
lnEN_ACC	-0.017	1.000						
FI_Index	0.557	0.492	1.000					
lnGDPPC	0.846	0.308	0.532	1.000				
INF	-0.266	0.211	0.284	-0.334	1.000			
lnTRADE	-0.516	-0.422	-0.325	-0.521	0.138	1.000		
lnURB	0.727	0.294	0.743	0.514	0.265	-0.611	1.000	
lnEDU	0.195	-0.141	0.463	0.073	0.326	0.543	0.205	1.000

Table 6. Correlation analysis for lower middle-income countries, source: Author's computation

	lnPOV	lnEN_ACC	FI_Index	lnGDPPC	INF	lnTRADE	lnURB	lnEDU
lnPOV	1.000							
lnEN_ACC	-0.173	1.000						
FI_Index	-0.655	0.292	1.000					
lnGDPPC	0.065	0.933	0.098	1.000				
INF	0.043	-0.247	-0.139	-0.180	1.000			
lnTRADE	0.603	-0.349	-0.689	-0.260	-0.102	1.000		
lnURB	0.060	0.947	0.030	0.983	-0.245	-0.175	1.000	
lnEDU	0.118	0.914	0.036	0.967	-0.275	-0.144	0.975	1.000

4.1.3. Panel unit root tests

Table 7 reports first-generation panel unit root tests, specifically Im–Pesaran–Shin and Levin–Lin–Chu, appropriate given the weak evidence of cross-sectional dependence established earlier. The results indicate a mixed order of integration across variables. lnPOV, FI_Index, lnGDPPC, and lnEDU are non-stationary in levels under IPS but become stationary after first differencing, suggesting they are integrated of order one. By contrast, INF is stationary in levels under both IPS and LLC, while lnURB and lnTRADE exhibit stationarity at levels under LLC (and lnURB under IPS), indicating that some structural controls may be I(0). The mixed integration orders are common in macro-panel settings and justify proceeding with cointegration testing to ascertain whether a stable long-run relationship exists among the variables in the core model.

Table 7. Unit root tests, source: Author's computation

Variable	Im–Pesaran–Shin		Levin–Lin–Chu	
	I(0)	I(1)	I(0)	I(1)
lnPOV	0.713	-7.487***	-2.604***	
lnEN_ACC			-3.670***	
FI_Index	5.380	-4.115***	2.265	-5.703***
lnGDPPC	0.830	-5.765***	-1.217	-7.868***
INF	-2.597**		-3.874***	
lnTRADE	-1.188	-6.771***	-2.828***	
lnURB	-3.570***		-6.734***	
lnEDU	2.901	-4.124***	0.542	-6.107***

4.1.4. Panel cointegration test

Table 8 reports Pedroni and Kao panel cointegration tests for the baseline specification (Model A). The Pedroni statistics provide partial support for cointegration: the modified Phillips–Perron t-statistic is significant (4.610, p = 0.000) and the Phillips–Perron t-statistic is also significant (-2.620, p = 0.004), while the ADF-type statistic is not significant (-1.079, p = 0.140). The Kao test provides stronger evidence overall, with the ADF statistic significant at the 5 per cent level (-1.677, p = 0.047) and both unadjusted statistics rejecting the null of no cointegration (p = 0.012 and p = 0.035). Taken together, these results suggest that the key variables in the poverty model share a long-run equilibrium relationship, notwithstanding some test-specific differences that are typical in finite samples.

The cointegration evidence is important for the study in two respects. First, it supports the interpretation of the estimated relationships as reflecting stable long-run associations rather than spurious correlations driven by trending behaviour. Second, it strengthens the rationale for estimating the poverty model in levels within a fixed-effects framework, with robust inference. In particular, the subsequent regressions employ two-way fixed effects with Driscoll–Kraay standard errors as the baseline and PCSE as a robustness estimator, ensuring that inference remains valid in the presence of heteroskedasticity and potential serial and contemporaneous correlation.

Table 8. Pedroni and Kao panel cointegration results for Model A**,** source: Author's computation

	Statistic	p-value
Pedroni Cointegration Test		
Modified Phillips–Perron t	4.610	0.000
Phillips–Perron t	-2.620	0.004
Augmented Dickey–Fuller t	-1.079	0.140
Kao Cointegration Test		
Modified Dickey–Fuller t	-1.047	0.148
Dickey–Fuller t	-1.174	0.120
Augmented Dickey–Fuller t	-1.677	0.047
Unadjusted modified Dickey–Fuller	-2.258	0.012
Unadjusted Dickey–Fuller t	-1.808	0.035

In summary, the pre-estimation results establish three central features of the BRICS Plus data. Welfare, financial inclusion, and energy access differ sharply across income groups, supporting heterogeneity-focused estimation. Correlation patterns are broadly consistent with the study's conceptual expectations while indicating co-movement among structural controls. Finally, the unit root and cointegration evidence indicates mixed integration orders with an underlying long-run relationship in the core model, providing a credible foundation for estimating both baseline and interaction specifications to evaluate whether financial inclusion amplifies the poverty-reducing effect of energy access in BRICS Plus economies.

4.2. Estimation results

4.2.1. Full-sample evidence: Driscoll–Kraay versus PCSE

This section presents the empirical results examining the relationship between financial inclusion, energy access, and poverty reduction across BRICS Plus economies. Two empirical models are estimated. Model A evaluates the independent effects of financial inclusion and energy access on poverty reduction, while Model B introduces the interaction term between financial inclusion and energy access to examine their complementarity. Estimation results are reported using two robust panel estimators: Driscoll–Kraay standard errors and Panel-Corrected Standard Errors (PCSE). The analysis also accounts for structural heterogeneity through three additional dimensions: income-group disaggregation (high-income, upper-middle-income, and lower-middle-income economies), regime heterogeneity (pre-COVID versus COVID periods), and robustness checks incorporating Russia.

4.2.2. Model A: Effects of financial inclusion and energy access on poverty reduction

4.2.2.1. Baseline full-sample results

Table 9 reports the baseline estimation results for the full sample using both Driscoll–Kraay and Panel-Corrected Standard Errors (PCSE) estimators. In this study, poverty reduction is proxied by household final consumption expenditure per capita, which reflects household welfare. Accordingly, positive coefficients indicate welfare improvements (higher consumption and lower poverty), while negative coefficients indicate reductions in welfare (lower consumption and higher poverty exposure).

Across all specifications, energy access exhibits a statistically significant negative association with household welfare. Under the Driscoll–Kraay estimator, the coefficient of lnEN_ACC ranges between −2.948 and −2.944 and remains significant at the 1 percent level. The PCSE results confirm this pattern, with coefficients ranging from −2.072 to −2.081, also statistically significant at conventional levels. These findings indicate that increases in access to electricity are associated with reductions in household consumption per capita in the BRICS Plus economies. This outcome suggests that expanding energy access alone may not automatically translate into improved welfare if households face affordability constraints, rising electricity tariffs, or limited productive opportunities to utilise energy services. In such contexts, the cost burden associated with energy access may outweigh the short-term income gains derived from improved infrastructure.

The results for financial inclusion reveal heterogeneous effects across estimators. In the Driscoll–Kraay specifications, the coefficient of the financial inclusion index is negative but statistically insignificant in the baseline estimation excluding Russia (−0.412), and close to zero when Russia is included (0.0466). These results suggest that financial inclusion does not exert a clear welfare effect under this estimator. In contrast, the PCSE estimates show a negative and statistically significant effect. The coefficient of financial inclusion is −1.106 ($p < 0.01$) in the main estimation excluding Russia and −0.500 ($p < 0.01$) when Russia is included. This implies that higher levels of financial inclusion are associated with lower household consumption per capita, indicating reduced welfare in the short run. One possible explanation is that expanding financial access may initially increase household borrowing costs, debt servicing obligations, or financial transaction expenses, thereby reducing disposable income available for consumption.

Economic growth, proxied by GDP per capita (lnGDPPC), consistently exhibits a positive and statistically significant relationship with household welfare across all specifications. Under the Driscoll–Kraay estimator, the coefficient ranges between 1.969 and 2.050 ($p < 0.01$), while the PCSE results show coefficients between 0.640 and 0.702 ($p < 0.01$). These results indicate that higher income levels substantially increase household consumption expenditure and therefore contribute to poverty reduction. The finding reinforces the central role of economic growth as a key driver of welfare improvements in emerging economies.

The control variables show mixed effects on household welfare. Inflation (INF) is statistically insignificant across all estimations, with coefficients ranging between 0.00247 and 0.00465 under PCSE and approximately 0.003 under Driscoll–Kraay. This suggests that price fluctuations during the study period did not exert a systematic effect on household consumption levels across the BRICS Plus economies.

Trade openness (lnTRADE) exhibits a positive and statistically significant association with household welfare under the Driscoll–Kraay estimator, with coefficients of 0.727 and 0.754 ($p < 0.05$). This implies that greater integration into global markets increases household consumption, likely through employment generation, export expansion, and improved economic opportunities. However, the PCSE results show weaker evidence, with the coefficient becoming statistically insignificant in the baseline estimation and only marginally significant when Russia is included (0.156, $p < 0.10$).

Urbanisation (lnURB) produces contrasting results across estimators. Under the Driscoll–Kraay specification, the coefficient is negative and statistically insignificant in the baseline model (−1.415) but becomes weakly significant when Russia is included (−1.907, $p < 0.10$), suggesting that rapid urban expansion may reduce household consumption in certain contexts, possibly due to congestion effects, urban inequality, and rising living costs. In contrast, the PCSE estimator indicates a positive and statistically significant relationship, with coefficients of 1.127 and 0.734 ($p < 0.01$). These results suggest that urbanisation may improve welfare by expanding access to employment opportunities, infrastructure, and social services.

Education (lnEDU), used as a proxy for human capital development, exhibits limited statistical significance across most specifications. The Driscoll–Kraay estimates show positive but insignificant coefficients of 0.425 and 0.356. Under the PCSE estimator, however, education becomes positive and statistically significant when Russia is included (0.461, $p < 0.05$). This suggests that improvements in educational attainment may enhance household welfare by increasing labour productivity, employment opportunities, and income potential.

Finally, the robustness checks incorporating Russia produce only minor changes in coefficient magnitudes and statistical significance. The core relationships remain largely stable across specifications, indicating that the baseline findings are robust to the inclusion of Russia despite the geopolitical and economic disruptions associated with the Russia–Ukraine conflict. Overall, the results highlight the dominant role of economic growth and trade integration in improving welfare, while also suggesting that the welfare effects of energy access and financial inclusion may depend on complementary institutional and structural conditions within the BRICS Plus economies.

Table 9. Regression results using Driscoll–Kraay and PCSE estimators for full sample, source: Author's computation

VARIABLES	Driscoll-Kraay Standard Errors		Panel-Corrected Standard Errors (PCSE)	
	Main Estimation Excluding Russia	Robustness Checks with Inclusion of Russia	Main Estimation Excluding Russia	Robustness Checks with Inclusion of Russia
	1	2	3	4
lnEN_ACC	-2.948***	-2.944***	-2.072***	-2.081***
	(0.58)	(0.58)	(0.33)	(0.32)
FI_Index	-0.412	4.66E-02	-1.106***	-0.500***
	(1.16)	(0.44)	(0.41)	(0.17)
lnGDPPC	1.969***	2.050***	0.640***	0.702***
	(0.48)	(0.40)	(0.10)	(0.09)
INF	0.00379	0.00322	0.00465	0.00247
	(0.01)	(0.01)	(0.01)	(0.00)
lnTRADE	0.727**	0.754**	0.139	0.156*
	(0.34)	(0.30)	(0.09)	(0.09)
lnURB	-1.415	-1.907*	1.127***	0.734***
	(1.58)	(1.03)	(0.32)	(0.20)
lnEDU	0.425	0.356	0.332	0.461**
	(0.25)	(0.21)	(0.21)	(0.18)
Constant	6.269*	7.442**	6.411***	7.014***
	(3.22)	(2.73)	(1.31)	(1.14)
Observations	180	200	180	200
Number of groups/c_d	9	10	9	10
R-squared		0.799	0.803	0.799

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2.2.2. Country heterogeneity

The country-specific estimates in Table 10 provide evidence on how financial inclusion and energy access independently influence household welfare across BRICS Plus economies. The results reveal considerable heterogeneity in both magnitude and statistical significance.

For energy access, the coefficient of lnEN_ACC is positive and statistically significant in Brazil (2.117, p<0.1), Ethiopia (1.964, p<0.05), Iran (14.02, p<0.01), and Russia (0.944, p<0.1), indicating that improved access to modern energy services enhances household consumption and welfare in these countries. The particularly large coefficient in Iran suggests that energy expansion plays a substantial role in improving living standards. In contrast, the coefficient is negative but insignificant in China (-2.031), India (-0.0675), and South Africa (-0.0301), and positive but insignificant in Egypt (0.920) and Saudi Arabia (5.207). This implies that, in these economies, energy access alone does not significantly translate into higher household consumption, potentially due to affordability constraints or uneven service quality.

Financial inclusion (FI_Index) exhibits mixed effects. It is positive and significant in Brazil (0.290, p<0.1), China (0.376, p<0.05), Ethiopia (4.398, p<0.05), Russia (0.179, p<0.01), and Saudi Arabia (0.949, p<0.01), suggesting that improved access to financial services supports household welfare through enhanced consumption smoothing, credit access, and income-generating opportunities. However, the coefficient is negative and significant in Egypt (-1.271, p<0.01), India (-0.732, p<0.01), South Africa (-0.472, p<0.01), and the UAE (-4.062, p<0.01), indicating that financial inclusion may be associated with reduced household consumption in these contexts. This may reflect unequal access, financial exclusion within inclusion, or increased indebtedness without corresponding income gains. In Iran, the coefficient is positive but insignificant (0.300), suggesting limited direct welfare effects.

Among the control variables, economic growth (lnGDPPC) consistently shows a positive and highly significant association with household welfare across most countries, including Brazil (0.870, p<0.1), China (0.837, p<0.1), Egypt (0.448, p<0.1), India (0.585, p<0.1), Iran (1.253, p<0.1), Russia (1.385, p<0.1), South Africa (1.098, p<0.1), and the UAE (3.232, p<0.1). Inflation negatively affects welfare in India (-0.0103, p<0.01) and South Africa (-0.00587, p<0.01), indicating erosion of purchasing power, while its effect is weak elsewhere. Trade openness enhances welfare in Ethiopia (5.470, p<0.01), Saudi Arabia (0.169, p<0.05), and the UAE (1.082, p<0.1), but reduces welfare in Russia (-0.163, p<0.05). Urbanisation is generally welfare-enhancing in China (2.187, p<0.1), Egypt (7.673, p<0.1), Ethiopia (14.16, p<0.1), India (3.409***), Saudi Arabia (14.51, p<0.1), and South Africa (1.970, p<0.1), but reduces welfare in Iran (-4.199, p<0.05) and Russia (-4.224, p<0.05). Education improves welfare in Egypt (0.918***) and South Africa (0.124, p<0.1), but is associated with welfare decline in China (-2.886, p<0.1) and Ethiopia (-19.60, p<0.01).

The country-specific analysis in Model A indicates that both financial inclusion and energy access can enhance household welfare, but their effectiveness varies significantly across countries, with evidence of both welfare-improving and welfare-reducing outcomes.

Table 10. Disaggregated analysis by country, source: Author's computation

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
VARIA-BLES	**BRAZIL**	**CHINA**	**EGYPT**	**ETHIO-PIA**	**INDIA**	**IRAN**	**RUSSIA**	**SAUDI ARABIA**	**SOUTH AFRICA**	**UAE**
lnEN_ACC	2.117*	-2.031	0.92	1.964**	-0.0675	14.02***	0.944*	5.207	-0.0301	-
	(1.10)	(1.79)	(0.73)	(0.79)	(0.13)	(5.08)	(0.57)	(20.64)	(0.13)	
FI_Index	0.290*	0.376**	-1.271***	4.398**	-0.732***	0.3	0.179***	0.949***	-0.472***	-4.062***
	(0.16)	(0.19)	(0.42)	(1.74)	(0.25)	(0.34)	(0.04)	(0.25)	(0.08)	(0.86)
lnGDPPC	0.870***	0.837***	0.448***	0.173	0.585***	1.253***	1.385***	0.167	1.098***	3.232***
	(0.06)	(0.23)	(0.14)	(4.83)	(0.08)	(0.26)	(0.11)	(0.18)	(0.09)	(0.90)
INF	-0.000538	-0.00339	0.000762*	-0.00149	-0.0103***	5.72E-05	0.0021	-0.000785	-0.00587***	-0.0104
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lnTRADE	-0.0253	0.0619	-0.0471	5.470***	0.0208	-0.0104	-0.163**	0.169**	0.0386	1.082*
	(0.03)	(0.08)	(0.03)	(0.64)	(0.02)	(0.11)	(0.08)	(0.07)	(0.03)	(0.55)
lnURB	1.402	2.187***	7.673***	14.16*	3.409***	-4.199**	-4.224**	14.51***	1.970***	-9.94
	(1.38)	(0.79)	(2.84)	(8.50)	(0.87)	(2.08)	(1.91)	(5.14)	(0.42)	(12.93)
lnEDU	0.0862	-2.886*	0.918***	-19.60***	-0.403	0.143	6.709	0.162	0.124***	-0.263
	(0.27)	(1.66)	(0.25)	(6.67)	(0.26)	(0.85)	(4.90)	(0.52)	(0.05)	(0.92)
Constant	-15.51*	6.501	-30.44***	-47.97***	-8.201***	-49.79**	-6.704	-81.93	-9.599***	15.86
	(8.64)	(8.76)	(10.60)	(11.31)	(2.13)	(19.67)	(7.18)	(103.60)	(1.24)	(50.34)
Observa-tions	20	20	20	20	20	20	20	20	20	20
R-squared	0.996	0.999	0.994	0.961	0.999	0.742	0.992	0.993	0.991	0.908
Number of c_id	1	1	1	1	1	1	1	1	1	1

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2.2.3. Income group heterogeneity

To account for structural differences in development levels within the BRICS Plus economies, Table 11 reports the disaggregated estimation results across income groups, namely High-Income Countries (HICs), Upper-Middle-

Income Countries (UMICs), and Lower-Middle-Income Countries (LMICs). The income-group results reveal considerable heterogeneity in the relationships between financial inclusion, energy access, and welfare outcomes, highlighting that the determinants of poverty dynamics differ across development stages.

Consistent with the full-sample results, energy access exhibits a negative relationship with household welfare in most income groups. However, the magnitude and statistical significance of this relationship vary substantially. In upper-middle-income economies, which include Brazil, China, Iran, Russia, and South Africa, energy access remains negative and highly significant, with a coefficient of −2.021 ($p < 0.01$). This finding closely mirrors the full-sample results where energy access was also negative and significant, with coefficients ranging from −2.948 to −2.072 depending on the estimator. The result suggests that in UMICs, increases in electricity access may be associated with short-term welfare reductions, potentially reflecting the rising costs of energy infrastructure expansion, energy pricing reforms, or increased household expenditure on electricity services that reduce disposable income.

In contrast, the relationship between energy access and welfare is statistically insignificant in high-income economies. The estimated coefficient for lnEN_ACC is −52.62, but the estimate is accompanied by extremely large standard errors and lacks statistical significance. This outcome contrasts with the full-sample results and likely reflects the structural characteristics of HICs such as Saudi Arabia and the United Arab Emirates, where energy access is already near universal. In such contexts, additional improvements in electricity access generate limited marginal welfare effects, and variations in household consumption are driven more strongly by macroeconomic conditions, labour markets, and fiscal policies rather than infrastructure access.

Lower-middle-income economies display a different pattern. Although the coefficient of energy access remains negative (−0.99), it is statistically insignificant, indicating that improvements in electricity access do not exert a measurable welfare effect in these economies during the study period. Compared with the full-sample results where energy access was consistently significant, this finding suggests that structural constraints may weaken the welfare transmission mechanism of energy expansion in LMICs. These constraints may include limited financial access, lower industrial capacity, infrastructure bottlenecks, and weaker institutional support systems that prevent households from translating energy access into productive economic activities.

Financial inclusion also demonstrates heterogeneous effects across income groups. In high-income economies, the coefficient of the financial inclusion index is −0.663 but statistically insignificant, suggesting that further financial deepening does not significantly affect household consumption levels. This outcome is consistent with the full-sample results where financial inclusion also exhibited weak or insignificant effects under the Driscoll–Kraay estimator. In upper-middle-income economies, financial inclusion remains statistically insignificant with a coefficient of 0.117, indicating that improvements in financial access do not directly translate into changes in household consumption. In lower-middle-income economies, however, the coefficient becomes more negative (−4.147), although it remains statistically insignificant. This pattern suggests that financial inclusion alone may not immediately improve welfare unless it is accompanied by complementary economic opportunities and productive investments.

Economic growth, measured by GDP per capita (lnGDPPC), remains consistently positive and statistically significant across all income groups, reinforcing the findings from the full-sample estimations. The coefficient is 1.458 ($p < 0.01$) in high-income economies, 0.777 ($p < 0.01$) in upper-middle-income economies, and 2.417 ($p < 0.01$) in lower-middle-income economies. These results indicate that increases in national income levels strongly improve household consumption and welfare across all development contexts. Notably, the effect is largest in lower-middle-income economies, suggesting that economic growth generates particularly strong welfare gains where baseline income levels are lower.

The control variables further illustrate the heterogeneous welfare dynamics across income groups. Inflation (INF) shows a positive and statistically significant coefficient in high-income economies (0.0172, $p < 0.01$), indicating that moderate price increases may coincide with stronger economic activity and higher consumption levels in advanced economies. In upper-middle-income economies, however, inflation exhibits a negative and significant coefficient (−0.00569, $p < 0.01$), suggesting that rising prices reduce household purchasing power and weaken welfare outcomes. In lower-middle-income economies, inflation remains negative but statistically insignificant.

Trade openness also exhibits varying welfare effects across income groups. In high-income economies, trade openness is negative and statistically significant (−0.309, $p < 0.01$), suggesting that greater exposure to global markets may reduce household consumption through external volatility or structural adjustments in domestic industries. This contrasts with the full-sample results where trade openness exhibited a positive effect under the Driscoll–Kraay estimator. In lower-middle-income economies, trade openness is positive and highly significant (1.336, $p < 0.01$), indicating that export-oriented economic activities and global market integration contribute substantially to household welfare improvements in these countries.

Urbanisation (lnURB) and education (lnEDU) also display heterogeneous effects. Urbanisation is positive and highly significant in upper-middle-income economies (1.051, $p < 0.01$), indicating that urban expansion enhances household welfare through improved employment opportunities, infrastructure, and public services. However, urbanisation is statistically insignificant in both high-income and lower-middle-income economies, suggesting that the welfare effects of urban growth depend on the stage of economic development and the absorptive capacity of urban labour markets. Education exhibits a positive and marginally significant effect only in lower-middle-income economies (1.000, p < 0.10), implying that improvements in human capital can contribute to higher household consumption where educational expansion is still in progress.

Overall, the income-group analysis highlights substantial heterogeneity in the finance–energy–welfare nexus across the BRICS Plus economies. While the full-sample results suggest broadly consistent relationships between the core variables and welfare, the disaggregated analysis reveals that these effects differ considerably across income levels. Economic growth emerges as the most consistent driver of welfare improvements across all groups, whereas the welfare effects of energy access, financial inclusion, and trade integration depend heavily on structural conditions, institutional capacity, and the stage of economic development. These findings underscore the importance of context-specific policy approaches when designing strategies aimed at achieving poverty reduction and inclusive development across heterogeneous emerging economies.

Table 11. Disaggregated estimation results by income group (HICs, UMICs, and LMICs), source: estimated and compiled by the authors

	Baseline Model		
VARIABLES	**HICs**	**UMICs**	**LMICs**
	1	**2**	**3**
lnEN_ACC	-52.62	-2.021***	-0.99
	-76.73	-0.178	-1.324
FI_Index	-0.663	0.117	-4.147
	-0.689	-0.082	-3.078
lnGDPPC	1.458***	0.777***	2.417***
	(0.19)	(0.04)	(0.89)
INF	0.0172***	-0.00569***	-0.00366
	(0.01)	(0.00)	(0.01)
lnTRADE	-0.309***	-0.0694	1.336***
	(0.10)	(0.07)	(0.30)
lnURB	13.66	1.051***	-5.13
	(12.90)	(0.09)	(3.98)
lnEDU	-0.703	0.0836	1.000*
	(1.16)	(0.07)	(0.59)
Constant	179.5	6.170***	5.334*
	(363.10)	(1.05)	(3.11)
Observations	40	100	60
R-squared	-0.94	-0.97	-0.67
Number of c_id	2	5	3

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2.2.4. Regime heterogeneity: pre-COVID and COVID periods

Table 12 presents the regime-based estimations comparing the determinants of household welfare across the pre-COVID (2004–2019) and COVID (2020–2023) periods. The results indicate that energy access exerts a statistically significant but welfare-reducing effect in both regimes. In the pre-COVID period, the coefficient of energy access (lnEN_ACC) is −2.024 (p < 0.01), suggesting that increases in electricity access are associated with reductions in household consumption per capita. This implies that improvements in energy infrastructure alone may not automatically translate into higher welfare if households face affordability constraints, high electricity tariffs, or limited productive opportunities to utilise energy services. The welfare-reducing magnitude declines during the pandemic period, with the coefficient falling to −0.672 (p < 0.01). Although still negative, the smaller magnitude suggests that the adverse consumption effect of energy access weakened during the pandemic, possibly because energy services became essential for household resilience during lockdowns and mobility restrictions.

Financial inclusion exhibits a consistently negative effect on household welfare across regimes. In the pre-COVID period, the coefficient of the financial inclusion index (FI_Index) is −0.433 (p < 0.10), indicating that increases in financial inclusion are associated with modest reductions in household consumption per capita. This pattern may reflect financial deepening processes where expanded access to credit is initially associated with household debt accumulation or financial costs that temporarily reduce disposable income. During the COVID period, the magnitude increases slightly to −0.471 ($p < 0.01$), suggesting that despite the expansion of digital financial services and financial transfers during the pandemic, the net effect on household consumption remained negative. This may reflect income shocks and debt servicing pressures experienced by households during the crisis.

Economic growth, measured by GDP per capita (lnGDPPC), shows a strong positive and statistically significant effect on welfare in both periods. In the pre-COVID period, the coefficient is 0.608 ($p < 0.01$), indicating that higher income levels significantly increase household consumption and reduce poverty. This positive welfare effect becomes slightly stronger during the COVID period, with the coefficient rising to 0.738 ($p < 0.01$). The result reinforces the importance of sustained macroeconomic growth as a fundamental driver of welfare improvements across BRICS Plus economies.

Among the control variables, inflation exhibits regime-dependent effects. In the pre-COVID period, inflation (INF) is statistically insignificant with a coefficient of 0.0066, suggesting that moderate price movements did not systematically affect household consumption. However, during the COVID period inflation becomes negative and statistically significant (−0.00417, $p < 0.01$), indicating that rising consumer prices eroded household purchasing power and reduced welfare levels during the pandemic.

Trade openness (lnTRADE) displays a positive welfare effect in the pre-COVID period, with a coefficient of 0.307 ($p < 0.05$). This suggests that integration into global markets improved household consumption through employment generation, export revenues, and economic diversification. However, during the COVID period the coefficient becomes −0.0125 and statistically insignificant, reflecting disruptions in global trade flows and supply chains that weakened the welfare gains from international trade.

Table 12. Pre-COVID and COVID estimates for full sample, source: estimated and compiled by the authors

VARIABLES	BASELINE MODEL	
	PRE-COVID	COVID
	1	2
lnEN_ACC	-2.024***	-0.672***
	(0.38)	(0.07)
FI_Index	-0.433*	-0.471***
	(0.23)	(0.05)
lnGDPPC	0.608***	0.738***
	(0.12)	(0.02)
INF	0.0066	-0.00417***
	(0.01)	(0.00)
lnTRADE	0.307**	-0.0125
	(0.15)	(0.02)
lnURB	1.094***	0.200***
	(0.28)	(0.05)
lnEDU	0.252	0.408***
	(0.23)	(0.03)
Constant	5.881***	3.351***
	(1.40)	(0.33)
Observations	160	40
Number of groups/c_d	10	10
R-squared	0.773	0.98

Urbanisation (lnURB) shows positive and significant welfare effects across both regimes. In the pre-COVID period, the coefficient is 1.094 ($p < 0.01$), indicating that urban expansion improves household welfare through better

access to infrastructure, labour markets, and public services. Although the magnitude declines during the pandemic, the coefficient remains positive and significant at 0.200 ($p < 0.01$), suggesting that urban environments continued to provide relatively stronger economic resilience and access to social support systems during the crisis.
Education (lnEDU), representing human capital development, shows a positive but statistically insignificant effect in the pre-COVID period (0.252), indicating that the welfare benefits of education may materialise gradually through productivity improvements rather than immediate consumption increases. During the COVID period, however, education becomes positive and statistically significant (0.408, $p < 0.01$). This result suggests that higher levels of human capital enhanced households' ability to adapt to economic disruptions, including transitions to digital work environments and new forms of employment.
Overall, the regime-based analysis demonstrates that economic growth, urbanisation, and education contribute positively to household welfare, while inflation undermines welfare during crisis periods. In contrast, energy access and financial inclusion exhibit negative associations with household consumption, indicating that the welfare benefits of these structural transformations may depend on complementary institutional conditions such as energy affordability, financial system stability, and productive economic opportunities. These findings highlight the importance of integrated development policies that ensure energy and financial expansion translate effectively into improved household welfare outcomes.

4.2.3. Model B: financial inclusion–energy access interaction and poverty reduction
4.2.3.1. Baseline interaction results
Model B extends the baseline specification by introducing the interaction term between financial inclusion and energy access (FI_EN) in order to examine whether financial systems condition the welfare effects of energy infrastructure. As in Model A, poverty reduction is proxied by household final consumption expenditure per capita. Consequently, positive coefficients indicate improvements in welfare, while negative coefficients indicate reductions in household consumption and worsening welfare outcomes.
The results reported in Table 13 reveal notable changes relative to the baseline model once the interaction term is introduced. First, the coefficient of energy access (lnEN_ACC) remains negative and statistically significant across all specifications. Under the Driscoll–Kraay estimator, the coefficient ranges between −1.756 and −1.871 ($p < 0.01$), while the PCSE estimates range between −2.275 and −2.234 ($p < 0.01$). Compared with Model A, where the coefficient ranged from −2.948 to −2.072, the magnitude of the negative effect becomes smaller in some specifications once the interaction term is included. This reduction suggests that part of the welfare impact of energy access operates through its interaction with financial inclusion. Nevertheless, the negative sign indicates that improvements in electricity access alone remain associated with reductions in household consumption per capita, implying that energy expansion may impose short-run financial burdens on households in the absence of supportive financial mechanisms.
Financial inclusion alone exhibits a strongly negative and statistically significant effect on welfare across all specifications. The coefficient of FI_Index ranges between −43.38 and −41.02 under the Driscoll–Kraay estimator and between −37.12 and −36.87 under PCSE, all significant at the 1 percent level. Relative to Model A, where the coefficient of financial inclusion was modest in magnitude, the introduction of the interaction term substantially increases the estimated negative effect of financial inclusion on household consumption. This suggests that financial inclusion, when considered independently from energy access, may initially reduce disposable income through borrowing costs, financial service charges, or increased debt obligations.
The key result emerges from the interaction term between financial inclusion and energy access (FI_EN). The coefficient of FI_EN is positive and highly significant across all specifications, with values ranging between 9.063 and 9.804 under the Driscoll–Kraay estimator and between 8.001 and 8.097 under PCSE ($p < 0.01$). The positive coefficient indicates that financial inclusion mitigates the negative welfare effects associated with energy access and energy-related financial costs. In other words, while energy access and financial inclusion individually appear to reduce household consumption, their combined effect generates welfare improvements. This finding provides strong evidence of complementarity between financial systems and energy infrastructure.
The positive interaction effect implies that households with better access to financial services are more capable of translating energy infrastructure into productive activities that raise income and consumption. Financial inclusion may enable households and firms to finance energy appliances, invest in small businesses, or adopt productivity-enhancing technologies that rely on electricity. As a result, financial systems appear to play a critical role in transforming energy access into tangible welfare gains.
The control variables maintain broadly consistent patterns with those observed in Model A. Economic growth (lnGDPPC) continues to exhibit a strong positive and statistically significant association with household welfare. The coefficient ranges between 1.694 and 1.836 under the Driscoll–Kraay estimator and between 0.900 and 0.906 under PCSE ($p < 0.01$), reinforcing the conclusion that higher income levels remain the most robust driver of improved household consumption.
Inflation (INF) remains statistically insignificant across most specifications, indicating that price fluctuations do not exert a systematic influence on household consumption within the full sample once the interaction term is

considered. Trade openness (lnTRADE) becomes statistically insignificant across both estimators, suggesting that part of the welfare effect previously attributed to trade integration in Model A may be captured indirectly through the financial and energy channels included in the interaction model.

Urbanisation (lnURB) exhibits a negative and statistically significant effect under the Driscoll–Kraay estimator, with coefficients of −2.835 and −1.811 ($p < 0.05$), indicating that rapid urban expansion may reduce household consumption due to congestion costs, higher living expenses, or labour market competition. However, under the PCSE estimator, urbanisation becomes statistically insignificant, reflecting the sensitivity of the urbanisation effect to econometric specification.

Education (lnEDU) shows a positive and statistically significant association with welfare under the PCSE estimator, with coefficients of 0.368 and 0.274 ($p < 0.01$ and $p < 0.05$ respectively). This suggests that improvements in human capital enhance labour productivity and income generation, thereby increasing household consumption. The Driscoll–Kraay results, however, show statistically insignificant coefficients, indicating that the welfare effects of education may materialise gradually over time.

Overall, the introduction of the interaction term significantly alters the interpretation of the finance–energy–welfare nexus. While both financial inclusion and energy access individually exhibit negative associations with household consumption, their interaction produces a strong positive effect. This indicates that financial systems play a crucial enabling role in allowing households to benefit from energy infrastructure.

Table 13. Regression results using Driscoll–Kraay and PCSE estimators for full sample, *source: Author's computation*

VARIABLES	Driscoll-Kraay Standard Errors		Panel-Corrected Standard Errors (PCSE)	
	Main Estimation Excluding Russia	Robustness Checks with Inclusion of Russia	Main Estimation Excluding Russia	Robustness Checks with Inclusion of Russia
	1	2	3	4
lnEN_ACC	-1.756***	-1.871***	-2.275***	-2.234***
	(0.34)	(0.33)	(0.23)	(0.23)
FI_Index	-43.38***	-41.02***	-37.12***	-36.87***
	(7.18)	(7.95)	(6.78)	(6.81)
FI_EN	9.804***	9.063***	8.097***	8.001***
	(1.46)	(1.69)	(1.47)	(1.48)
lnGDPPC	1.836***	1.694***	0.906***	0.900***
	(0.34)	(0.23)	(0.06)	(0.06)
INF	-0.00585	-0.00405	0.000945	0.00159
	(0.01)	(0.01)	(0.00)	(0.00)
lnTRADE	0.435	0.378	-0.0427	-0.0459
	(0.29)	(0.26)	(0.07)	(0.07)
lnURB	-2.835**	-1.811**	-0.0941	0.013
	(1.24)	(0.63)	(0.16)	(0.13)
lnEDU	-0.144	0.0278	0.368***	0.274**
	(0.21)	(0.10)	(0.13)	(0.11)
Constant	9.760***	7.553***	10.38***	10.06***
	(2.43)	(2.32)	(1.03)	(0.99)
Observations	180	200	180	200
Number of groups/c_d	9	10	9	10
R-squared		0.799	0.878	0.877

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2.3.2. Country heterogeneity

Table 14 extends the analysis by incorporating the interaction term (FI_EN), capturing the joint effect of financial inclusion and energy access on household welfare. The inclusion of this term alters both the magnitude and interpretation of the coefficients relative to Model A. Control variables largely retain their patterns. Economic growth continues to promote household welfare across most countries. Inflation remains welfare-reducing in China (-0.00302, p<0.1), India (-0.00354, p<0.1), and South Africa (-0.00463, p<0.01). Trade openness becomes more welfare-enhancing in India (0.0796, p<0.01), while remaining positive in Ethiopia and Saudi Arabia and negative in Russia. Urbanisation and education continue to display mixed and country-specific effects.

The coefficient on energy access (lnEN_ACC) changes notably. It becomes negative and statistically significant in China (-17.44, p<0.01), India (-0.339, p<0.01), and South Africa (-2.321, p<0.01), indicating that, when considered independently, increased energy access is associated with lower household consumption in these countries. However, it remains strongly positive and significant in Iran (66.62, p<0.01), and positive but insignificant in Brazil (3.016), Egypt (4.093), Ethiopia (0.591), Russia (4.315), and Saudi Arabia (5.143). Compared to Model A, this shift suggests that the welfare impact of energy access is conditional on financial inclusion.

The coefficient on financial inclusion (FI_Index) also exhibits substantial changes. It becomes negative and highly significant in China (-626.1, p<0.01), India (-14.53, p<0.01), and South Africa (-35.77, p<0.01), indicating that financial inclusion alone is associated with reduced household welfare in these economies once interaction effects are considered. Conversely, it is positive and significant in Iran (621.5, p<0.05), while remaining statistically insignificant in Brazil (8.014), Egypt (264.3), Ethiopia (-19.11), and Russia (17.02).

The interaction term (FI_EN) provides the most critical insight. It is positive and statistically significant in China (136.1, p<0.01), India (3.351, p<0.01), Saudi Arabia (0.206, p<0.01), and South Africa (7.957, p<0.01), indicating that the joint expansion of financial inclusion and energy access significantly enhances household welfare in these countries. This represents a key departure from Model A, where the individual effects of these variables were weak or even negative. The results suggest that households benefit more when access to energy is complemented by access to financial services that enable productive utilisation.

Table 14. Disaggregated estimation results by country

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
VARIABLES	BRAZIL	CHINA	EGYPT	ETHIO-PIA	INDIA	IRAN	RUSSIA	SAUDI ARA-BIA	SOUTH AFRICA	UAE
lnEN_ACC	3.016	-17.44***	4.093	0.591	-0.339***	66.62***	4.315	5.143	-2.321***	-
	(10.62)	(2.93)	(2.92)	(1.24)	(0.11)	(21.17)	(8.10)	(20.63)	(0.69)	
FI_Index	8.014	-626.1***	264.3	-19.11	-14.53***	621.5**	17.02	-	-35.77***	-
	(90.80)	(110.50)	(237.20)	(17.01)	(2.98)	(244.50)	(40.38)		(10.44)	
FI_EN	-1.676	136.1***	-57.61	6.349	3.351***	-134.9**	-3.662	0.206***	7.957***	-0.882***
	(19.71)	(23.99)	(51.43)	(4.57)	(0.72)	(53.10)	(8.78)	(0.05)	(2.35)	(0.19)
lnGDPPC	0.866***	1.431***	0.331**	-1.867	0.604***	1.161***	1.377***	0.167	1.027***	3.232***
	(0.08)	(0.17)	(0.17)	(4.84)	(0.06)	(0.23)	(0.11)	(0.18)	(0.08)	(0.90)
INF	-0.000562	-0.00302*	0.000902**	-0.00536	-0.00354*	-0.000736	0.0023	-0.000785	-0.00463***	-0.0104
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
lnTRADE	-0.0239	0.0494	-0.0443	5.407***	0.0796***	0.066	-0.149*	0.169**	0.0232	1.082*
	(0.04)	(0.05)	(0.03)	(0.62)	(0.02)	(0.10)	(0.09)	(0.07)	(0.02)	(0.55)
lnURB	1.418	0.711	7.271***	18.32**	1.645**	-5.405***	-3.804*	14.51***	3.009***	-9.94
	(1.39)	(0.55)	(2.77)	(8.66)	(0.71)	(1.87)	(2.15)	(5.14)	(0.46)	(12.93)
lnEDU	0.0858	-3.470***	0.922***	-12.04	-0.312*	1.401	4.377	0.162	0.119***	-0.263
	(0.27)	(1.03)	(0.24)	(8.38)	(0.18)	(0.89)	(7.42)	(0.52)	(0.04)	(0.92)
Constant	-19.69	79.25***	-42.65***	-48.51***	-1.66	-289.2***	-18.13	-81.63	-3.067	15.86
	(49.93)	(13.92)	(14.99)	(10.81)	(2.05)	(95.78)	(28.32)	(103.50)	(2.17)	(50.34)
Observations	20	20	20	20	20	20	20	20	20	20
R-squared	0.996	1	0.994	0.965	1	0.805	0.992	0.993	0.994	0.908
Number of c_id	1	1	1	1	1	1	1	1	1	1

In contrast, the interaction term is negative and significant in Iran (-134.9, p<0.05) and the UAE (-0.882, p<0.01), indicating that the combined effect of financial inclusion and energy access reduces household welfare in these contexts. This contrasts with Model A, where energy access alone had a strong positive effect in Iran, suggesting that complementarities between finance and energy may be constrained by institutional inefficiencies or unequal access. In Brazil (-1.676), Egypt (-57.61), Ethiopia (6.349), and Russia (-3.662), the interaction term is statistically insignificant, indicating limited complementarity.

Control variables largely retain their patterns. Economic growth continues to promote household welfare across most countries. Inflation remains welfare-reducing in China (-0.00302, p<0.1), India (-0.00354, p<0.1), and South Africa (-0.00463, p<0.01). Trade openness becomes more welfare-enhancing in India (0.0796, p<0.01), while remaining positive in Ethiopia and Saudi Arabia and negative in Russia. Urbanisation and education continue to display mixed and country-specific effects.

In summary, Model B reveals that the welfare effects of financial inclusion and energy access are not merely additive but conditional. The introduction of the interaction term uncovers strong complementarities in countries such as China, India, Saudi Arabia, and South Africa, where combined access significantly improves household welfare. At the same time, it highlights adverse interactions in Iran and the UAE, reinforcing the importance of aligning financial systems with energy infrastructure to achieve inclusive welfare gains.

4. 2.3.3. Income group heterogeneity in the interaction model

Table 15 presents the disaggregated interaction results across income groups. The findings again reveal strong heterogeneity across development levels.

Table 15. Disaggregated estimation results by income group (HICs, UMICs, and LMICs), source: estimated and compiled by the authors

	Interaction Model		
VARIABLES	**HICs**	**UMICs**	**LMICs**
	1	**2**	**3**
lnEN_ACC	-52.57	-1.835***	-2.553**
	-76.71	-0.288	-1.219
FI_Index		3.587	-40.68***
		-4.916	-10.61
FI_EN	-0.144	-0.755	9.269***
	-0.15	-1.065	-2.529
lnGDPPC	1.458***	0.775***	2.498***
	(0.19)	(0.04)	(0.75)
INF	0.0172***	-0.00568***	-0.00862
	(0.01)	(0.00)	(0.01)
lnTRADE	-0.309***	-0.0765	0.778**
	(0.10)	(0.07)	(0.36)
lnURB	13.66	1.045***	-0.904
	(12.90)	(0.10)	(3.74)
lnEDU	-0.703	0.0902	-1.007
	(1.16)	(0.07)	(0.73)
Constant	179.3	5.369***	1.789
	(363.00)	(1.36)	(2.82)
Observations	40	100	60
R-squared	-0.94	-0.97	-0.76
Number of c_id	2	5	3

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

In high-income economies, the interaction coefficient between financial inclusion and energy access is negative and statistically insignificant (−0.144), indicating that financial systems do not significantly alter the welfare impact of energy access. This outcome is consistent with the near-universal levels of financial access and energy infrastructure in these economies, where additional complementarities generate limited marginal welfare effects.

In upper-middle-income economies, the interaction term also remains statistically insignificant (−0.755), suggesting that financial inclusion does not significantly modify the welfare impact of energy access in these economies. This contrasts with the full-sample results and may reflect structural differences within the UMIC group, where energy access is already relatively high and financial systems are moderately developed.

The most notable result emerges in lower-middle-income economies. The interaction coefficient is positive and highly significant (9.269, $p < 0.01$), indicating strong complementarity between financial inclusion and energy access. In these economies, financial systems appear to play a critical role in enabling households to utilise energy infrastructure productively. Access to credit, savings instruments, and financial services allows households to finance electricity connections, energy appliances, and small business investments that increase income and consumption.

This finding highlight that the finance–energy complementarity is strongest in economies where both financial and energy systems are still expanding.

4.2.3.4. Regime heterogeneity: interaction effects pPre-COVID versus during COVID

Table 16 compares the interaction model across the pre-COVID and COVID periods. The results indicate that the complementarity between financial inclusion and energy access was strongest before the pandemic. During the pre-COVID period, the interaction coefficient is positive and statistically significant (8.190, $p < 0.01$), confirming that financial inclusion enhanced the welfare benefits of energy access.

Table 16. Pre-COVID and COVID estimates for full sample, source: estimated and compiled by the authors

VARIABLES	INTERACTION MODEL	
	PRE-COVID	COVID
	1	1
lnEN_ACC	-2.217***	-0.942***
	(0.27)	(0.22)
FI_Index	-37.66***	-5.389
	(8.07)	(3.64)
FI_EN	8.190***	1.071
	(1.75)	(0.79)
lnGDPPC	0.868***	0.736***
	(0.08)	(0.02)
INF	0.00362	-0.00440***
	(0.01)	(0.00)
lnTRADE	0.00868	-0.012
	(0.11)	(0.02)
lnURB	0.148	0.197***
	(0.18)	(0.05)
lnEDU	0.197	0.416***
	(0.15)	(0.02)
Constant	9.617***	4.598***
	(1.20)	(1.00)
Observations	160	40
Number of groups/c_d	10	10
R-squared	0.861	0.98

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

During the COVID period, however, the interaction term becomes statistically insignificant (1.071). This suggests that the pandemic weakened the finance–energy transmission mechanism. Economic contraction, mobility restrictions, and supply disruptions likely constrained households' ability to translate financial access and energy infrastructure into productive economic activities.

Nevertheless, financial inclusion itself continues to play a stabilising role. Although the coefficient of FI_Index becomes statistically insignificant during the COVID period (−5.389), the magnitude remains negative, indicating that financial pressures continued to affect household consumption during the crisis.

Taken together, the interaction model provides important insights into the structural dynamics of poverty reduction in BRICS Plus economies. While energy access and financial inclusion individually appear to reduce household consumption in the short run, their interaction generates a positive welfare effect. This indicates that financial systems enable households to convert energy infrastructure into productive economic opportunities.

The results further show that this complementarity is strongest in lower-middle-income economies and weaker in higher-income economies where both systems are already mature. Moreover, the complementarity weakened during the COVID period, highlighting the vulnerability of development channels to global economic disruptions.

These findings underscore the importance of integrated policy frameworks that simultaneously expand financial inclusion and energy infrastructure. In particular, strengthening financial access alongside energy development may allow emerging economies to translate infrastructure expansion into sustained improvements in household welfare and poverty reduction.

4.2 Discussion of results

Our findings provide direct answers to the three research questions and reveal that the poverty implications of financial inclusion and energy access in BRICS economies are conditional rather than automatic. First, energy access is associated with lower household final consumption expenditure per capita in the baseline full-sample models, indicating that expansion in electricity access, on its own, does not necessarily reduce poverty in the short run. Second, financial inclusion is either welfare-neutral under Driscoll–Kraay or welfare-reducing under PCSE, showing that broader participation in the financial system does not automatically raise household welfare. Third, and most importantly, the interaction between financial inclusion and energy access is positive and strongly significant, especially in the full sample and in lower-middle-income economies, indicating that financial systems can offset the welfare-reducing effects of energy expansion by enabling households to finance energy uptake and use electricity more productively. The novelty of the study therefore lies in demonstrating that the finance-energy-poverty nexus is best understood as a question of complementarity rather than isolated sectoral effects. In SDG terms, the results suggest that progress under SDG 7 is more likely to support SDG 1 when it is reinforced by inclusive financial systems linked to SDG 8 and SDG 10.

These results are consistent with the development finance and inclusive growth literature, which argues that the value of financial inclusion depends not merely on access, but on whether financial systems broaden participation, strengthen resilience, and support productive use of resources (Demirgüç-Kunt et al., 2017; Hay et al., 2020). The negative or weak effect of financial inclusion in the baseline estimations is in line with the caution that inclusion can deepen household liabilities where access is credit-led, fees are high, and regulation is weak (Davoodi, 2021; Yue et al., 2022). The energy results also fit the energy-poverty literature, which stresses that welfare gains depend not only on electricity connections but also on affordability, reliability, and the ability to convert access into livelihood improvement (Rao and Pachauri, 2017). More importantly, the positive interaction term aligns with studies showing that financial inclusion lowers energy poverty by relaxing liquidity constraints and enabling households to afford modern energy services and related technologies (Kar and Bali, 2023; Sen et al., 2023). This also resonates with work arguing that the welfare returns to energy infrastructure rise when households can sustain and productively use that access (Manko and Watkins, 2022; Wei et al., 2025). The heterogeneity across countries and income groups is similarly consistent with the literature showing that benefits from finance and infrastructure are uneven where structural inequalities, institutional weaknesses, or limited usage capacity persist (Park and Mercado, 2018; Ndlovu and Toerien, 2020).

The negative coefficient on energy access in the baseline model is economically meaningful once household welfare is proxied by consumption expenditure. In this setting, the coefficient captures not only the potential productivity gains from electrification but also the immediate household costs associated with gaining and maintaining access. Where electricity expansion is accompanied by connection charges, tariff increases, prepaid metering, or poor reliability, the cost-of-access channel may dominate the productivity-of-use channel, thereby reducing disposable income and compressing consumption. This helps explain why the full-sample energy coefficients remain strongly negative, ranging from about -2.95 under Driscoll–Kraay to about -2.07 under PCSE, and why upper-middle-income economies show a significant welfare-reducing effect while high-income and lower-middle-income groups do not. In upper-middle-income countries, access may be expanding under cost recovery conditions, while the productive use of electricity is still uneven across households. In high-income countries, by contrast, near-universal access implies low marginal welfare returns from further expansion. In lower-middle-income countries, the coefficient is not significant until interaction effects are considered, suggesting that access alone is insufficient where households remain constrained by low incomes, weak enterprise opportunities, and limited financing options. This interpretation reinforces the argument that SDG 7 targets centred solely on coverage rates may deliver weak or even adverse short-run welfare effects unless affordability and quality are protected.

The financial inclusion results point to a similar conditionality. In Model A, the negative PCSE coefficients of about -1.106 and -0.500 suggest that early-stage financial deepening may reduce welfare when the expansion of accounts and credit is not matched by low-cost services, savings mobilisation, consumer protection, and productive opportunities. In practical terms, households may be entering the formal financial system through expensive borrowing rather than through welfare-enhancing instruments such as savings, payments, and insurance. That interpretation is consistent with the literature showing that financial inclusion supports poverty reduction when it improves consumption smoothing, entrepreneurship, and resilience, but may be less effective when access is shallow, usage is weak, or disadvantaged groups are unable to use financial products effectively (Saha and Qin, 2023; Lyons et al., 2019). Model B clarifies this mechanism more sharply. Once the interaction term is introduced, the main effects of financial inclusion and energy access remain negative, but the interaction term FI_EN becomes positive and highly significant, with coefficients around 8.0 to 9.8. This means that the private costs of financial entry and energy adoption are visible when each variable is treated separately, yet the welfare benefits emerge when both systems operate together. In other words, financial inclusion becomes developmentally meaningful when it enables households to pay connection costs, smooth electricity bills, purchase appliances, or finance small productive activities that depend on energy. That result is precisely the complementarity channel emphasised in the literature on energy poverty reduction through finance-enabled energy uptake (Kar and Bali, 2023; Sen et al., 2023; Wei et al., 2025). For policy, the implication is clear: pro-poor finance should not be designed as an isolated banking agenda, but as an instrument that supports energy affordability, productive electricity use, and inclusive enterprise development.

The heterogeneity results substantially deepen the interpretation of the finance–energy–poverty nexus by revealing both country-specific variations and a broader development gradient. At the country level, the results show that the welfare effects of financial inclusion and energy access are highly context-dependent. The interaction term is positive and significant in countries such as China, India, Saudi Arabia, and South Africa, indicating that financial systems effectively support the productive use of energy in these settings. In contrast, the negative interaction observed in Iran and the UAE suggests that complementarity may be constrained by institutional inefficiencies, unequal access, or structural distortions in financial and energy markets. These country-level differences highlight the role of national conditions, including tariff structures, financial sector depth, and labour market dynamics, in shaping how households translate access into welfare gains.

Beyond these country-specific patterns, the income-group analysis reveals a clearer and more generalisable development-stage effect. The complementarity between financial inclusion and energy access is strongest in lower-middle-income economies, where the interaction term is large and highly significant, but remains weak or insignificant in high-income and upper-middle-income groups. This indicates that the finance–energy linkage operates most effectively where structural constraints are most binding. In lower-middle-income economies, financial inclusion relaxes liquidity constraints, enabling households to overcome upfront energy costs and invest in productive activities that raise income and consumption. In contrast, in high-income economies where both financial systems and energy infrastructure are already mature, additional gains from joint expansion are limited due to diminishing marginal returns. Upper-middle-income economies reflect a transitional stage, where infrastructure expansion is ongoing but not yet fully supported by inclusive and efficient financial systems. This pattern is consistent with the distributional literature, which shows that the poverty-reducing effects of financial inclusion depend on initial levels of exclusion, institutional quality, and the capacity of households to utilise financial services effectively (Park and Mercado, 2018; Ndlovu and Toerien, 2020). It also reinforces the policy implication that integrated finance–energy strategies are most critical in lower-income settings, where poverty, infrastructure gaps, and inequality remain closely intertwined.

The regime analysis adds an important resilience dimension. In Model A, the energy coefficient remains negative during both pre-COVID and COVID periods, but the adverse magnitude weakens from -2.024 before the pandemic to -0.672 during the pandemic. This suggests that although electricity still imposed net cost pressures, it became more essential for coping under lockdowns, remote work conditions, and restricted mobility. Financial inclusion also remains negative across both periods, with the slightly more adverse COVID coefficient suggesting that financial access during crisis may have been used more for coping with distress than for welfare-enhancing investment. The interaction results are particularly instructive: FI_EN is positive and significant before COVID at 8.190, but becomes insignificant during COVID at 1.071. This implies that the finance-energy complementarity weakened under crisis conditions, most likely because income losses, disrupted supply chains, reduced business activity, and constrained movement limited households' ability to convert finance and energy access into productive outcomes. The implication is that the interaction between COVID and the finance-energy nexus is not merely a level effect but a transmission effect. The pandemic appears to have impaired the mechanism through which financial inclusion makes energy access welfare-enhancing. This interpretation aligns with the broader literature that emphasises macroeconomic conditioning and the role of shock-responsive systems in preserving inclusive development outcomes (Davoodi, 2021; Liu et al., 2024). It also suggests that future specifications could explicitly interact COVID with both finance and energy variables to test whether crisis conditions systematically altered their marginal effects.

These conclusions should, however, be interpreted with appropriate caution. A major strength of the study lies in its use of two robust panel estimators, the incorporation of interaction terms, and the disaggregation by income group, regime, and country, all of which improve confidence that the central complementarity result is not driven by a single specification choice. The robustness check with Russia further shows that the main relationships are relatively stable. At the same time, several limitations remain. Household final consumption expenditure per capita is a defensible welfare proxy, but it may reflect short-run transitional pressures as much as longer-run welfare gains. Similarly, the energy access variable captures access rates rather than reliability, affordability, or service quality, while the financial inclusion index may not fully distinguish between benign inclusion through savings and payments and potentially harmful inclusion through costly borrowing. For this reason, the negative baseline coefficients should not be read as evidence that financial inclusion or electrification are inherently welfare-damaging; they more plausibly capture transitional burdens, affordability problems, and incomplete institutional support. Future work should therefore incorporate more refined indicators of energy quality, tariff structures, usage intensity, and responsible finance in order to better map the channels linking access to welfare.

Overall, the evidence suggests that poverty reduction in BRICS economies depends less on expanding finance and energy in parallel than on ensuring that they function together. Energy expansion without affordability protection can reduce consumption, and financial inclusion without safeguards can widen household liabilities. Yet when the two are aligned, they create a pathway through which households can absorb energy costs, invest in productive assets, and raise welfare. The practical implication is that poverty-oriented policy should move beyond siloed reforms towards integrated packages that combine targeted tariff relief, flexible connection financing, low-cost digital payments, savings instruments, appliance credit, and support for microenterprise electrification. Such interventions would strengthen SDG 1, improve the inclusiveness of SDG 7, support the productivity objectives of SDG 8, and advance SDG 10 by targeting the structural disadvantages faced by poorer households and poorer economies. Future research should model COVID and other shocks explicitly as interaction terms, while also testing whether the complementarity identified here is stronger under renewable energy transitions, better consumer protection frameworks, and more mature digital finance ecosystems.

5. Conclusions

This study examined how financial inclusion and energy access interact to influence poverty reduction in BRICS Plus economies. It evaluated both the independent and joint effects of these variables on household welfare, while explicitly accounting for cross-country differences, income-group heterogeneity, and structural disruptions associated with the COVID-19 period. By combining full-sample estimation with disaggregated analyses, the study provides a more nuanced understanding of the finance–energy–poverty nexus across economies at different stages of development.

The empirical findings yield several important insights. First, energy access, when considered independently, is associated with lower household consumption in the short run across the full sample, indicating that expanding electricity access alone does not automatically translate into welfare gains. This effect is particularly evident in upper-middle-income economies, where infrastructure expansion appears to impose cost burdens through tariffs, connection charges, and service inefficiencies. However, the country-level results reveal that this relationship is not uniform. Energy access contributes positively to welfare in countries such as Brazil, Ethiopia, Iran, and Russia, suggesting that where energy is more closely linked to productive activities and supported by favourable institutional conditions, its welfare-enhancing potential is realised. In contrast, weak or insignificant effects in countries such as China, India, and South Africa point to constraints related to affordability and uneven utilisation.

Second, financial inclusion does not exhibit a universally positive effect on household welfare. While it supports welfare improvements in countries such as China, Ethiopia, Russia, and Saudi Arabia, it is associated with reduced consumption in others, including Egypt, India, South Africa, and the United Arab Emirates. This divergence reflects differences in financial system quality, access conditions, and usage patterns. In some contexts, financial inclusion enhances consumption smoothing and investment capacity, whereas in others it may increase household exposure to borrowing costs and debt obligations without corresponding income gains. These findings underscore that the welfare implications of financial inclusion depend not only on access but also on the structure, inclusiveness, and efficiency of financial systems.

Third, and most importantly, the interaction between financial inclusion and energy access generates a strong and consistent positive effect on household welfare. This complementarity indicates that financial systems play a critical enabling role in transforming energy access into productive and welfare-enhancing outcomes. The income-group analysis further clarifies this relationship by revealing a clear development gradient. The interaction effect

is strongest and most significant in lower-middle-income economies, where financial constraints are more binding and energy access remains costly relative to income. In these contexts, financial inclusion enables households to overcome upfront costs, invest in energy-dependent activities, and improve consumption levels. In contrast, the interaction effect is weak or insignificant in high-income and upper-middle-income economies, reflecting structural maturity, broader access, and diminishing marginal returns.
Taken together, these findings challenge the assumption that financial inclusion or energy expansion alone is sufficient for poverty reduction. Instead, they demonstrate that development outcomes are shaped by the interaction between these systems and the broader institutional and economic context. The results highlight the importance of moving beyond aggregate interpretations towards a more differentiated understanding that accounts for country-specific conditions and income-level disparities. In particular, the evidence suggests that the finance–energy linkage is most developmentally significant in poorer economies, where coordinated expansion of financial services and energy infrastructure can generate substantial welfare gains.
The policy implications are therefore clear. Strategies aimed at reducing poverty in emerging economies should prioritise integrated approaches that combine affordable and reliable energy provision with inclusive and well-regulated financial systems. In lower-income contexts, targeted interventions such as subsidised energy financing, flexible payment systems, and support for small-scale enterprise development can enhance the productive use of energy and improve household welfare. In more advanced economies, policy efforts should focus on improving efficiency, reducing inequality in access and usage, and strengthening the quality of both financial and energy systems.
Future research should extend this analysis by incorporating more detailed measures of energy affordability, reliability, and service quality, as well as more granular indicators of financial usage and inclusion depth. Further work could also examine how climate shocks, digital financial innovation, and the transition to cleaner energy systems reshape the finance–energy–poverty nexus across different development contexts. Such efforts would provide deeper insights into the institutional and structural conditions necessary for ensuring that financial and energy expansion translate into sustained and inclusive improvements in living standards.

Funding

Shandong Provincial Humanities and Social Sciences Project

References

1. ACHEAMPONG A.O., OPOKU E.E.O., AMANKWAA A., DZATOR J., 2024, Energy poverty and gender equality in education: Unpacking the transmission channels, *Technological Forecasting and Social Change*, 202: 123274, https://doi.org/10.1016/j.techfore.2024.123274.
2. AKTER S., MATHEW N.M., FILA M.E., 2023, The impact of an improvement in the quality and reliability of rural residential electricity supply on clean cooking fuel adoption: Evidence from six energy poor Indian states, *World Development*, 172: 106366, https://doi.org/10.1016/j.worlddev.2023.106366.
3. ASGHAR N., AMJAD M.A., REHMAN H.U., MUNIR M., ALHAJJ R., 2022, Achieving sustainable development resilience: Poverty reduction through affordable access to electricity in developing economies, *Journal of Cleaner Production*, 376: 134040, https://doi.org/10.1016/j.jclepro.2022.134040.
4. BARKAT K., ALSAMARA M., MIMOUNI K., 2023, Can remittances alleviate energy poverty in developing countries? New evidence from panel data, *Energy Economics*, 119: 106527, https://doi.org/10.1016/j.eneco.2023.106527.
5. BELMIN C., HOFFMANN R., PICHLER P.-P., WEISZ H., 2021, Fertility transition powered by women's access to electricity and modern cooking fuels, *Nature Sustainability*, 5(3): 245–253, https://doi.org/10.1038/s41893-021-00830-3.
6. BYARO M., MMBAGA N.F., MAFWOLO G., 2024, Tackling energy poverty: Do clean fuels for cooking and access to electricity improve or worsen health outcomes in sub-Saharan Africa? *World Development Sustainability*, 4: 100125, https://doi.org/10.1016/j.wds.2024.100125.
7. DAVOODI H., 2021, Macroeconomic stability and inclusive growth, *IMF Working Papers*, 2021(081): 1, https://doi.org/10.5089/9781513574363.001.
8. DEMIRGUC-KUNT A., KLAPPER L., SINGER D., 2017, Financial inclusion and inclusive growth: A review of recent empirical evidence, *World Bank*, Washington, DC, https://doi.org/10.1596/1813-9450-8040.
9. DEMIRGÜÇ-KUNT A., KLAPPER L., SINGER D., 2018a, Financial inclusion and inclusive growth. In Beck T., Levine R. (Eds), *Handbook of Finance and Development*: 534–549, Edward Elgar Publishing, https://doi.org/10.4337/9781785360510.00029.
10. DU Q., ZHOU F., YANG T., DU M., 2023, Digital financial inclusion, household financial participation and well-being: Micro-evidence from China, *Emerging Markets Finance and Trade*, 59(6): 1782–1796, https://doi.org/10.1080/1540496X.2022.2153592.

11. GREENWOOD N., WARREN P., 2022, The role of climate finance beyond renewables: Behavioural insights, *Journal of International Development*, 34(8): 1570–1586, https://doi.org/10.1002/jid.3656.
12. HAY C., HUNT T., MCGREGOR J.A., 2022, Inclusive growth: The challenges of multidimensionality and multilateralism, *Cambridge Review of International Affairs*, 35(6): 888–914, https://doi.org/10.1080/09557571.2020.1784849.
13. HUANG F., LI W., JIN S., YUE M., SHUAI C., CHENG X., SHUAI Y., 2022, Impact pathways of photovoltaic poverty alleviation in China: Evidence from a systematic review, *Sustainable Production and Consumption*, 29: 705–717, https://doi.org/10.1016/j.spc.2021.11.015.
14. JACOB-UDEME M.O., 2024, Fostering sustainable growth through inclusive financial practices, *International Journal of Multidisciplinary Trends*, 6(4): 01–07, https://doi.org/10.22271/multi.2024.v6.i4a.400.
15. KAR A.K., BALI SWAIN R., 2024a, Does financial inclusion improve energy accessibility in Sub-Saharan Africa? *Applied Economics*, 56(49): 5789–5807, https://doi.org/10.1080/00036846.2023.2270227.
16. KATOCH O.R., SHARMA R., PARIHAR S., NAWAZ A., 2024, Energy poverty and its impacts on health and education: A systematic review, *International Journal of Energy Sector Management*, 18(2): 411–431, https://doi.org/10.1108/IJESM-10-2022-0007.
17. KHAN Z., HAOUAS I., TRINH H.H., BADEEB R.A., ZHANG C., 2023, Financial inclusion and energy poverty nexus in the era of globalization: Role of composite risk index and energy investment in emerging economies, *Renewable Energy*, 204: 382–399, https://doi.org/10.1016/j.renene.2022.12.122.
18. KOOMSON I., DANQUAH M., 2020, Financial inclusion and energy poverty: Empirical evidence from Ghana, *SSRN Electronic Journal*, https://doi.org/10.2139/ssrn.3759480.
19. KUMAR S.S., JIE Q., 2023, Exploring the role of financial inclusion in poverty reduction: An empirical study, *World Development Sustainability*, 3: 100103, https://doi.org/10.1016/j.wds.2023.100103.
20. LEVINE R., 2021, Finance, growth, and inequality, *IMF Working Papers*, 2021(164): 1, https://doi.org/10.5089/9781513583365.001.
21. LI Z., QAMRUZZAMAN MD., 2023, Nexus between environmental degradation, clean energy, financial inclusion, and poverty: Evidence with DSUR, CUP-FM, and CUP-BC estimation, *Sustainability*, 15(19): 14161, https://doi.org/10.3390/su151914161.
22. LIN H., ZHANG Z., 2023, The impacts of digital finance development on household income, consumption, and financial asset holding: An extreme value analysis of China's microdata, *Personal and Ubiquitous Computing*, 27(4): 1607–1627, https://doi.org/10.1007/s00779-022-01667-z.
23. LIU C., XU Q., GONG X., MA X., 2024, Health shocks and consumption smoothing: The role of digital financial inclusion, *SSRN Electronic Journal*, https://doi.org/10.2139/ssrn.4815031.
24. LYONS A., KASS-HANNA J., LIU F., GREENLEE A., ZENG L., 2019, Building financial resilience through financial and digital literacy in South Asia and Sub-Saharan Africa, *SSRN Electronic Journal*, https://doi.org/10.2139/ssrn.3496562.
25. MANKO K., WATKINS T.A., 2022, Microfinance and SDG 7: Financial impact channels for mitigating energy poverty, *Development in Practice*, 32(8): 1036–1048, https://doi.org/10.1080/09614524.2020.1863338.
26. MINAS A.M., GARCÍA-FREITES S., WALSH C., MUKORO V., ABERILLA J.M., APRIL A., KURIAKOSE J., GAETE-MORALES C., GALLEGO-SCHMID A., MANDER S., 2024, Advancing sustainable development goals through energy access: Lessons from the Global South, *Renewable and Sustainable Energy Reviews*, 199: 114457, https://doi.org/10.1016/j.rser.2024.114457.
27. NDLOVU G., TOERIEN F., 2020, The distributional impact of access to finance on poverty: Evidence from selected countries in Sub-Saharan Africa, *Research in International Business and Finance*, 52: 101190, https://doi.org/10.1016/j.ribaf.2020.101190.
28. OKOLO-OBASI N.E.V., NWANMUOH E.E., IFEDIORA C.U., DIKE R.A., OZUMBA I.U., ANYACHEBELU N.C., 2025, Financial inclusion and poverty reduction among rural women in Sub-Saharan Africa: Evidence from Nigeria, *African Journal of Management and Business Research*, 17(1): 452–474, https://doi.org/10.62154/ajmbr.2024.017.010572.
29. OLAYIWOLA A.S., AKINBOBOLA T.O., 2022, Role of financial sector development in the nexus between inclusive growth and poverty: A regional comparative analysis from Sub-Saharan Africa, *Research in Applied Economics*, 14(1): 18, https://doi.org/10.5296/rae.v14i1.19855.
30. ONATUNJI O.G., 2025, The potency of financial inclusion for income inequality reduction in BRICS economies: Does institutional quality matter? *Global Journal of Emerging Market Economies*, 17(1): 49–72, https://doi.org/10.1177/09749101241256095.
31. PANDEY T.D., 2023, Impact of financial inclusion on human development index: Special reference to BRICS countries, *BRICS Journal of Economics*, 4(2): 209–223, https://doi.org/10.3897/brics-econ.4.e96288.
32. PARK C.-Y., MERCADO R., 2018, Financial inclusion: New measurement and cross-country impact assessment, *SSRN Electronic Journal*, https://doi.org/10.2139/ssrn.3199427.

33. RAO N.D., PACHAURI S., 2017, Energy access and living standards: Some observations on recent trends, *Environmental Research Letters*, 12(2): 025011, https://doi.org/10.1088/1748-9326/aa5b0d.
34. SAHA S.K., QIN J., 2023, Financial inclusion and poverty alleviation: An empirical examination, *Economic Change and Restructuring*, 56(1): 409–440, https://doi.org/10.1007/s10644-022-09428-x.
35. SAID R., ACHEAMPONG A.O., 2023, Financial inclusion and energy poverty reduction in Sub-Saharan Africa, *Utilities Policy*, 82: 101567, https://doi.org/10.1016/j.jup.2023.101567.
36. SEN K.K., KARMAKER S.C., HOSAN S., CHAPMAN A.J., UDDIN M.K., SAHA B.B., 2023, Energy poverty alleviation through financial inclusion: Role of gender in Bangladesh, *Energy*, 282: 128452, https://doi.org/10.1016/j.energy.2023.128452.
37. SODOKIN K., DJAFON J.K., COUCHORO M.K., AGBODJI A.E., 2023, Digital transformation, financial access and discrepancies in household wealth accumulation, *Cogent Economics & Finance*, 11(2): 2241700, https://doi.org/10.1080/23322039.2023.2241700.
38. SONG Y., GONG Y., SONG Y., CHEN X., 2024, Exploring the impact of digital inclusive finance on consumption volatility: Insights from household entrepreneurship and income volatility, *Technological Forecasting and Social Change*, 200: 123179, https://doi.org/10.1016/j.techfore.2023.123179.
39. TADESSE TULU D., 2023, Inclusive financing in developing countries: A systematic review, *Journal of World Economic Research*, https://doi.org/10.11648/j.jwer.20231201.12.
40. TAMASIGA P., ONYEAKA H., BAKWENA M., OUASSOU E.H., 2024, Pricing the future: Unveiling the effects of carbon pricing on socio-economic outcomes and energy poverty, *International Journal of Sustainable Energy*, 43(1): 2362334, https://doi.org/10.1080/14786451.2024.2362334.
41. THO PESCH G., EINARSDÓTTIR A.K., DILLMAN K.J., HEINONEN J., 2023, Energy consumption and human well-being: A systematic review, *Energies*, 16(18): 6494, https://doi.org/10.3390/en16186494.
42. WANG X., FU Y., 2022, Digital financial inclusion and vulnerability to poverty: Evidence from Chinese rural households, *China Agricultural Economic Review*, 14(1): 64–83, https://doi.org/10.1108/CAER-08-2020-0189.
43. WEI R., ADELEKE O.K., OKOGOR K.C., OSABOHIEN R., 2025, Climate risks and clean cooking energy for sustainable futures: Empirical evidence from Southeast Asia, *Applied Ecology and Environmental Research*, 23(4): 8297–8316, https://doi.org/10.15666/aeer/2304_82978316.
44. XIE Y., CHEN T., 2024, A study on the impact of digital financial literacy on household entrepreneurship - Evidence from China, *Sustainability*, 17(1): 117, https://doi.org/10.3390/su17010117.
45. YUE P., KORKMAZ A.G., YIN Z., ZHOU H., 2022, The rise of digital finance: Financial inclusion or debt trap? *Finance Research Letters*, 47: 102604, https://doi.org/10.1016/j.frl.2021.102604.