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**Energy Risks, Financial Access and
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Abstract

Purpose – Energy risks, financial access and women's economic participation remain crucial scholarly and policy concerns in the achievement of the United Nations Sustainable Development Goals (SDGs). This study assesses the link between energy risks, financial access, and women's economic participation in Africa.

Design/methodology/approach – The focus is on 31 African countries for the period 2000-2019. The empirical evidence is based on Quantile Regressions (QR) and the Generalized Method of Moments (GMM). Interactive regressions are employed in order to provide more room for policy implications.

Findings – Positive and negative financial access thresholds are consistently established for the QR and GMM results. Positive financial access thresholds are turning points where the negative effect of energy risk on women's economic participation (i.e., female labour force participation and female employment) is completely mitigated. Negative financial access thresholds are turning points where the positive effect of energy risk on female unemployment is completely crowded-out. The financial access thresholds are within policy range and contingent on the conditional distribution of women's economic participation.

Practical implications – Reaching financial access thresholds is necessary to change the unconditional impact of energy risks on women's economic participation (unemployment) from negative (positive) to positive (negative). It follows that financial access critical levels are necessary to reverse the unfavorable negative (positive) influence of energy risks on female employment (unemployment). The recommended financial access thresholds in order to completely mitigate the unfavorable effect of energy risk on women's economic participation are both feasible and implementable. The policy implications are directly related to promoting SDG5 on the economic empowerment of women as well as SDG7 on affordable and clean energy. Other policy implications are discussed.

Originality/value – The study complements the extant literature by examining linkages between energy risks, financial access and women's economic participation.

Keywords : women's economic participation; financial access; energy risks.

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1.Introduction

Women are the primary economic force in many developing nations (Mengstie, 2022). In fact, a sizable section of the workforce in many nations is employed in the unorganized or informal sector. Women make-up a sizable share of this industry, whether they are employed in agriculture, street commerce or domestic services. Women must participate in the economy in order to exercise their rights, grow in their role as family decision-makers, and gain more influence in the community (Mengstie, 2022). Shaheen et al. (2013) asserted that women's empowerment leads to equal societies. Nevertheless, in most countries, the percentage of women living in poverty is higher than that of men, and they frequently have less control over their financial resources (Munoz et al., 2018). For instance, a significant portion of married women in developing nations lack financial independence and rely on their husbands to make crucial financial decisions (United Nations, 2015). In addition, women continue to receive lower wages than males for equivalent labor, which hinders their potential to achieve financial independence and self-sufficiency (Reshi & Sudha, 2023). This problem is not unique to Africa.

Therefore, the primary goal of this research is to ascertain how financial access affects the impact of energy risks on women's economic participation in Africa. The issue under discussion is based on three main motivations, specifically: (i) the question of women's economic participation in the context of the Sustainable Development Goals (SDGs) after 2015. (ii) The significance of financial access in women's economic participation; and (iii) the gaps in the body of existing literature. These three viewpoints are developed in the next paragraphs using the same chronology.

First, the SDGs emphasize women's economic participation, especially SDG 5, which seeks to empower all girls and women and achieve gender equality (Asongu & Odhiambo, 2020) as well as SDG7 on affordable and clean energy. Economic empowerment is one of the issues facing policymakers in developing nations, especially those with high rates of unemployment and poverty (Demirgüç-Kunt & Singer, 2017)¹.

Second, there is widespread agreement in theoretical and empirical research that financial access boosts household and business investment opportunities, which in turn lead to improvements in socioeconomic development and living standards (Wale & Makina, 2017; Mertens & Mensah, 2017; lyke & Odhiambo, 2017; Chapoto & Aboagye, 2017). When faced

¹ According to research by the National Agency for Statistics and Demography in 2025, the unemployment rate for women in Africa was estimated at 34.2% in 2023, more than three times higher than that of men (10.9%). In addition, women make up 72% of the unemployed population. However, women in Africa have the lowest participation rate in the labor market in the world, at 36%, when compared to men, whose rate is 57% (ANSD, 2025). It is concerning to note that over 70% of working women are employed in the informal sector, where social guarantees are nonexistent and working conditions are unstable (World Bank, 2024).

with challenges that women in households engaged in economic activity may encounter, financial access would help them better manage and, in the best situation, overcome these challenges. Such challenges represent issues that affect the progress of their activities. For instance, the consequences of energy risks are becoming more noticeable in Africa. Financial institutions can be crucial in the funding and investments required for renewable energy, thereby assisting in the expansion of access to contemporary energy services in underserved areas and mitigating the impact of energy risks (Mukhtarov & Mikayilov, 2023), consequently, supporting the growth of women's economic endeavors. Therefore, by lowering perceived risks, financial access encourages the private sector and minorities to participate in the economy and mobilizes the capital required to build energy infrastructure in areas with low energy levels (Mukhtarov & Mikayilov, 2023).

Third, despite the significant role that financial access can play in the link between energy risks and women's economic participation, our review of the current literature on economic inclusion has primarily focused on topics not covered in this study. Such topics already covered include: the impact of women's financial inclusion on inclusive economic development (Cabeza-García et al., 2019). Some authors have examined the influence of financial access on the impact of information and communication technologies on women's economic participation (Asongu & Odhiambo, 2018). The relationship between governance, inequality thresholds, and women's economic participation has also been assessed (Asongu & Odhiambo, 2020) as well as the effect of inequalities on women's economic participation with the moderating role of financial access (Asongu et al. 2020). Langnel et al. (2021) have focused on the relationship between environmental degradation and women's economic participation in Africa while Ozoemena (2018) is concerned about the impact of gender justice and economic inclusion. Adera and Abdisa (2023) focus on the impact of financial inclusion on women's economic participation whereas Kabagerayo et al. (2022) assess the impact of rural women entrepreneurs on social and economic inclusion. The relationship between environmental taxation, carbon emissions, and women's economic participation has also been examined in the extant literature (Soku et al., 2023).

In the light of the same factors related to women's economic participation that are used in the present study, this research is more similar to those of Asongu and Odhiambo (2018) and Asongu et al. (2020). The former investigates how information and communication technologies (ICTs) affect women's economic participation in Africa. While taking into account the moderating influence of financial access, the latter investigates the relationship between inequality and women's economic participation in Africa. This study differs from others in that it evaluates the relationship between energy risks and women's economic participation in relation to financial access. Hence, the originality of the present study is framed as an extension beyond ICT and inequality-based frameworks on gender equality and financial access which

have neglected the sparse energy risks dimension which, the present study integrates to provide a distinctive contribution to the extant literature.

The article's remaining content is organized as follows: The theoretical underpinnings are briefly analyzed in Section 2. In Section 3, the data and empirical technique are disclosed. The results are presented and analyzed in Section 4, and the study is concludes in Section 5.

2. Theoretical Foundations

In this section, the theoretical underpinnings of the relationship between energy risks and women's economic participation are presented, along with the ways in which financial access can affect the effects of energy risks on women's economic participation. It is crucial to remember that the relationship between energy risks and women's economic participation primarily depends on how women who are employed in the economy may be impacted by energy-related issues or excessive energy prices. It also based on how they can profit from having access to dependable and reasonably priced energy sources to expand their economic endeavors. Thus, in the same order, the two primary theoretical strands that support: (i) the relationship between financial access and women's economic participation and (ii) the connection between energy risks and women's economic participation are discussed.

First, the main theoretical insights that explain the connection between women's financial access and economic inclusion may be found within the framework of theoretical underpinnings related to the intensive and extensive margin theories (Tchamyu et al., 2023). These insights support the intensive margin theory, which states that those who already benefit from financial access opportunities will have more opportunities to finance projects that could raise their standard of living. This theory applies to those who are already financially included and who are customers of one or more financial institutions. Conversely, the extensive margin theory is premised on the idea that financial services are not limited to the conventional recipients of the underlying financial access opportunity. As a result, opportunities to enhance their socioeconomic activities are given to those who previously did not have access to financial services. This is true for women, who make up a group of people who are less able to use financial services (Ngono, 2021). As a result, financial access promotes women's involvement in the economy by giving them the capital they need to launch and run their enterprises and take part in other initiatives that support women's economic empowerment (Assairh et al., 2020).

The underlying theoretical foundations motivate the following testable hypothesis:

Hypothesis 1. Financial access promotes women's economic participation.

The impact of energy on women's economic participation is the subject of the second stream of theoretical work in this area. The energy dependency theory serves as the primary theoretical foundation for the relationship between energy risks and development outcomes. This notion holds that energy is essential to both the operation and expansion of individuals and enterprises. The economy, culture, environment, and other areas may all be significantly impacted by this dependency. It is true that energy use has a significant impact on society, but the risks involved are far more significant. Energy services have the potential to increase women's economic participation, but the risks involved in using them can seriously impede

their economic inclusion, claims Mohideen (2018). Given power outages or high energy prices, these hazards may result in women's decreased productivity and competitiveness in economic activities. This position is broadly consistent with extant studies on the link between gender inclusion and sustainable development, *inter alia*: in the nexus between energy justice and gender (Raman et al., 2025) and women's empowerment in driving energy transition (Sen et al. 2025). The stance is also supported by Zheng and Ma (2025) on fuel choices and gender empowerment and Butty et al. (2025) on the linkage between energy poverty and gender inequality.

The following testable hypothesis is motivated by the theoretical underpinnings:

Hypothesis 2: The economic participation of women is decreased by energy risks.

Taking into account both Hypotheses 1 and 2, Hypothesis 3 is put out as follows:

Hypothesis 3: Financial access mitigates the unfavorable impact of energy risks on women's economic participation.

Hypothesis 3 is assessed by looking at how financial access mitigates the impact of energy risks on women's economic participation, whereas Hypothesis 2 is examined with the unconditional effect of energy risk on the outcome variable. Given that in interactive regressions, the unconditional effect of the moderating variable (i.e., financial access) is null when the partial derivative of the outcome variable (i.e., women's economic participation) is taken with respect to the main channel (i.e., energy risk), the validity of Hypothesis 1 is contingent on the validity of Hypothesis 3. The following part examines the empirical validity of the underlying hypotheses through an empirical investigation.

3. Data and Methodology

3.1 Data

Based on yearly data for the years 2000–2019, the research focuses on 31 African nations in light of the study's motivation². The selection of nations and periodicity is also influenced by limitations on data availability during the study. There are four sources of the information. First, the International Labor Organization provides three indicators of women's economic involvement, consistent with Asongu et al. (2020), partly motivating the study. These include female employment, female unemployment, and female labor force participation (Ofori et al., 2023). Research recommends evaluating robustness by alternatively using independent variables of interest (Efobi et al., 2018; Asongu et al., 2020). The financial access indicator, also known as private domestic credit, is then retrieved from the Financial Structure and Development Database (FSDS) of the World Bank.

Third, consistent with Kuziboev et al. (2025), data on energy risks are obtained from Refinitive which is clarified in Appendix 1. The higher the score is, the higher risk a country faces energy risk and vice versa. Finally, data on the three control variables used in the model, are obtained from the World Bank's World Development Indicators (WDI): (i) GDP growth rate per capita; (ii) remittances; and (iii) mobile cellular subscription. Current studies on gender economic inclusion are in line with the control variables that were selected (Adera & Abdisa, 2023; Bashir et al., 2023; Ofori et al., 2024; Asongu & Odhiambo, 2024). It should be underlined that the reason for using less control variables is that more of them could result in more instruments in the GMM model, and the associated instrument proliferation issue could render the estimated models invalid (Asongu & Nwachukwu, 2017; Ndour & Asongu, 2024).

According to the expected signals of the control variables, women's active involvement in the economy is thought to be correlated with GDP per capita, remittances, and mobile cellular subscription (de Melo Avila et al., 2015; Khowsehawati & Jantarakolica, 2021). Numerous studies have examined the connection between economic growth and women's economic inclusion in relation to GDP per capita. The two variables have a contentious relationship that can be either favorable (Ndjokou & Asaloko, 2024) or negative (Lahoti & Swaminathan, 2016). The predicted sign is therefore ambiguous. According to Ibourk and Amaghous (2014), there is a paradoxical relationship between remittances and women's economic empowerment. As a result, the anticipated sign may be either positive or negative. As the last variable considered, mobile cellular subscription could be an effective measure to promote women's economic participation (Kankaria & Dutta, 2021). Therefore, the expected sign is positive.

² Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Rep., Cote d'Ivoire, Egypt, Arab Rep., Ethiopia, Gabon, Ghana, Guinea, Kenya, Madagascar, Mali, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia.

Appendix 1 presents the definitions of the variables and their corresponding sources, the summary statistics are provided in Appendix 2 and the Appendix section is supplemented by information on paired correlations provided in Appendix 3.

3.2 Methodology

3.2.1 Quantile Regression

Contrary to recent studies (Asongu & Odhiambo, 2018; Asongu et al., 2020; Adera & Abdisa, 2023), the study uses as its first estimation technique the quantile regressions (QR) approach. This estimation method allows the study to evaluate the studied links across the conditional distributions of women's economic participation. It is relevant to take into account the already existing levels of the dependent variable, which is in line with studies that focus on evaluating the links throughout the conditional distribution of the outcome variable using the QR method (Billger & Goel, 2009; Asongu, 2024; Fu et al., 2026; Mete et al., 2025).

It should also be noted that, unlike the Ordinary Least Squares (OLS) approach which is based on the principle of normal distribution of error terms, the QR approach does not take this assumption into account. This is mainly due to the possibility of estimated coefficient errors resulting from estimates based on such an assumption. According to recent and not current research on the subject, the parameters calculated in QR do not rely on regularly distributed error terms (Koenker & Bassett, 1978; Koenker et al. Hallock, 2001; Boateng et al., 2018).

According to the relevant literature, under the QR approach, the estimator of θ^{th} the quantile of women's economic participation variable is obtained by solving the optimization problem of Equation (1), which is revealed without any subscripts in order to simplify the presentation.

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_i' \beta\}} \theta |y_i - x_i' \beta| + \sum_{i \in \{i: y_i < x_i' \beta\}} (1 - \theta) |y_i - x_i' \beta| \right] \quad (1)$$

Where $\theta \in (0,1)$. According to the OLS method, which is mainly based on the reduction of the total sum of squares of the residuals, the estimation process is consistent with the maximization of the corresponding absolute deviations. The corresponding procedure consists of optimizing the absolute deviations associated with the corresponding quantiles. For example, we obtain the 90th quantile (i.e., corresponding to $\theta = 0.90$) by approximately weighting the residuals. The parameter estimates related to female economic participation or y_i given x_i is :

$$Q_v(\theta / x_i) = x_i' \beta_\theta \quad (2)$$

Where, for the corresponding quantile θ is to be determined, the single-slope parameters are evaluated in the conditional distribution of women's economic participation. The

corresponding estimate is orthogonal to the slope $E(y/x) = x_i\beta$ of the Ordinary Least Squares (OLS) method, characterized by an evaluation of the parameters exclusively at the conditional mean of the outcome variable. Regarding the estimation process of Equation (2), the dependent variable y_i is women's economic participation measured by the female unemployment rate, the female employment rate and female labour force participation. Conversely, x_i contains a constant; energy risks, financial access measured by domestic credit to the private sector, the growth rate of gross domestic product (GDP) per capita, remittances and mobile cellular subscription. There are extant contemporary gender and energy studies that are based on the QR approach in order to improve room for policy implications (Fu et al., 2026; Mete et al., 2025).

3.2.2 GMM Specification

To give more room to policy implications, the study also uses an estimation method founded on the mean value of the outcome variable. Based on the literature, four main constraints are required. First, as recommended by Roodman (2009), the study must cover a large number of individuals and a comparatively shorter period ($N > T$). This is the case for our study, as the research focuses on 31 countries with a period from 2000 to 2019 (i.e., 19 years). Second, the women's economic participation variables display persistence not least because the relationships between the dependent variables and their first lag exceeds the empirical threshold of 0.800, which is the established rule of thumb to demonstrate the persistence of an indicator (Meniago & Asongu, 2018; Tchamyou, 2019). Third, given the panel configuration of the data studied, the GMM strategy takes into account disparities between countries during the estimation process. Fourth, endogeneity is considered for at least two main reasons: (i) simultaneity is controlled for by internal instruments and (ii) accounting for unobserved heterogeneity by controlling for time fixed effects.

The GMM method used in this study is an adaptation of Arellano and Bover (1995) by Roodman (2009). The objective of this strategy is to provide more efficient estimates, given the proliferation of instruments and the possibility of reducing them. Several studies, such as Boateng et al. (2018), corroborate this view.

The following equations levels and first difference or Equation (3) and Equation (4), respectively, articulate the standard system GMM presentation.

$$WEP_{i,t} = \sigma_0 + \sigma_1 WEP_{i,t-\tau} + \sigma_2 ER_{i,t} + \sigma_3 FA + \sigma_4 FAX_{i,t} + \sum_{h=1}^3 \delta_h W h_{i,t-\tau} + \eta_i + \vartheta_t + \varepsilon_{i,t} \quad (3)$$

$$WEP_{i,t} - WEP_{i,t-\tau} = \sigma_1 (WEP_{i,t-\tau} - WEP_{i,t-2\tau}) + \sigma_2 (ER_{i,t} - ER_{i,t-\tau}) + \sigma_3 (FA_{i,t} - FA_{i,t-\tau}) + \sigma_4 (FAX_{i,t} - FAX_{i,t-\tau}) + \sum_{h=1}^3 \delta_h (W h_{i,t-\tau} - W h_{i,t-2\tau}) + (\vartheta_t - \vartheta_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \quad (4)$$

Where WEP is a variable for women's economic participation (i.e., female labor force participation, female unemployment, and female employment) of country i in period t , σ_0 is a constant while ER is a measure of energy risks. FA stands for financial access (or private domestic credit), FAX represents the interaction between indicators of energy risks and financial access ("financial access" $\times$ "energy risks"), W denotes the vector of control variables (i.e., consisting of the growth rate of GDP per capita, remittances, and mobile cellular subscription). τ represents the autoregression coefficient which is represented by 1 because in the study, a one-year lag is sufficient to capture information from the past. ϑ_t indicates the time-specific effect, η_i reflects the country-specific effect, and $\varepsilon_{i,t}$ the error term. Since heteroscedasticity is taken into account, the two-step procedure is preferred.

3.2.3 Identification and Exclusion Restrictions

A thorough explanation of the identification approach and the accompanying exclusion restrictions is crucial, according to current research on GMM (Asongu & Nwachukwu, 2017; Tchamyou & Asongu, 2017; Boateng et al., 2018; Tchamyou et al., 2019). Years are considered purely exogenous variables according to the relevant literature, while predefined variables are considered as both independent variables of interest and components of the conditioning information set. Roodman (2009) argued that the exclusion restrictions technique is justified because years are unlikely to become endogenous after an initial first difference.

It is crucial to emphasize that in the non-contemporary instrumental variable (IV) method, the Sargan/Hansen overidentification bounds test is not rejected to determine whether the identification strategy is valid. Therefore, to ensure the validity of the instruments, it is crucial not to reject the null hypothesis of the corresponding test (Beck, 2009; Asongu & Nwachukwu, 2017; Amavilah et al., 2017). However, the validity of the exclusion criteria and the matching identification technique is assessed using the Difference in Hansen Test (DHT) and a GMM strategy based on direct orthogonal variations. Since the instruments only clarify the outcome variable by using the exogenous components of the predefined indicators, they are valid if the null hypothesis of the DHT is not rejected. There are also extant contemporary gender and energy studies that are based on the GMM approach in order to improve room for robustness (Kuziboev et al., 2024; Bellepea & Tüüç, 2025).

3.2.4 Note on endogeneity

It is relevant to clarify how the study deals with the concern of endogeneity, especially as it pertains to the four main causes of endogeneity which are: variable omission bias, measurement errors, the unobserved heterogeneity and simultaneity or reverse causality (Hill et al., 2021; Khatib, 2025). First, the study accounts for variable omission bias by adopting control variables which have been documented in the extant literature to influence the

outcome variables, consistent with the narrative in the data section on the selection of variables. Second, concerns pertaining to measurement errors are tackled by using alternative gender economic inclusion variables. Thus, female unemployment, female employment and female labour force participation are employed in order to control for potential measurement errors linked to the gender economic inclusion variables. Third, the GMM approach is tailored to account for time fixed effects which represent some control for the unobserved heterogeneity. Moreover, by assessing the linkages throughout the conditional distribution of the outcome variable using the QR approach, heterogeneity in the outcome variables is also taken into account. Fourth, simultaneity or reverse causality is controlled by employing internal instruments in the GMM approach.

It relevant to note that consistent with extant threshold literature (Mete et al., 2025), in the empirical results section that follows both positive and negative financial access thresholds are established. Positive financial access thresholds are turning points where the negative effect of energy risk on the economic participation of women (i.e., female labour force participation and female employment) is completely mitigated. Negative financial access thresholds are turning points where the positive effect of energy risk on female unemployment is completely crowded-out.

4. Empirical Results

4.1 Presentation of Results

The tables below show the empirical findings. Tables 1 and 2 provide the quantile regression (QR) estimates, whereas Table 3 discloses the system GMM estimates. When we examine interactions across the conditional distribution of the women's economic participation, Tables 1 and 2 provide us with a more thorough understanding of the link between the variables in the first set of results. The three economic inclusion variables utilized in this study are depicted in the various tables. The first panel of Table 1 shows the links between energy risks, financial access and female labour force participation. Moreover, the second panel of Table 2 depicts, nexuses between energy risks, financial access, women's employment. Table 2 uses women's unemployment as a proxy for women's economic participation. Three types of results are obtained. Firstly, regarding Table 1, Hypotheses 1 and 3 are valid. In essence, energy risk decreases women's economic participation because its unconditional effect is negative in Table 1, positive in Table 2 and both positive and negative in Table 3. Hence, Hypothesis 2 is valid because energy risk unconditionally decreases female labour force participation and female employment while also unconditionally increases female unemployment. The validity of Hypothesis 3 which is contingent on the validity of Hypothesis 1 is also apparent because financial access crowds-out the unfavorable effect of energy risk on women's economic participation.

Accordingly, positive and negative financial access thresholds are consistently established for the QR and GMM results. Positive financial access thresholds are turning points where the negative effect of energy risk on women's economic participation (i.e., female labour force participation and female employment) is completely mitigated. Negative financial access thresholds are turning points where the positive effect of energy risk on female unemployment is completely crowded-out. The financial access thresholds are within policy range and contingent on the conditional distribution of female economic inclusion. In other words, the financial access policy thresholds are within the statistical range of the financial access policy or moderating variable disclosed in the summary statistics (i.e., -0.491 to 142.422) (% of GDP). The thresholds are computed by dividing the unconditional effect of energy risk by its corresponding interactive or conditional effect and then, taking the absolute value quotient.

Table 1: Energy Risk, Financial Access and Women's Economic Participation (Quantile Regressions)

	Dependent variable: Female Labor Force participation					
Variables	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	92.349*** (2.816)	79.923*** (8.113)	83.506*** (5.517)	86.669*** (3.967)	105.029*** (2.853)	112.008*** (3.567)
Enrisk	-0.387***	-0.392**	-0.317**	-0.259***	-0.514***	-0.575***

	(0.061)	(0.181)	(0.123)	(0.088)	(0.063)	(0.079)
Financial Access (FA)	-0.668***	-0.654	-0.403	-0.630***	-0.809***	-0.822***
	(0.128)	(0.428)	(0.291)	(0.209)	(0.150)	(0.188)
Enrisk_FA	0.015***	0.016	0.009	0.014***	0.017***	0.016***
	(0.003)	(0.011)	(0.007)	(0.005)	(0.003)	(0.004)
GDP	0.062	0.408*	0.106	0.004	0.080	-0.013
	(0.082)	(0.236)	(0.160)	(0.115)	(0.083)	(0.103)
Remittances	-0.053	-1.178***	-0.541***	0.081	0.031	-0.004
	(0.096)	(0.211)	(0.143)	(0.103)	(0.074)	(0.092)
Mobile Cellular Subs	-0.087***	-0.071***	-0.086***	-0.058***	-0.077***	-0.075***
	(0.010)	(0.026)	(0.018)	(0.013)	(0.009)	(0.011)
Times Effects	Yes	Yes	Yes	Yes	Yes	Yes
Positive Thresholds	25.800	na	na	18.50	30.235	35.93
Observations	558	558	558	558	558	558
Fisher	56.920***					
R-squared /Pseudo R ²	0.242	0.138	0.134	0.131	0.205	0.237
	Dependent variable: Female Employment					
Variables	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	93.216***	60.065***	81.632***	96.152***	120.948***	127.548***
	(4.244)	(13.851)	(6.794)	(4.482)	(5.499)	(4.825)
Enrisk	-0.676***	-0.421	-0.514***	-0.705***	-1.075***	-1.081***
	(0.091)	(0.308)	(0.151)	(0.100)	(0.122)	(0.107)
Financial Access (FA)	-1.522***	-1.027	-0.917**	-1.408***	-2.102***	-1.725***
	(0.196)	(0.732)	(0.359)	(0.237)	(0.291)	(0.255)
Enrisk_FA	0.036***	0.027	0.021**	0.032***	0.049***	0.038***
	(0.005)	(0.019)	(0.009)	(0.006)	(0.007)	(0.006)
GDP	0.068	0.540	-0.026	0.041	-0.023	-0.310**
	(0.113)	(0.410)	(0.201)	(0.133)	(0.163)	(0.143)
Remittance	-0.089	-0.457	-0.708***	-0.432***	0.039	0.196
	(0.158)	(0.360)	(0.177)	(0.116)	(0.143)	(0.125)
Mobile Cellular Subscri	-0.131***	-0.116**	-0.150***	-0.114***	-0.137***	-0.114***
	(0.014)	(0.047)	(0.023)	(0.015)	(0.019)	(0.017)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Positive Thresholds	18.777	na	24.476	22.031	21.938	28.447
Observations	541	541	541	541	541	541
Fisher	63.52***					
R-squared/Pseudo R ²	0.280	0.128	0.171	0.191	0.196	0.249

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The average value of FA is 19.633; the range of FA is -0.491 to 142,422. Enrisk_FA: Energy risks × Financial Access. "na" is assigned in place of thresholds for some quantiles because at least one estimated coefficient needed for the computation of the corresponding thresholds is not significant.

Source: Authors own work

Table 2 : Energy Risk, Financial Access and Female Unemployment (Quantile Regressions)

Variables	Dependent variable : Female Unemployment					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	-13.969*** (2.150)	-7.293*** (0.989)	-8.985*** (1.353)	-13.336*** (1.648)	-19.800*** (2.306)	-15.666*** (3.633)
Enrisk	0.392*** (0.050)	0.150*** (0.022)	0.212*** (0.030)	0.369*** (0.037)	0.566*** (0.051)	0.498*** (0.081)
Financial Access (FA)	0.797*** (0.117)	0.504*** (0.052)	0.498*** (0.071)	0.724*** (0.087)	1.126*** (0.122)	0.990*** (0.192)
Enrisk_FA	-0.015*** (0.003)	-0.008*** (0.001)	-0.008*** (0.002)	-0.014*** (0.002)	-0.024*** (0.003)	-0.018*** (0.005)
GDP	-0.107** (0.042)	-0.023 (0.029)	-0.056 (0.039)	-0.116** (0.048)	-0.092 (0.067)	0.007 (0.106)
Remittances	-0.108*** (0.024)	-0.026 (0.026)	-0.035 (0.035)	-0.068 (0.043)	-0.103* (0.060)	-0.199** (0.094)
Mobile Cellular Subs	0.019*** (0.005)	-0.000 (0.003)	0.005 (0.004)	0.014*** (0.005)	0.030*** (0.007)	0.026** (0.012)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Negative Thresholds	26.133	18.75	26.50	26.35	23.58	27.666
Observations	558	558	558	558	558	558
Fisher	107.460***					
R-squared/ /Pseudo R ²	0.582	0.144	0.164	0.266	0.418	0.470

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Enrisk_FA : Energy risks × Financial Access. Source: Authors own work

It important to note that the findings pertaining to the QR are also contingent on the initial levels of the women's economic participation variables, not least, because compared to the OLS findings in the second column, the corresponding QR vary in term of significance and magnitude of estimated coefficients. The variability is also apparent in the financial access thresholds which are different from one quantile to another. Hence in Tables 1-2, lower quantiles represent countries with comparatively lower levels of women's economic participation while higher quantile denote countries with correspondingly higher levels of women's economic participation. The moderating variable of financial access is more relevant in the top quantiles of the female economic inclusion distributions compared to the bottom quantiles of the corresponding distributions. Accordingly, in Tables 1-2, "na" is assigned in place of thresholds for some quantiles because at least one estimated coefficient needed for the computation of the corresponding thresholds is not significant.

Regarding Table 3, the system GMM is the estimating method employed. It is separated into three primary specifications, each of which stands for a distinct measure of women's economic participation. From left to right, the female employment rate is in the first specification, female

labor force participation in the second specification, and female unemployment in the final specification. It is crucial to stress that there is a positive and strong unconditional association between female labor force participation, energy risk and financial access. It should be underlined that in order to validate our GMM results, the estimates obtained must take into consideration a few information requirements³. In the light of the information criteria, the Sargan test can be significant because it is not robust, but not affected by instruments while the Hansen test is robust but affected by instrument proliferation. Hence, the Hansen test is adopted because it is robust and we ensure that for every specification, the number of instruments are lower than the corresponding number of countries in order to limit instrument proliferation, even when the collapse option is employed in the specification to restrict instrument proliferation. Moreover, it is expected that AR(1) test is significant while AR(2) test should not be significant (Asongu & De Moor, 2017).

According to the information regarding expected signs revealed in the data section, the majority of the significant control variables have the expected signs. Additionally, it should be mentioned that the multicollinearity issue is ignored in interactive regressions. Since interactive regressions incorporate both the unconditional and conditional impacts of the interaction variables, thresholds and/or net effects can therefore be understood with confidence (Brambor et al., 2016). Since the multicollinearity problem can impact the expected signs of control variables, such multicollinearity does not affect the independent variables of interest because of the computation of net effects and/or thresholds associated with these independent variables of interest. As a result, analyzing the control variables independently would be comparable to analyzing linear additive models.

Table 3: Energy Risk, Financial Access and the Women's Economic Participation (GMM)

Variables	Dependent variables		
	Employment	FLFpart	Unemployment
Constant	99.942*** (10.778)	125.753*** (7.830)	-7.111*** (1.879)
Enrisk	-0.770*** (0.247)	-1.148*** (0.177)	0.202*** (0.040)
Financial Access (FA)	-2.070*** (0.349)	-1.551*** (0.264)	0.880*** (0.064)

³ “First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR(2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen overidentification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fisher test for the joint validity of estimated coefficients is also provided” (Asongu & De Moor, 2017, p.200).

Enrisk_FA	0.044***	0.036***	-0.014***
	(0.008)	(0.006)	(0.001)
GDP	-0.044*	-0.105***	0.023*
	(0.025)	(0.018)	(0.013)
Remittance	0.164***	0.118***	-0.011
	(0.058)	(0.022)	(0.018)
Mobile Cellular Sub	-0.048***	-0.059***	-0.025***
	(0.012)	(0.009)	(0.003)
Time Effects	Yes	Yes	Yes
Thresholds (+ve & -ve)	17.500 (+ve)	31.888 (+ve)	14.428(-ve)
AR(1)	(0.001)	(0.061)	(0.013)
AR(2)	(0.273)	(0.674)	(0.806)
Sargan OIR	(0.000)	(0.000)	(0.000)
Hansen OIR	(0.729)	(0.475)	(0.327)
DHT for instruments			
(a) Instruments in levels			
H excluding group	(0.779)	(0.826)	(0.933)
Dif(null, H=exogenous)	(0.545)	(0.242)	(0.100)
(b) IV (years, eq(diff))			
H excluding group	(0.710)	(0.431)	(0.242)
Dif(null, H=exogenous)	(0.469)	(0.511)	(0.792)
Fisher	901.830***	11248.870 ***	888.950***
Observations	541	558	558
Instruments	29	29	29
Number of Countries	30	31	31

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Enrisk_FA: Energy risks × Financial Access. FLFpart : Female Labor Force participation

Source: Authors own work

4.2 Further Discussion of the Results

We will look more closely at the results in this part and discuss how they relate to previous research. It is crucial to first stress the significance of repositioning the investigation as closely as possible to previous studies in the literature before examining the data. As a result, two points should be noted: (i) the validation of the findings of Asongu and Odhiambo (2018) and Asongu et al. (2020) regarding women's economic participation. While the second emphasized the impact of inequality, the first showed how information and communication technology affects women's economic participation. (ii) The significance of the underlying connections evaluated across the outcome variable's distribution sets this study apart from others. Moreover, the findings in the study broadly confirm extant gender and energy scholarship the subject (Sadeghi & Shavvalpour, 2006; Yang et al., 2022; Chang et al., 2023; Arshad, 2023).

Considering the aforementioned, the findings have improved the body of knowledge about the detrimental relationship between energy risks and women's economic participation (Bera et al., 2024; Sarabdeen et al., 2024). They show how the effect of energy risks on women's

economic participation can be mitigated by financial access. According to the narratives, financial access can therefore moderate four points. First, women who have access to financial services can take steps to reduce energy risks, like buying more energy-efficient equipment. Second, women can invest in less energy-risky economic ventures, like services or goods that do not rely as much on energy. Third, women can increase their productivity by investing in tools and technologies that enable them to work more productively even during energy shortages. Fourth, by enabling women to save savings or purchase insurance that guards against energy-related losses, credit can help them become more resilient to energy hazards. Given the theoretical literature on the topic, the results confirm the intensive and extensive margin theories and energy dependence, respectively (Tchamyou et al., 2023; Asongu et al., 2024; Yenilmez & Yenilmez, 2025). Given that the conditional effect of financial access and energy risks benefits women's economic participation, the established findings are thus consistent with the discussed theoretical underpinnings in Section 2.

5. Concluding Implications and Future Research Directions

5.1 Conclusion

This study evaluated the relationships between women's economic participation, financial access, and energy risks in 31 African nations between 2000 and 2019. Quantile Regression (QR) and the Generalized Method of Moments (GMM) estimation techniques serve as the empirical strategies. Positive and negative financial access thresholds are consistently established for the QR and GMM results. Positive financial access thresholds are turning points where the negative effect of energy risk on women's economic participation (i.e., female labour force participation and female employment) is completely mitigated. Negative financial access thresholds are turning points where the positive effect of energy risk on female unemployment is completely crowded-out. The financial access thresholds are within policy range and contingent on the conditional distribution of the women's economic participation. Reaching financial access thresholds is necessary to change the unconditional impact of energy risks on women's employment (unemployment) from negative (positive) to positive (negative). It follows that financial access critical levels are necessary to reverse the unfavorable negative (positive) influence of energy risks on female employment (unemployment). Theoretical and practical policy implications are discussed in what follows.

5.2 Theoretical implications

In terms of theoretical implications, it is relevant to articulate how the findings confirm as well as extend the intensive/extensive margin theoretical underpinnings used to motivate the study. The findings confirm the engaged theoretical underpinnings because minimum financial access levels or critical financial access thresholds are established beyond which energy risk no longer has a negative influence on women's economic participation. It follows that enhancing access to financial resources by banking institutions to both existing (i.e., intensive margin theory) and new (i.e., extensive margin theory) bank customers improves opportunities for hedging against the negative effects of energy risks on women's economic participation.

Beyond confirming the extant theoretical underpinnings, the present study has also improved the attendant theoretical underpinnings from two main premises. On the one hand, the validity of the intensive/extensive margin theories is contingent on financial access reaching a critical level. It implies that in economies where financial access is below the established critical levels, the underlying theories do not withstand empirical scrutiny. It follows that economic theorists who have been viewing the intensive/extensive margin theories as linear from a practical standpoint are getting the dynamics inaccurately. On the other hand, the study has also shown that financial access can also mitigate the potential of energy risks in promoting a policy syndrome such as female unemployment. Thus, critical levels of financial access are also

relevant in mitigating the positive effect of one policy syndrome (i.e., energy risk) on another policy syndrome (i.e., female unemployment). It follows that the non-linearity of the intensive/extensive margin theories can also be contingent on avoiding policy syndromes which are channels and outcomes. Within the context of the study, both energy risk and female unemployment are policy syndromes and the established financial access thresholds simultaneously mitigate both policy syndromes by dampening the positive effect of energy risk on female unemployment.

In a nutshell, the present study has improved the non-linear understanding of the intensive/extensive margin theories by showing that when financial access is the moderating variable, positive macroeconomic outcomes can be promoted through the mitigation of policy syndrome channels (e.g., energy risks). Moreover, in the same vein negative macroeconomic outcomes can be mitigated by dampening policy syndrome channels (i.e., energy risk) when financial access is the moderating variable.

5.3 Policy and practical implications

In the area of economic development, addressing energy risks in the formal and informal sectors will play an important role in promoting women's economic participation. This is mainly because, on average, energy risks can have significant adverse impacts on economies, communities and individuals, especially women, and they need to be taken into account to ensure sustainable and reliable energy security. The findings in this study have shown that such policies should be contingent on initial levels of female economic inclusion, not least, because the nexuses vary throughout the conditional distribution of female economic inclusion and female unemployment. Hence financial access policies that are designed to promote female economic participation, contingent on energy risks should be based on initial levels of female economic participation and thus, tailored differently across countries with high, moderate and low initial levels of women's economic participation. Accordingly, the moderating variable of financial access is more relevant in the top quantiles of women's economic participation distributions compared to the bottom quantiles of the corresponding distributions.

Financial access to Africa is a crucial element of post-2015 development, as the majority of countries in the sub-region did not achieved the Millennium Development Goals as planned. We observed in this study that access to finance reduces the unfavorable impact of energy risks on women's economic participation. It is therefore necessary to implement adequate measures to promote access to finance in order to stimulate the financing of the resources needed to promote and improve renewable energy and by extension, promote female labour participation, boost female employment and mitigate female unemployment. Furthermore, it should be stressed that access to financial services plays a role in economic stability. It is

therefore essential that policymakers understand the importance of access to finance in promoting women's economic participation. Communities should also be encouraged to create resilience plans to energy risks, such as increasing energy efficiency and diversifying their energy sources.

A major policy relevance of this research is that two main notions of thresholds were considered and emphasized in the study, in particular with regard to, among others, positive policy thresholds and negative policy thresholds. In essence, as established in the results: (i) positive financial access policy thresholds are critical levels of financial access that need to be achieved in order to change the negative impact of energy risk on women's economic participation from negative to positive. (ii) Conversely, negative financial access policy thresholds are critical levels of financial access that need to be achieved in order to change the positive impact of energy risk on women's unemployment from positive to negative.

The established financial access thresholds are within statistical range and thus make economic and policy sense. Moreover, the fact that the financial access thresholds are closer to the mean value and further from the maximum value is an indication that many countries can leverage resources to reach the targeted policy thresholds. It follows that the recommended financial access thresholds in order to completely mitigate the unfavorable effect of energy risk on female economic participation are both feasible and implementable. In the light of the above, in interactive regressions, the provided thresholds have direct policy relevance because these are actionable levels of the moderating or policy variables that can be used to tailor the adopted mechanisms to influence the outcome variables in the targeted direction. The policy implications are directly related to promoting SDG5 on the economic empowerment of women because the findings are tailored to promoting gender economic inclusion as well as SDG7 on affordable and clean energy, not least, because the financial access thresholds are tailored to completely dampen energy risks which inter alia, constraint clean and affordable energy.

5.4 Limitations and Future Research Directions

The results of this study obviously leave room for future research, particularly to determine whether the established conclusions stand up to in-depth empirical scrutiny in light of the other United Nations Sustainable Development Goals (SDGs). As part of future research directions, country-specific studies should also be targeted to identify more country-specific policy implications. This recommendation is based on the shortcoming of the adopted GMM approach which eliminates country-specific effects in order to avoid potential concerns of endogeneity. In addition, the GMM was used based on internal instruments because of the difficulty of finding credible external instruments needed for other Instrumental variables (IVs)

techniques. Furthermore, future studies can improve the present research agenda by employing microeconomic data to complement insights from the macroeconomic findings provided in the present study. To this end, the future research agenda should consider, *inter alia*, household-level data, country case studies, or mixed-method approaches. Moreover, owing to data availability constraints on energy risks at the time of the study, the use of alternative measures of energy risks should be considered in future research. In addition, alternative financial access indicators should also be considered in future research in order to provide more insights into the investigated linkages. For instance the financial access proxy used in this study measures financial activity while alternative measures such as bank account access measures financial depth. Moreover, the mobile money data is limited for the periodicity under consideration. Last but not the least, contingent on data availability, future studies should explore other plausible mechanisms (energy-efficient equipment, sectoral choice, productivity investments, insurance), such as interacting financial access with sectoral composition or including a proxy for equipment adoption.

Appendices

Appendix 1: Definitions and Sources of Variables

Variables	Definitions	Sources
Energy Risk	Energy risk is measured as a score. The higher the score is, the higher risk a country faces energy risk and vice versa	LSEG Data & Analytics, formerly Refinitiv, is an American-British global provider of financial market data and infrastructure.
Unemployment of women	Female unemployment rate (% of female labor force) (national estimate)	ILO (International Labour Organization)
Employment of Women	Employment in agriculture, female (% of female employment) (ILO modeled estimate)	ILO (International Labour Organization)
Women's participation in the labor market	Labour force participation rate, women aged 15-64 (%) (ILO model estimate)	ILO (International Labour Organization)
Financial access	Private Domestic credit (% of GDP)	FDSD
GDP per capita growth	GDP per capita growth (% of annual)	World Bank Development Indicators(WDI)
Remittance	Personal remittance received (% of GDP)	World Bank Development Indicators(WDI)
Mobile cellular subscription	Mobile cellular subscription (% of 100)	World Bank Development Indicators(WDI)

FDSD: Financial Development and Structure Database. Source: Authors own work

Appendix 2: Summary Statistics (2000-2019)

	Mean	SD	Minimum	Maximum	Obs
Female Labor Force participation	70.163	10.420	46.582	90.340	620
Employment	56.122	14.640	22.308	84.142	620
Unemployment	6.837	6.596	0.317	33.473	620
Energy Risks	43.726	10.011	24.315	78.862	620
Financial Access	19.633	22.663	0.491	142.422	560
GDP	4.558	4.290	-36.391	33.629	620
Remittance	2.361	4.624	0.000	16.646	620
Mobile Cellular Subscription	47.387	43.291	0.017	185.559	617

Source: Authors own work

Appendix 3: Correlation Matrix

	FLFpart	Empl	Unempl	Enrisk	Fin.Ac	GDP	Remit	MCS
FLFpart	1.000							
Empl	0.802	1.000						
Unempl	-0.542	-0.598	1.000					
Enrisk	-0.164	-0.116	0.127	1.000				
Fin.Ac	-0.287	-0.316	0.652	-0.243	1.000			
GDP	0.068	0.055	-0.159	-0.130	-0.083	1.000		
Remit	-0.045	-0.053	-0.074	-0.168	0.094	0.039	1.000	
MCS	-0.428	-0.441	0.430	0.077	0.446	-0.066	0.127	1.000

FLFpart: Female Labor Force participation. MCS : Mobile Cellular Subscription. Empl: Employment.

Unempl: Unemployment. Enrisk: Energy Risk. Fin.Acc: Financial Access. Remit: Remittance.

Source: Authors own work

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