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Rainfall Variabilty, Climate Finance and Gender Inequality: A Zoom in on Sub-saharan Africa Women

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ABSTRACT

Sustainable Development Goal (SDG)-10 opines that all countries should reduce inequality (being it gender, income, regional or emission inequality) by 2030. However, the exacerbating effect of climate variability seems to widen gender inequality in developing countries such as Sub-Saharan Africa. It is on this backdrop that the UNFCCC mentioned the need for gender mainstreaming in raising climate finance to support developing countries. The main purpose of the study is to find out whether climate finance and rainfall variability impacts gender inequality among 46 Sub-Saharan Africa countries. Data was analysed using system generalised method of moment, to deal with the endogeneity problem inherent in the model. Sensitivity of the estimates was carried out to test the robustness of our results using panel quantile regression. The findings indicate that, SSA countries experiencing high rainfall variability are facing worsening gender inequality both in the short-run and long-run. For climate finance, it showed a significant gender equality strengthening effect in SSA both in the short-run and long-run. This indicates that, CF geared toward developing countries is not only helping mitigate and adapt to climate change, but bridging the gender gap too. Based on that, several policy implications are discussed.

Keywords: Climate Finance, Rainfall Variability, Gender Inequality and Generalised Method of Moment
JEL Classification: Q56

1. INTRODUCTION

If the world turns a gender-blind eye on climate change and disaster risk reduction interventions, it can escalate structural gender inequalities; by putting women and girls' at risk via limiting their access to resources and opportunities, and creating new types of exclusions (McQuigg, 2017; FAO and ARC, 2021). Even though climatic shocks do not discriminate in gender, women compared to men have a lower capacity to adapt or respond to its effect. The reason is that, women are more likely to live in poverty than men, have less access to basic human rights like the ability to freely move and acquire land, and face systematic violence that escalates during periods of instability, and women are normally uniquely situated in combating climate change; including being responsible for household energy consumption decisions (Nyahunda et al., 2021). Further, women have to travel longer distances in search of water for domestic use, wood for cooking and heating, and other forest related products to feed; which increases women vulnerability to the risks of sexual violence and trafficking (Resurrección et al., 2019; Meinzen-Dick et al., 2019; FAO and ARC, 2021; Doku and Phiri, 2024). It is also established in extant literature that, women are the largest of the world's population living in poverty, underscoring their perennial vulnerability to climate change (UN Women, 2012; Turpie and Visser, 2013; Bessah et al., 2021). In that vein, Ecofeminism theorists like Macgregor (2010) summarised that women's vulnerability to climate change impacts is caused by low levels of education, limited social mobility, exclusion in decision-making processes, and unequal access to education and other resources, land and productive employment.

All countries globally have begun experiencing the exacerbating effect of climate change, especially on welfare and livelihoods. However, developing countries and within them, together have the most vulnerable populations that suffer the greatest impacts. Asia and Africa are expected to bear the brunt as compared to anywhere in the world. Yet, women and girls in developing countries are the most vulnerable. For instance, Faria (2021) reported that close to 40% of people in Sub-Saharan Africa (SSA) above 15 years cannot read and write, and the literacy gender gap in the sub-region has widened between the year 2000 and 2019. A widening literacy gender gap is hampering the ability of women to comprehend and access climate change and disaster information and services(Brody et al., 2008; FAO and ARC, 2021). In that vein, the lower literacy levels of women make them less responsive to written early warning signs, which tend to worsen their vulnerability (UNICEF, 2021). In addition, in times of disaster, girls may be withdrawn from school to cut household expenses whereas boys are left to continue their education (Gay-Antaki and Liverman, 2018; FAO and ARC, 2021). If the situation remains unchecked, the world may miss Sustainable Development Goal-5 (SDG-5); achieving gender equality and women and girl's empowerment.

SSA is classified as highly vulnerable to both social and ecological impacts of climate change. That is why a recent report by Intergovernmental Panel on Climate Change (IPCC) pronounced the sub-region as a "climate change hot spot"; implying countries where human security is highly threatened due to projected climate change impacts (IPCC, 2019; Diffenbaugh and Giorgi, 2012; de Sherbinin, 2014; McOmber, 2020). Uncertainties of the weather and climate forecasting, cum challenges of pests and diseases, have made sustenance very difficult, especially for those living in extreme poverty. Interestingly, those with the wherewithal to do so shift livelihood strategies and adapt to changing socio-economic pressures. On the contrary, those without resources are left vulnerable to current and future climate disaster. SSA women have been found to be among the most vulnerable to the excruciating effects of climate change. The reason is that, SSA women overwhelmingly rely on agricultural and food economies, contributes to 80% of agricultural processing, 40% of agricultural production, and 70% of agricultural distribution of labour regionally (Allen et al., 2018; McOmber, 2020).

Due to the exacerbating effect of climate change on gender inequality, developed countries promised to raise enough climate finance; to support developing economies mitigate and adapt to climate change. Explaining why SDG-13 target 13a commits all developed-country parties to the United Nations Framework Convention on Climate Change (UNFCCC) to a goal of mobilizing jointly $100 billion annually by 2020 onwards from all sources. For the purpose of addressing the needs of developing countries, in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization. A prerequisite of all climate funds by UNFCCC is to ensure gender equality[1]. Other funding bodies, task groups, action plans and policies, including the Green Climate Fund, the IPCC and the Global Environment Facility, require gender equality to be addressed across all aspects of delivery (Resurrección et al., 2019; Lau et al., 2021).

Several studies in extant literature have looked at climate change and gender inequality in SSA (Nnadi et al., 2019; McOmber, 2020). This study contributes to extant literature in two ways: (1) By empirically testing the impact of climate finance on gender inequality at the macro-level using GMM: And (2) focusing on one of the sub-regions in the world with most vulnerable number of women. To that end, this study seeks to find out the impact of climate finance and rainfall variability on gender inequality in SSA.

2. LITERATURE REVIEW

In the gender literature, studies that looked at women/gender and the environment/ecology are summarised in a theory known as ecofeminism (Bloodhart and Swim, 2010; Nicol et al., 2022). Ecofeminism theorists argue that, any view that supports discrimination and prejudice toward humans because of differences due to gender, sexuality or class among other factors, also supports the subjugation of the environment (Nicol et al., 2022). This implies that the more we destroy the environment, the worse gender inequality becomes.

Climate change worsening gender inequality and propelling migration to affirm the ecofeminism theory has been firmly established in the gender literature (Abebe, 2014; Eastin, 2018; Mbow et al., 2019; Vaqué, 2020; Glazebrook et al., 2020; Tantoh et al., 2022). For instance Abebe (2014) found out that women in East Africa have weaker adaptive capacity to climate change in comparism to their male counterparts; as a result of differences in cultural, social, political, economic and religious factors. Religion plays a major role in determining women role in SSA countries such as Ethiopia, Somalia and both north and south Sudan. Socially, the differentiated impacts of climatic shocks on women are manifested in the gender roles and responsibilities; assigned to them by society. Abebe (2014) added that, women are given responsibilities which make them more susceptible to climate change. For example, in the dry seasons women have to walk for long hours to get water and food for the family. This adds to the workload of women which affects their health as they are exposed to sexual and physical violence. For formal education, a lot of girls have higher rates of dropout from schools as a result of their responsibilities due to climate change.

To add, Glazebrook et al. (2020) indicated that the agriculture sector of Oceania, Southern Asia, and sub-Saharan Africa employed close to 60% of women, although the figure hovers around 80% for Least Developed Countries in Africa. Even though 80% of women work in agriculture in some areas with as much as 90% in some African countries (Mbow et al., 2019): They grow majority of the food crops for domestic consumption and are responsible for storing, processing, and preparing food, handling livestock, gathering food, fodder and fuel wood, managing the domestic water supply, and providing most of the labor for post-harvest activities (Vaqué, 2020). At the same time, they are challenged in each of what the IPCC identifies as the four pillars of food security: Concerning availability, women have less opportunity to grow food; concerning access, gendered norms can leave women with smaller portions at mealtimes, less

1 Adoption of the Paris Agreement Report FCCC/CP/2015/L.9 (UNFCCC, 2015)

money to buy food, and fewer transport options to get to market; concerning utilization, women can have different nutritional needs, for example, during pregnancy and breast-feeding; and, concerning stability, they are disproportionately affected by food strikes and often reduce intake more than others when food is in short supply for their kids (Vaqué, 2020). Women in the global South accordingly have greater responsibility for maintaining food security but little control over the factors that constitute and affect productivity and post-harvest activities.

Eastin (2018) espoused this argument by evaluating whether the unequal distribution of costs women bear as a result of climate change are reflected across broader macro-social institutions to the detriment of gender equality and women's rights. Eastin argues that gender disparities in climate change vulnerability not only reflect preexisting gender inequalities, but rather reinforces them. Inequalities in the ownership and control of household assets and rising familial burdens due to male out-migration, declining food and water access, and increased disaster exposure can undermine women's ability to achieve economic independence, enhance human capital, and maintain health and wellbeing. Consequences for gender inequality include reductions in intra-household bargaining power, as women become less capable of generating independent revenue. Outside the home, gender discrimination continues and widens as women are less able to participate fully in the formal labour market, join civil society organizations, or collectively mobilize for political change. All of these reduce society's level of gender equality, by increasing constraints on the advancement of laws and norms that promote co-equal status. In addition, Eastin (2018) found that climate shocks have negative impact on gender equality; deviations from long-term mean temperatures increases incidence of climatological and hydro-meteorological disasters, which weakens women's economic and social rights. The findings further indicated that, the situation is dire in areas that are relatively less-democratic, have greater dependence on agriculture with lower levels of economic development like SSA.

Finally, Tantoh et al. (2022) examined the adverse effects of climate change across several sectors of the economy; they found that the effects are mostly felt in rural communities, especially among indigenous people in developing countries. They found that climate change threatens to worsen gender inequalities partly due to unequal distribution of resources, and restricted rights to resources to cope with climate change that see women being disadvantaged. This is an unfortunate circumstance in the agricultural sector, which could erode progress made in ensuring gender equality. Tantoh et al. (2022) found that differentiated gender roles and patriarchy at the household level are probable factors that make indigenous African women vulnerable to climate change than males. Notwithstanding, they suggested social capital and community-based adaptation as a means to curb the gender vulnerability of women conundrum via network building.

It is on this backdrop that the UNFCCC and IPPC enjoins all developing countries seeking climate funds to have as part of their policy documents a part geared towards gender mainstreaming. Some prior studies have examined climate finance in developing countries on hunger (Mason-D'Croz et al., 2019; Doku and Phiri, 2022), food security (Lipper et al., 2014; Rahaman and Rahman, 2020; Doku et al., 2022), poverty (Atmadja et al., 2021; Doku, 2022), emission reduction and deforestation (Kotchen and Segerson,, 2020; Doku et al., 2021a and b). A limited number of studies looked at climate finance on gender equality, by undertaking a meta-analysis: The study tried to establish a theoretical framework for studying climate finance and gender equity through case study literature review (Wong, 2016; Atmadja et al., 2020; Price, 2021). Some studies were carried out to propagate the need to include women in climate finance negotiations by UNFCCC (Schalatek and Nakhooda, 2016; Frenova, 2021). This study contributes to the climate finance literature, by empirically testing the impact of climate finance on gender inequality at the macro-level in SSA, using the generalised method of moment (GMM) algorithm.

2.1. Stylised Facts

There are some interesting facts about gender inequality and rainfall variability brought out by the data and extant literature, the study delves into. Gender inequality (GI) data employed for our analysis was compiled from World Inequality Dataset (WID) with a value ranging from 0 to 1: Values close to 1 indicates higher gender equality and values close to 0 represents higher gender inequality. Figure 1 shows that, gender inequality is low in Southern Africa (with a score of 0.34) as compared to anywhere in the sub-region. This is confirmed by the Social Institutions and Gender Index, SIGI (2019) Global Report, which indicated that South Africa has the best gender parity in SSA. Central Africa (GI score of 0.29) and West Africa (GI score of 0.26) have proved to be areas with the worst gender inequality in SSA. Interestingly, the correlation matrix in Table 1 shows a positive relation between GDP per capita (serving as a poverty (POV) measure in this study) and GI. This points out that, SSA countries striving hard to bridge the gender gap experience an improvement in their GDP and growth.

By contrast, countries with weaker gender equality are more likely to experience a loss in income. For instance, the SIGI (2019) global report indicated that gender discrimination stimulated a loss of up to USD 6 trillion, equivalent to 7.5% of global income; representing an average of USD 1,552 per capita. Geographically, losses in regional income due to gender-based discrimination as depicted in Figure 2

Figure 1: Gender inequality

Source: Authors own diagram with data from World Inequality Database (2021)

Table 1: Pairwise correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) GI	1.000					
(2) RV	−0.017	1.000				
(3) CF	0.126	−0.140	1.000			
(4) POV	0.214	0.048	−0.128	1.000		
(5) POPCH	−0.230	0.023	0.113	−0.139	1.000	
(6) GR	0.422	0.015	0.054	0.332	−0.380	1.000

includes: Nearly USD 3722 billion in OECD economies (representing USD 3 266 per capita); USD 1 598 billion in Asia (representing USD 1 652 per capita); USD 294 billion in the Americas (representing USD 1 104 per capita); USD 169 billion in Africa (representing USD 466 per capita); and USD 164 billion in Europe (representing USD 1 584 per capita). Although SSA have low productivity and income level, it still bears the brunt of income loss due to the excruciating effect of climate change (as depicted on Figure 2).

Next, the study looks at the main climate variable employed in this study-rainfall variability or shocks (Figure 3). From Figure 3, it is clear that West Africa has the highest rainfall variability in SSA with a deviation of 0.745. This may be the case due to the extreme weather conditions experienced in that sub-region; extreme temperature and rainfall. Southern Africa region is the area with the least rainfall shock. This is due to the low rainfall level in that region in the past 2 decades; as a result experiencing high water shortages but seeing low rainfall variability. A negative rainfall variability score for all regions in SSA is a signal that almost all parts of SSA is becoming drier and drier. Interestingly, Table 1 shows a negative correlation between rainfall variability and GI. This shows that areas in SSA with high climatic shocks-rainfall variability-are experiencing worsening gender inequality to support the ecofeminism theory.

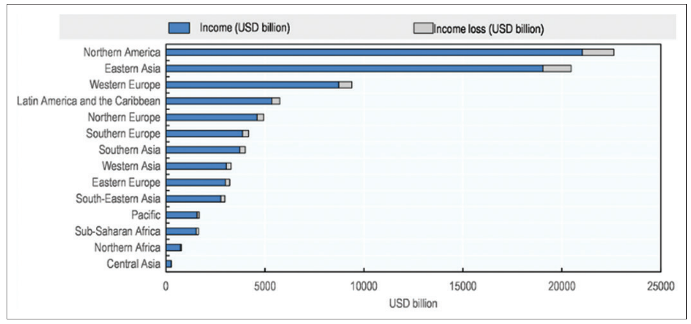
SIGI (2019) report indicated that 45% of all account holders globally are women. Although bank-account ownership and access to financial resources is equal for men and women in Europe, the situation is different in other regions. For instance, 40% and 45% of account holders in Africa and Asia respectively are women (Figure 4). This shows that Africa is home to the majority of unbanked women globally. If that is the case, this may inhibit them from accessing climate funds to help them mitigate and adapt to climate change.

3. DATA AND METHODOLOGY

The main objective of the study is to find out the impact of climate finance and climate change (rainfall variability) on gender inequality in SSA. Data was collated for 46 SSA countries for the period 2006-2018. Based on that, we specify a reduced form model below following the study by (Gleditch, 2012; Chuang, 2019; Lee and Vu, 2020 and Doku et al., 2021c).

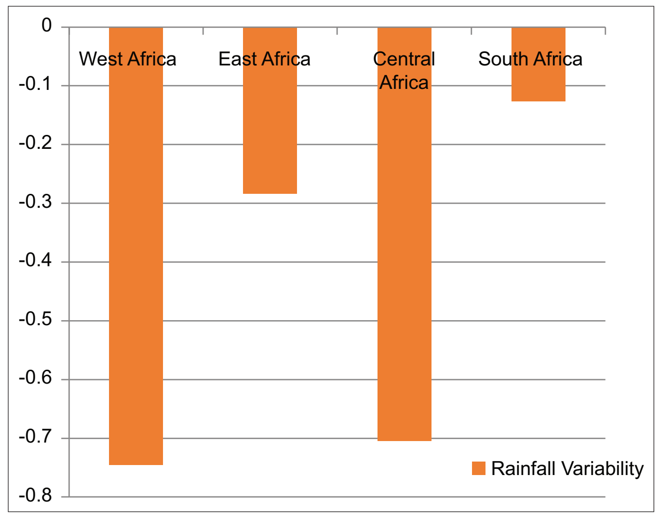
$$GI_{it} = \gamma_1 + \gamma_2 GI_{it-1} + \gamma_3 CF_{it} + \gamma_4 CF_{it}^2 + \gamma_5 CF_{it-1} + \gamma_6 RV_{it} + \gamma_7 RV_{it}^2 + \gamma_8 RV_{it-1} + \gamma_9 AGL_{it} + \gamma_{10} POPCH_{it} + \gamma_{11} POV_{it} + \gamma_{12} \sum_{i=1}^{4} D_i + \gamma_{13} \sum_{i=1}^{4} (CF_{it-1} * D_i) + \gamma_{14} \sum_{i=1}^{4} (CF_{it-1}^2 * D_i) + \gamma_{15} GR_{it} + \epsilon_{it} \quad (1)$$

Figure 2: Income loss due to gender inequality



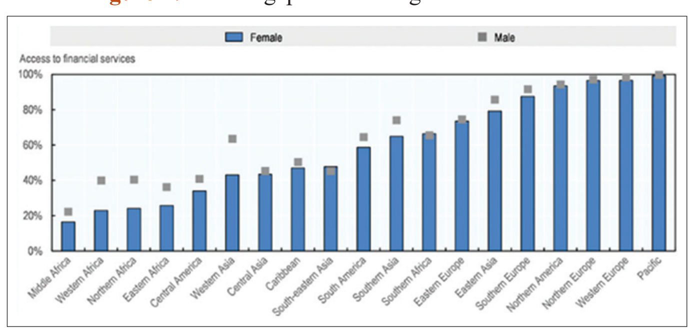
Source: OECD (2019); Gender institutions and Development Database, http://stats.oecd.org; Social Institutions and Gender Index, SIGI (2019) Global Report [Accessed on August 31, 2022]

Figure 3: Rainfall variability



Source: Authors own diagram with data from World Bank Climate Change Knowledge Portal

Figure 4: Gender gap in accessing financial resources



Source: Global Findex Database https://globalfindex.worldbank.org; SIGI (2019) Global Report [Accessed on August 31, 2022]. NB: Gender gap in access to financial services in Figure 4 is measured as the percentage of individuals aged 15 years and above that have an account directly or in conjunction with another person at a bank or another type of financial institution by sex

Where γ_1-γ_1 represent the coefficients of the explanatory variables.

$$\epsilon_{it} = \eta_i + \lambda_t + \mu_{it} \quad (2)$$

Where $\in_{it}$ stands for the error term, η_i signifies the individual country effect, λ_t stands for the time specific effect and μ_{it} signifying the random disturbance term. D_i in equation (2) represents the regi--onal dummies all for four regional blocks in Sub-Sahara Africa; Southern Africa (SADC), East Africa (EAC), West Africa (ECOWAS) and Central Africa (COMESA). However, ECOWAS was omitted from the regression analysis to serve as a reference category. Next, $CF_{it-1} * D_i$ represent and interaction term between climate finance and the various regional blocs. This is to find out how each regional bloc is using climate finance to reduce gender inequality in their area compared to the ECOWAS region.

GI_{it} represents gender inequality for country i at time t. GI is the main dependent variable of the study. Although most prior studies measure gender inequality using the gender inequality index data from World Development indicators (WDI) and Gender, Institutions and Development Database, we measure it using the new index by the World Inequality Database (WID)[2] for the period 2006-2018. They computed gender inequality as pre-tax income of female adults as a proportion of total labour income. This indicates that an index close to 1 represents gender equality, and an index near 0 represents inequality. The descriptive statistics indicate that SSA is facing serious gender inequality problem-with a mean value of 0.273 (Table 2). Guinea-Bissau and Burundi are among the countries with the best gender equality index-averaging over 0.4-throughout the study period. However, Somalia and Chad are the areas experiencing the worse from of gender inequality with an index <0.025. It can be argued that conflict-ravaged areas in the sub-region are the ones experiencing the worse forms of gender inequality. In the model, lagged GI is included as a regressor to capture the persistence of the dependent variable.

In this study, two main independent variables are employed; climate finance (CF) and rainfall variability (RV). CF variable used in this study is the amount of commitment flows from developed to developing countries in 2018 constant USD; CF data was collated from the OECD-DAC climate-related finance database. Due to the gender mainstreaming requirements of most climate funds, CF is expected to positively influence gender equality. Rainfall data used is the annual standardised mean of rainfall for a given country, and sourced from World Bank Climate Change Knowledge Portal (WBCCKP). To model rainfall variability or shocks the study employed the deviation approach by Gleditsch (2012), Chuang (2019) and Le and Nguyen (2021); they computed rainfall variability as deviations from the long-term means for a given country, divided by the panel's standard deviation[3]. Several prior studies computed rainfall variability as percentage change in annual rainfall in country i year t from the previous year (Miguel et al., 2004; Hendrix and Glaser, 2007; Jensen and Gleditsch, 2009). As argued by Ciccone (2011) and Gleditsch (2012), such a measure yields misleading results when identifying whether a given country-year was a wet or dry year. The descriptive statistics in Table 2 shows a mean of −0.487 (negative represent dryness and positive represents wetness), showing that SSA is becoming drier and drier by day. Model 1 includes both linear and squared terms of CF and RV variables, and their lags, to establish the linear and curvilinear relationship between the independent and dependent variable. Current and lags of CF and RV are included in model 1 to capture their long and short run effects. In line with the ecofeminism theory, climatic shocks are expected to worsen gender inequality. Based on the foregoing, the study will test two main null hypotheses

H_{O1}: CF positively influences GI
H_{O2}: RV negatively impacts GI.

For the control variables, governance readiness (GR) is an index computed by the Notre-Dame Global Adaptation Index (ND-GAIN) using four main variables; control of corruption, political stability and non-violence, regulatory quality and rule of law. GR shows the readiness of governments in using climate funds to mitigate and adapt to climate change. Population growth change (POPCH) is the rate at which population of a country grows from the previous year. Finally, poverty (POV) is measured using GDP per capita (at Constant 2018 USD). All three control variables were sourced from NDG-GAIN.

Next, to find out whether the explanatory variables are not highly correlated with each other-due to the problem of multicollinearity-a pairwise correlation between all the variables is carried out (Table 1). From Table 1, apart from GR which positively correlates with GI at 0.42, the rest of the variables show a correlation value below 0.4. This shows the absence of multicollinearity in the model.

3.1. Estimation Technique

In other to test the effect of CF and RV on GI, we employ an unbalanced panel data for 46 countries in SSA- countries with missing data points were omitted from the study-for the period 2006-2018, using Generalised Method of Moment (GMM). Sensitivity of our estimates is carried out using fixed effect panel quantile regression. GMM estimator is employed for a number of reasons: (1) Endogenous relationship between CF and GI; and (2) inclusion of the lagged dependent variable in model 1 will all cause endogeneity in the model. Further, in estimating the distributional effect of CF, RV and POV in model 1 will give rise to the problem of endogeneity bias due to measurement errors, omitted variable bias, and reverse causality (Lee and Vu, 2022). Lastly, the data has a large cross sectional unit (46 countries) with a shorter time period (T = 13 years). All this issues raised will cause the OLS estimator to yield biased and inconsistent results.

Table 2: Descriptive statistics

Variable	Mean	SD	Minimum	Maximum
GI	0.27	0.077	0.082	0.424
RV	−0.487	3.626	−47.472	3.509
CF	125596.3	238309.3	0	2428679
POV	5133.58	6505.373	761.5	41249.4
POPCH	2.502	0.844	−2.629	4.606
GR	0.381	0.123	0.001	0.669

2 https://wid.world/data/

3 More formally, this is ($\frac{X_{it}-\pi_i}{\sigma_i}$), where π_i represents the panel mean for country i, X_{it} is the current rainfall at time t for country i, σ_i and is the standard deviation for country i.

To circumvent this problem, one needs to employ external instruments that will satisfy the exclusion restrictions: That is an exogenous instrument that correlates with the endogenous variables, and at the same time uncorrelated with the stochastic error terms (Doku et al., 2021c). However, it is a daunting task in obtaining external instruments that meet these conditions. As a result, model 1 is estimated using internal instruments- that is lags of the endogenous variables. To remove the biasedness associated with the unobserved country heterogeneity, Nguyen (2021) and Arellano and Bond (1991) proposed the use of first differences of the variables for estimation to eliminate the country-fixed effects; known as difference GMM. A situation where the variables are highly persistent, past values of the variables show little information about their future changes; this makes lag variables weak instruments for the differenced series (Nguyen, 2021; Doku et al., 2021a). On that backdrop, Arellano and Bover (1995) suggested combining the difference equation instrumented by lagged levels and the level equation instrumented by lagged differences to yield system GMM (SYS-GMM). Based on the foregoing the study employs SYS-GMM by Arellano and Bover (1995) and Blundell and Bond (1998) as the main estimator of the study, for its ability to promote efficiency; this is done by dealing with the problem of weak instruments in the difference GMM estimator and reducing biases in its estimates (Roodman, 2009). In summary, SYS-GMM is used in this study due to its ability to overcome the problem of endogeneity using lagged values of explanatory variables as instruments, eliminates problem of information loss in cross-sectorial regressions and able to give consistent estimates in the face of small time periods. The study employed Arrelano-Bond (AR[2]) and Sargan test to determine the validity of the instruments. To find out whether the second order autocorrelation exist in the model, we employed the Arrelano-Bond test (AR[2]). The post estimation test will be climaxed by the Sargan test of overidentifying restrictions.

4. FINDINGS AND DISCUSSION

The AR (2) test shows the absence of serial correlation in the error term (Table 3), and the Sargan test also failed to reject the model specifications and affirms the validity of our instruments. SYS-GMM estimates are presented in Table 3. Although CF did not show any current and level significant impact on GI, rather a significant positive impact of lag of CF on GI is established. This shows that GI is improved a year after CF is received in the short run. This may be the case because climate funds received by women must be put to good use (in year t), and its potential inequality reduction effect will be felt in the following year (year t+1). Next, model 1 is employed to estimate Semykina and Wooldridge (2013) and Lee and Vu (2020) test of long-run propensity in distributed lag model as

$$\frac{\partial GI}{\partial CF} = \frac{\gamma_3 + \gamma_5}{1 - \gamma_2}$$

$$= \frac{0.00000000328 + 0.00000000671}{1 - 0.916} = 8.38\text{E}-08 \ > \ 0 \qquad (2)$$

From the result, it is seen that increases in CF helps improve GI in SSA in the long-run, and even better than the short-run. All this indicates that CF extended to the sub-region is really yielding expected results, although inadequate. The result lends support to the first hypothesis (H_{O1}). This might be due to the gender requirement associated with many climate funds extended to SSA. Interestingly, CF squared variable showed that higher increases in CF leads to GI improvement; indicating that if developed countries honour their pledge to raise USD 100 billion in CF and increase it to support developing countries, SDG-5 (achieving gender equality) may be achieved by 2030 (Doku et al., 2021a and b; Doku, 2022; Doku and Phiri, 2022). Implying that, CF plays a major role now and future in achieving SDG-5 in SSA. Both the lag level and lag square term of the CF variable shows a positive monotonicity, against the expected curvilinear relationship. This result lends support to the climate finance effect (climfin effect) proposed by Doku et al. (2021c).

Table 3: SYS-GMM regression result

Variables	Model 1	Model 2	Model 3
GIi_{t-1}	0.916***	0.903***	0.979***
	(0.0174)	(0.0254)	(0.0162)
RV	−4.91e−05	3.21e−05	−0.000322**
	(6.89e−05)	(0.000117)	(0.000135)
RV_{it-1}	−0.000672***	−0.000621***	−0.000637***
	(8.64e−05)	(7.81e−05)	(0.000112)
RV^2	3.50e−06	6.90e−06**	−3.60e−06
	(2.16e−06)	(3.27e−06)	(3.19e−06)
RV^2_{it-1}	−9.25e−05*	−0.000118***	6.99e−05
	(5.31e−05)	(4.44e−05)	(8.37e−05)
CF	3.28e−10	−2.01e−10	4.16e−09
	(2.02e−09)	(2.51e−09)	(4.12e−09)
CF_{it-1}	6.71e−09***	4.73e−09**	2.29e−08***
	(1.60e−09)	(2.30e−09)	(8.44e−09)
CF^2	0	0	-0
	(0)	(0)	(0)
CF^2_{it-1}	0***	-0	0***
	(0)	(0)	(0)
GR	0.0707***	0.0539***	0.0678***
	(0.00994)	(0.0110)	(0.00802)
POPCH	−0.00513***	−0.00237*	−0.00366***
	(0.00115)	(0.00132)	(0.000868)
$CEMAC*CF_{it-1}$			−1.15e−08
			(2.63e−08)
$EAC*CF_{it-1}$			4.66e−08***
			(8.70e−09)
$SADC*CF_{it-1}$			2.24e−08**
			(1.05e−08)
$CEMAC*CF^2_{it-1}$			0
			(0)
$EAC*CF^2_{it-1}$			−0***
			(0)
$SADC*CF^2_{it-1}$			−0***
			(0)
POVERTY	1.09e−06**	6.85e−07	
	(5.09e−07)	(5.92e−07)	
CEMAC		0.0103	
		(0.00759)	
EAC		0.0152***	
		(0.00444)	
SADC		0.0156	
		(0.0124)	
Constant	0.00432	−0.000555	−0.0108**
	(0.00629)	(0.00619)	(0.00517)
AR (1)	0.0865	0.0847	0.161
AR (2)	0.925	0.914	0.985
Sargan test	0.999	0.999	0.999

Standard errors in parentheses, *** P<0.01, ** P<0.05, * P<0.1

Further, the study attempts to examine the effect of CF on GI among the four regional blocs in SSA: Economic Community of West African States (ECOWAS), Central African Monetary and Economic Community (CEMAC), Southern Africa Development Community (SADC) and the East African Community (EAC). An interaction term between dummy of the regional blocs and lag of CF with their square terms are presented in model 3 of Table 3. Following the study by Doku et al. (2021c), ECOWAS is set as the reference category in the study; partly due to the fact that it is the warmest and driest area in the sub-region. From model 3 of Table 3, CF positively influence GI in EAC and SADC regions at 5% level of significance as compared to West Africa. The squared terms for both regional blocs indicated a significant negative effect at 1%. This indicates a curvilinear relationship between CF and GI in the EAC and SADC regions. EAC is the best performer so far in using CF to reduce GI in SSA, followed by the SADC region. CEMAC did not experience any significant impact of CF on GI, making it the least performer. This finding harmonises with the regional dummy results as presented in model 2 of Table 3. This indicates the possibility of rainfall shocks, CF, poverty level measured using GDP, governance readiness and population growth change to jointly improve GI in EAC. This point out that EAC is the sub-region more prepared to reduce GI come what may, compared to other regional blocs in the sub-region.

The findings further showed that RV evokes a negative impact on GI, especially for RV lags at 1% significance level for all three models; affirming the second hypothesis (H_{02}) of the study. This indicates that, in the short-run higher rain shocks lead to worsening GI and women poverty, especially in the following year: Implying that climatic shocks are biting hard on women in SSA, worsening their plight and needs to be given more attention. The finding of rain shocks on gender inequality affirms the study by Nnadi et al. (2019) and the ecofeminism theory in SSA. For the squared term, lag of rainfall shocks negatively influence GI in the long run for the first two models; to show a negative monotonicity of RV on GI. Further, the long run effect of RV on GI is computed using Wooldridge (2013) test of long-run propensity in distributed lag models, as expressed in equation 2. Finding of the long-run effect of rainfall shocks on gender inequality is shown in equation 3

$$\frac{\partial GI}{\partial RV} = \frac{-0.0000491 + -0.000672}{1-0.916} = -8.58\text{E}-03 \ < \ 0 \tag{3}$$

The result from equation (3) reinforces that RV shocks worsen GI in both the long and short-run. Indicating that, if the world does not make concerted effort to mitigate and adapt to climate shocks, women in SSA will bear the brunt as compared to their male counterparts. Therefore, it is in other that both UNFCCC and IPCC called for gender mainstreaming in extending funds to Non-Annex-1 parties.

For the control variables, governance readiness (GR) showed a significant positive impact on GI at 1% level for all 3 models (Table 3). This iterates that SSA countries that are controlling corruption, enforcing rule of law with sound regulatory quality are better able to put climate funds to good use; which finally translates to a reduction in gender inequality. This result confirms the study by Doku et al. (2021c), which found all this governance readiness variables to aid in environmental protection. As opined by the ecofeminism theory, any activity that protects the environment is protecting women. Since GR has been found to be protecting women in this study, it shows that this result aligns with the dictates of ecofeminism theory. Next, population growth change (POPCH) saw a significant negative impact on GI; indicating that SSA countries with higher population growth are experiencing worsened gender inequality. Finally, poverty which is measured in this study as GDP per capita showed a significant positive impact on GI. This shows that, richer SSA countries are able to better bridge the gender gap as compared to their poorer counterparts.

4.1. Sensitivity Analysis

Sensitivity of the estimates is carried out using panel quantile regression (PQR), following the study by Powell (2020) to complement the GMM estimates. Most prior studies including the GMM estimator computes panel models at their conditional means, and ignoring the heterogenous impacts of climatic shocks on gender inequality. Neglecting heterogeneity would result in biased estimations of the panel data models; leading to over or under-estimation of relevant coefficients, and making it difficult to determine relevant coefficients (Zhu et al., 2016). To circumvent this difficulty, the study utilizes PQR with fixed effects to estimate our model, for this estimator offers a systematic strategy for examining how rainfall shocks and climate finance influence gender inequality in SSA across the entire conditional distribution of gender inequality. Further, PQR is robust to heavy distributions and outliers. However, it does not take into account the unobserved heterogeneity of a country. In that vein, this paper employed a panel quantile method with fixed effects; making it possible to estimate the conditional heterogeneous covariance effects of the explanatory variables, while controlling the unobserved individual heterogeneity (Zhu et al., 2016). In model 3, the study specifies a conditional panel quantile function for quantile τ as follows.

$$Q_{GIit}(\tau|\gamma_i, \epsilon_t, X_{it}) = \gamma_i + \epsilon_t + \gamma_3\, CF_{it} + \gamma_6\, RV_{it} + \gamma_9\, AGL_{it} + \gamma_{10}\, POPCH_{it} + \gamma_{11}\, POV_{it}$$

Where GI_{it} represents the conditional quantile; X_{it} denotes the matrix of explanatory variables; γ_i represents the individual specific fixed effects and ϵ_t represents time specific fixed effects.

Furthermore, quantile regression provides a more robust estimation results compared to the conditional mean regressions (Koenker and Bassett, 1978). In Table 4, the study presents the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th and 90th percentiles for the gender inequality model.

Clearly, the findings showed a heterogeneous effect of rainfall variability and climate finance on gender inequality. Rainfall variability showed a gender inequality worsening effect up till the 60th percentile but a non-significant, and then a negative significant impact at the 90th percentile. This result harmonises with the GMM estimates, indicating that climate variability worsens gender inequality. Climate finance showed a heterogeneous effect on gender inequality; it indicated a gender equality improvement

Table 4: Panel quantile regression

Variables	10th	20th	30th	40th	50th	60th	70th	80th	90th	(9) Model 1
RV	−0.000905	−0.00131	−0.00105	−0.000278	−0.000452	−6.53e−05	0.000248	−0.00119	−0.00295*	−0.00295*
	(0.00287)	(0.00116)	(0.000815)	(0.000643)	(0.000457)	(0.000679)	(0.00122)	(0.00162)	(0.0017)	(0.00175)
CF	4.93e−08**	7.29e−08***	7.84e−08***	8.48e−08***	7.29e−08***	4.97e−08***	2.85e−08**	1.49e−08	−2.14e−08**	−2.14e−08**
	(2.06e−08)	(1.72e−08)	(1.68e−08)	(1.51e−08)	(1.32e−08)	(1.60e−08)	(1.33e−08)	(1.20e−08)	(9.92e−09)	(9.92e−09)
GR	0.353***	0.300***	0.267***	0.235***	0.226***	0.219***	0.176***	0.118**	0.0869	0.0870
	(0.0154)	(0.0442)	(0.0466)	(0.0356)	(0.0479)	(0.0539)	(0.0670)	(0.0561)	(0.0589)	(0.0589)
POPCH	−0.00504	−0.00294	−0.00529	−0.00918**	−0.00983	−0.00762	−0.00675	−0.0104	−0.00029	−0.000299
	(0.00780)	(0.00475)	(0.00488)	(0.00384)	(0.00785)	(0.00762)	(0.00637)	(0.0105)	(0.01008)	(0.0101)
POV	1.48e−06	2.33e−06***	2.64e−06***	2.64e−06***	2.42e−06***	1.02e−06	4.24e−07	−3.80e−07	−8.15e−07	−8.15e−07
	(1.22e−06)	(6.25e−07)	(4.09e−07)	(4.47e−07)	(5.87e−07)	(6.76e−07)	(7.00e−07)	(7.08e−07)	(1.78e−06)	(1.78e−06)
Constant	0.0656***	0.0918***	0.121***	0.157***	0.183***	0.212***	0.253***	0.316***	0.3396***	0.340***
	(0.0225)	(0.0271)	(0.0257)	(0.0133)	(0.0301)	(0.0323)	(0.0412)	(0.0458)	(0.0316)	(0.0316)

Standard errors in parentheses, *** P<0.01, ** P<0.05, * P<0.1

up till the 70th percentile and a gender inequality worsening effect at the 90th percentile. The control variables display results very similar to the GMM estimates. This shows that the GMM estimates are robust, since they findings are similar to the PQR results.

5. CONCLUSION

This study began by finding out the impact of rainfall variability and climate finance on gender inequality, using SYS-GMM estimates for 46 SSA countries based on the ecofeminism theory. In other to determine the heterogeneous effect of rainfall variability and climate finance on gender inequality, the study employs panel quantile regression for robustness check.

The findings indicate that high rainfall shocks worsen gender inequality both in the long and short-run in SSA. Climate finance showed a significant gender equality strengthening effect both in the short-run and long run. Further, governance readiness measured using control of corruption, regulatory quality and rule of law indicated a gender inequality improvement both in the GMM estimates and the panel quantile regression result. It is clear from the findings that extending more climate funds to developing countries, will not only mitigate and adapt to climate change-and achieve SDG-13-but also realising gender equality, to achieve SDG 5. In addition, SSA countries strengthening their governance readiness- through stronger control of corruption, regulatory quality and rule of law-are in a better position to reduce gender inequality. SSA countries should make concerted effort to reduce warming to 1.5°C, to reduce the exacerbating effect on women and to attract more climate finance and enjoy more from carbon trading.

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