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The role of mobile money innovations in transforming unemployed women to self-employed women in sub-Saharan Africa

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Abstract

The study examines how mobile money innovations transform unemployed women to self-employed women. The empirical evidence is based on interactive quantile regressions focusing on data in 44 countries from sub-Saharan Africa for the period 2004 to 2018. The hypothesis that mobile money innovations transform female unemployment to female self-employment is tested. Eight mobile money innovation dynamics presented in four categories are employed.
Three main common findings are apparent from interactions between female unemployment, eight mobile money innovation dynamics and female self-employment: (i) the investigated hypothesis is valid exclusively at the top quantiles of female self-employment; (ii) the net effects are consistently negative and (iii) the corresponding conditional or interactive effects upon which the net effects are based are consistently positive. This is an indication that critical masses at which money innovation innovations have an overall positive net effect on female self-employment are apparent. The corresponding mobile money innovation policy thresholds at which the net effects on female self-employment change from negative to positive are provided. Policy implications are discussed.

Keywords: Mobile phones; financial inclusion; women; inequality; sub-Saharan Africa
JEL Classification: G20; O40; I10; I20; I32

1. Introduction

The positioning of this study on the role of mobile money innovations in transforming unemployed women to self-employed women in sub-Saharan Africa (SSA) is premised on four fundamental factors in the extant scholarly and policy literature, notably: (i) the exclusion of the female gender in economic activities and the corresponding relevance of involving more women in politico-economic activities; (ii) the policy concern of the unequal distribution of the fruits of economic growth owing of exclusive development; (iii) the importance of mobile money innovations in promoting inclusive development outcomes and (iv) gaps in the extant literature on the subject. The highlighted fundamentals are expanded in the same order of chronology as highlighted.

First, the issue of gender inclusion is prominently articulated in the fifth goal of the United Nations' sustainable development goals (SDGs) (i.e. SDG5) which is founded on the promotion of female economic empowerment and gender equality. Accordingly, the focus of the present exposition on gender economic empowerment by means of female self-employment is situated

along the lines of understanding the progress towards SDG5. The orientation towards gender economic empowerment through employment builds on the policy and scholarly literature which maintains that SSA on which the present study is focused is the sub-region in the world characterized by the highest number of women that are excluded from the formal economic sector (World Bank, 2018; Asongu *et al*., 2021a). According to the attendant literature, the exclusion of women from the formal economic sector generates a loss of approximately 160 trillion USD with respect of gross domestic product (GDP). The premise of the present study is positioned as an extension of the extant gender inclusion literature by examining how mobile money innovations can transform female unemployment to female self-employment in SSA, not least because, beyond the policy concern of gender exclusion on the subject, there is also a general concern of income inequality that is standing on way to the achievement of most poverty- and inequality-related SDGs.

Second, the policy syndrome of income inequality is critical in reaching SDGs, especially within SSA in which according to a recent study from Bicaba *et al*. (2017), unless the corresponding income inequality is addressed in the sub-region, most countries in this attendant region are not going to reach most SDGs targets by the year 2030. Mitigating gender economic exclusion by means of promoting female self-employment as framed in the present study, is a means of mitigating the underlying policy syndrome of income inequality. Moreover, the specific character of SSA also builds on the scholarly literature maintaining that the region is host to countries among the highest in terms of income inequality in the world (Asongu & Nwachukwu, 2016; Tchamyou, 2020). The corresponding contemporary evidence illustrates that the prevailing high levels of income inequality are substantially traceable to the fruits of economic prosperity not being evenly distributed across the population (Tchamyou, 2019, 2021). The underlying unequal distribution has engendered, *inter alia*, growing poverty levels and such poverty reached a considerable height in 2019 when SSA overtook Asia to become the region hosting the highest number of people surviving on extreme poverty in the world (Nwani & Osuji, 2020). Inequalities, including gender income inequality can be reduced by means of mobile money innovations, in accordance with attendant literature (Awel & Yitbarek, 2022; Kim, 2022; Ngono, 2021).

Third, the importance of mobile money innovation is of relevance in reaching most inclusive and sustainable development targets, especially those surrounding the United Nations' sustainable development goals (SDGs) agenda (UNCDF, 2022; Asongu & Odhiambo, 2018a; Asongu & Nting, 2021). Accordingly, the narrative maintains that mobile money innovations provide inclusive mechanisms which are related to financial inclusion and by extension, linked to, *inter alia*: SDG1 in relation to the reduction of poverty; SDG2 focused on eliminating hunger and addressing food security concerns; SDG3 concerned with wellbeing and health; SDG5 related to gender equality and female empowerment; SDG8 linked to the promotion of economic growth; SDG9 oriented towards consolidating innovation, infrastructure and the industry; SDG10 connected to the reduction of income inequality and SDG17 concerned with consolidating mechanisms of implementation, especially as it relates to the incidence of financial inclusion via sustained consumption and investment of resources (Asongu & le Roux, 2019; Tchamyou *et al*., 2019a, 2019b; Achuo *et al*., 2021; UNCDF, 2022; Abdulqadir & Asongu, 2022). In the light of the relevance of financial inclusion in facilitating the achievement of a plethora of SDGs, the present study is focused on understanding the transformation of female unemployment to female self-employment by means of mobile money innovations, not least, because of an apparent gap in the extant scholarly literature.

Fourth, the existing contemporary studies can be articulated in two main categories, notably: research focusing on innovations in mobile money and studies concerned with gender

empowerment. In the first category of studies, the corresponding literature concerned with mobile money innovation has focused on, among others: mobile money adoption in response to idiosyncratic shocks (Koomson *et al*., 2021); determinants of FinTech services' diffusion among medium and small size enterprises (Coffie *et al*., 2021); the importance of innovations in mobile money in the payment of utility bills (Awel & Yitbarek, 2022); determinants of mobile money innovations (Lashitew *et al*., 2019; Asongu *et al*., 2020, 2021b); the relevance of inclusive finance in inclusive development among households in rural areas (Serbeh *et al*., 2022); the mining of digital currencies as well as establishment of corresponding fees (Easley *et al*., 2019; Huberman *et al*., 2021); the pricing of digital currencies (Schilling & Uhlig, 2019; Biais *et al*., 2020; Choi & Rocheteau, 2021) and a robust framework for operating digital platforms (Eyal & Sirer, 2014; Biais *et al*., 2019; Chiu & Koeppl, 2019; Saleh, 2021; Pagnotta, 2021).

In the second category, the linkage between innovations in the mobile phone and gender economic empowerment has focused on *inter alia*, the prospect of banking channels, mobile money innovations and entrepreneurship in women (Ngono, 2021); how inclusive finance is affected by mobile money innovations (Kim, 2022); linkages between information and communication technology (ICT) usage, access to finance among women and mobile money (Asongu & Odhiambo, 2018a; Osabuohien & Karakara, 2018) and gender differences within the remit of inclusive finance (Mndolwa & Alhassan, 2020).

The closest exposition to the present research is Ngono (2021) which has investigated how mobile money, bank mechanisms and microfinance institutions (MFIs) are important to funding entrepreneurial activities from women in SSA. Accordingly, Ngono (2021) has employed the generalized method of moments (GMM) approach on data for the period 2004 to 2018 to establish that whereas banking services do not engender a significant incidence on the self-employment of women, alternative services (i.e. microfinance and mobile money) are significant. There are two similarities in the light of Ngono (2021), notably: (i) the importance of mobile money innovations in promoting the economic empowerment of women and (ii) a SSA-centric focus.

Three distinguishing characteristics are apparent between the present study and Ngono (2021), notably:
(i) considering the indirect incidence of mobile money innovations on female self-employment. In essence, as opposed to Ngono (2021) which has introduced mobile money as directly affecting female entrepreneurship, mobile money innovations influence the outcome of female self-employment via the channel of female unemployment. In essence, the empirical outline is framed in such a way that mobile money innovations promote female self-employment by reducing the unemployment of females.

(ii) Linkages between the two independent variables of interest (i.e. mobile money innovations and female unemployment) and the outcome variable are contingent on existing levels of female self-employment and vary from country to country with respect to initial levels of self-employment among women (i.e. high, intermediate and low levels of female self-employment).

(iii) To avail more space for policy implications, the interactive regressions are framed in order to provide plausible mobile money innovations thresholds that are worthwhile for the promotion of female self-employment via the mitigation of female unemployment. This is the contrary to Ngono (2021) who has concluded that mobile money innovations directly affect female self-employment. Accordingly, the present study provides actionable critical masses of mobile money innovations that can be acted upon by policy makers in order to achieve overall positive effects on female self-employment.

Given the above, the adopted empirical approach which is tailored to provide linkages throughout the conditional distribution of female self-employment, is premised on the perspective that plain policies on linkages between female unemployment, mobile money innovations and female self-employment are not very likely to succeed unless such linkages are based on initial values of female self-employment. In essence, a Quantile regression approach is used to pin-point the attendant conditional relevance of linkages between female unemployment, mobile money innovations and female self-employment.

The rest of the study of organized as follows. The empirical literature, theoretical underpinnings and related testable hypothesis are covered in Section 2 while the methodology and data are provided in Section 3. The empirical results are disclosed in Section 4 while Section 5 is concerned with concluding implications and future research directions.

2. Empirical literature, theoretical underpinnings and testable hypothesis

2.1 Empirical literature

Consistent with the adopted elements of style in the introduction, this empirical literature section is discussed in two main strands, notably: studies on mobile money innovations and research that has been concerned with the nexus between mobile innovations and gender inclusion. These strands are expanded in the same chronology as highlighted.

In the first strand of studies, Koomson *et al*. (2021) have considered how mobile money adoption responds to idiosyncratic shocks. Accordingly, the authors motivate their study on the premise that compared to other regions of the world, financial inclusion in sub-Saharan Africa remains comparatively low. Using an instrumental probit approach and household data from five countries, the authors find that mobile money adoption is linked to a higher likelihood to receiving financial support from relatives, co-workers families as well as acquaintances, especially during shocks of idiosyncratic nature. Coffie *et al*. (2021) examine drivers of Fintech services' diffusions in 407 registered small and medium sized corporations in Ghana using a hierarchical logistic regression approach to establish that the combined incidences of technology, human and business factors drive the diffusion of Fintech payment services. Serbeh *et al*. (2022) assess the relevance of inclusive development among households in rural areas within the remit of the Sunyani West District of Ghana using a qualitative approach. The authors establish that whereas mobile money provides savings and transfer services, the persistence in corresponding constraints negatively affects the potential for financial inclusion. Awel and Yitbarek (2022) assess the relevance of innovations in mobile money in the payment of utility bills in Ethiopia using household survey data as well as a dichotomous choice experiment which offers a plethora of prices randomly by means of mobile money used to pay utility bills. The authors establish that households can pay more in order to use mobile money compared to the actual price that is conventionally charged for the payment of commodities. Moreover, there is substantial latent demand for mobile money in payments processing and the attendant demand is sensitive to price variations.

Lashitew *et al*. (2019) have examined determinants of mobile money innovations in developing countries using a Tobit empirical strategy to establish how interest and power dynamics are critical factors in the system of innovation that influence the adoption of mobile money. The findings of Lashitew *et al*. (2019) have been first extended by Asongu *et al*. (2020) using the same dataset and empirical strategy to test whether both demand-side and supply-side mobile money drivers have African-centric characteristics. The comparative findings reveal that there is an African-specificity that is fundamentally linked to the 'unique mobile subscription rate'.

Furthermore, an extended analysis reveals that the underlying African specificity, especially as it pertains to the mobile phone used to receive and send money could be linked to the informal sector of the economy which is not taken into account by Lashitew *et al*. (2019). In another extension of Lashitew *et al*. (2019), Asongu *et al*. (2021b) have taken into account a concern of multicollinearity that is neglected by the underlying study to establish that when the empirical results are robust to multicollinearity, two main trends are visible: many new significant estimated coefficients are apparent and there is confirmation of the significant findings from the underlying study. Whereas the results of the underlying study are confirmed, the extension improves agreement in the narratives between the mobile money innovations and their drivers. In summary, when multicollinearity is taken into account, previous findings are more consistent across determinants (i.e. both supply and demand features) and the corresponding mobile money innovation outcomes.

In the second strand on the nexus between mobile money innovation and gender inclusion, still consistent with the elements of style in the previous strand, the highlighted studies in the introduction are expanded accordingly. Kim (2022) has investigated how inclusive finance is affected by mobile money innovations with particular emphasis on women in Kenya. Accordingly, the study assesses at what level and by which mechanism mobile money has influence in women's financial inclusion in the country. The paper shows that innovations in mobile money have substantially reduced the proportion of women in the city of Nairobi that are not involved in the use of financial services. Accordingly, mobile money has provided women with opportunities of service payment and instant remittance especially as it pertains to the channel of storing value. Younger women especially those characterized by low income and educational attainment are benefiting more from the use of mobile money services. Moreover, it is established that mobile money innovations do not necessarily tackle the plethora of structural determinants of gender-related financial inequality, though financial inclusion levels have been enhanced especially for women that were previously excluded.

On the nexuses between the usage of ICT, financial access and mobile money, Asongu and Odhiambo (2018a) have assessed the importance of ICT in moderating the impact of financial access on the participation of women in the formal economic sector. The findings which are based on 48 African countries and the generalized method of moments show that policy thresholds are apparent at which ICT moderates' access to finance in order to positively affect the formal economic participation of women. Osabuohien and Karakara (2018) examine both household and individual access to financial service and ICT for men in Ghana in comparison to women to establish that women have a higher likelihood of saving with mobile money as well as in using mobile money innovation opportunities to improve their socio-economic wellbeing. The authors conclude by recommending enhanced effort to be devoted towards providing women with access to and use of ICT which engender a plethora of financial inclusion avenues. Mndolwa and Alhassan (2020) have examined the drivers and status of gender differences in terms of financial inclusion in Tanzania on the bases on 4,466 individuals to provide support of the perspective that gender differences with respect to financial inclusion are significant in formal accounts, mobile money accounts and formal savings. In essence, the corresponding results further provide support for gender mainstreaming in order to boost the education and employment of women in view of ultimately mitigating the corresponding extant gap in financial inclusion. Ngono (2021) has examined how microfinancial institutions, banks and mobile money innovation influence female entrepreneurship opportunities. How the present study departs from the extant empirical literature and specifically to Ngono (2021) has been discussed in the introduction.

2.2 Theoretical underpinnings and testable hypothesis

This section engages the theoretical nexuses on which the testable hypothesis is premised. The corresponding section is engaged in three main categories, notably: (i) insights into the theoretical underpinnings; (ii) contextualizing the theoretical framework within the premise of the present research and (iii) a statement on the corresponding hypothesis to be tested in the empirical section of the study. The highlighted categories are expanded in what follows in the same chronology.

First, on the premise of the theoretical framework for the linkage between mobile money innovations, in the light of the documented insights that mobile money innovations are a means of financial inclusion (Ngono, 2021), this study theoretically borrows from Tchamyou *et al*. (2019a) who have provided a theoretical framework for the linkage between financial inclusion, information technology and inclusive development outcomes, such as income inequality. Consistent with the attendant narrative, financial inclusion and information technology (both embodied in the mobile money innovation proxies used in this study) are critical in promoting inclusive development by means of *inter alia*, income inequality reduction and gender economic empowerment. This foundational insight is in line with the attendant literature on the linkage between financial inclusion and inclusive development (Greenwood & Jovanovic, 1990; Galor & Zeira, 1993; Galor & Moav, 2004; Aghion & Bolton, 2005; Beck *et al*., 2007; Tchamyou & Asongu, 2017a; Asongu & Odhiambo, 2018b), not least, because the corresponding literature supports the perspective that when the population is provided with means by which to be more financially-included, concerns around exclusive development are concurrently addressed in the attendant population. Moreover, this theoretical premise withstands logical scrutiny when the majority of the population being financially-included with mobile-related opportunities was previously financially-excluded.

As posited by Tchamyou *et al*. (2019), the connection between financial inclusion and inclusive outcomes of economic development can be understood from two main theoretical standpoints, namely: the intensive and extensive margin theories. First, consistent with the intensive margin theory, inclusive development can be achieved when information technology instruments, *inter alia*, are leveraged upon to provide more financial services to existing customers in the banking sector. The theory is founded on the basis that even when existing customers are provided with financial inclusion opportunities (especially by means of mobile money innovations currently being employed in the present study), these existing customers are by extension, provided with enhanced avenues of inclusive development. The theoretical position is supported by extant literature; *inter alia*, Chipote *et al*. (2014).

Second, in accordance with the extensive margin theory, financial access especially by means of mobile money innovations as within the remit of this study can be extended to customers who did not previously have bank accounts with existing financial institutions. Accordingly, when financial inclusion is extended to the population that was hitherto excluded from financial services, especially owing to novel information technology mechanisms such as mobile money innovations, inclusive development outcomes, especially in terms of reduction of income inequality among the poor can be apparent. As already motivated in the introduction of this study, some of the most excluded, especially in terms of financial access in SSA are women; hence, the positioning of this study on how mobile money innovations can be leveraged upon in order to promote inclusive development such as female economic empowerment within the framework for female self-employment. It is worthwhile to emphasize that the extensive margin theory is consistent with the positions in the outstanding literature on the nexus between inclusive finance and outcomes of inclusive development (Odhiambo, 2014; Orji, Aguegboh & Anthony-Orji, 2015; Chiwira *et al*., 2016) and by extension, the theoretical premise is even more relevant in terms of withstanding logical scrutiny when a large part of the population being offered the

corresponding financial inclusive services was previously excluded from reaping the fruits of such services (Evans & Jovanovic, 1989; Holtz-Eakin *et al*., 1994; Black & Lynch, 1996; Bae *et al*., 2012; Batabyal & Chowdhury, 2015).

Second, within the remit of contextualizing the discussed theoretical insights, it is worth articulating that such contextualization is simple to follow, not least, because connecting the theoretical insights with the purpose of this study can be summarized in the following: financial inclusion services, especially by means of mobile money innovations engender inclusive development outcomes such as gender economic empowerment within the framework female self-employment. Mobile money innovations are employed as the policy or moderating variables and these moderating variables are anticipated to moderate female unemployment in order to promote female self-employment. The underlying contextualization builds on the documented evidence of a negative nexus between income inequality and gender economic inclusion in SSA (Asongu & Odhiambo, 2019).

Third, in the light of the theoretical exposition in the first category and the contextualization of the theoretical insights in the second category of this section, the corresponding arguments support the formulation of the following testable hypothesis.

Hypothesis 1: mobile money innovations moderate female unemployment to promote female self-employment in SSA.

3. Data and methodology

3.1 Data

The study is concerned with 44 countries in SSA employing data from 2004 to 2018 from three principal sources, namely: (i) World Development Indicators of the World Bank (2020a), (ii) the Financial Access Survey (IMF, 2020) and (iii) the Gender and Parity Statistics for Men and Women of the World Bank (2020b). The sample and related periodicity are chosen based on the premises of: (i) data availability at the time of the study of Ngono (2021) and (ii) since this study is an extension of Ngono (2021) using the same dataset, it is normal that the same dataset and periodicity as in Ngono (2021) are applied in this study. The dependent variable is female self-employment (% of female employment), in accordance with Ngono (2021) whereas consistent with the motivation and theoretical framework of the study, the main independent variables of interest are female unemployment (% of female labor force or the main channels) and mobile money innovations considered as the moderating or policy variables.

Eight mobile money innovation variables provided in four main categories are employed, namely: (i) registered mobile money agents (registered mobile money agents per 100 000 adults and registered mobile money agents per 1000 km2); (ii) active mobile money agents (active mobile money agents per 100 000 adults and active mobile money agents per 1000 km2); (iii) registered mobile money accounts (number of registered mobile money accounts per 1000 adults and balances in the mobile accounts active money as a percentage of GDP) and (iv) number and volume of transactions (number of transactions per 1000 adults and volume of transactions via mobile money as a percentage of GDP).

Consistent with Ngono (2021), the following control variables are adopted in the conditioning information set in order to control for variable omission bias: *secondary female high school enrollment rate, trade openness, the cost it takes for a woman to set up a business, the time for women to set up a business and the procedures a woman has to go through to start a business.* Selection of the control variables is informed by the extant inclusive and gender enhancement

literature (Duflo, 2012; Tchamyou *et al*., 2019a, 2019b; Asongu & Odhiambo, 2020; Ngono, 2021; Ofori *et al*., 2021; Asongu *et al*., 2021c; Nchofoung *et al*., 2021).

As substantiated in the empirical results section of the study, the expected signs from the control variables cannot be projected with certainty because the specifications in the present study are non-linear or based on interactive regressions in which concerns of multicollinearity are overlooked for the main independent variables of interest. It is for this reason that in order to assess the overall incidence of the independent variables of interest, net effects and/or thresholds are computed in the empirical results section. It follows that contrary to Ngono (2021), the expected signs of the control variables cannot be established with certainty. It is relevant to acknowledge that the same variables in the conditioning information set in Ngono (2021) are employed in this research.

The corresponding variables and the related sources are disclosed in Appendix 1 whereas Appendix 2 provides a summary statistics. This section of the appendix is completed with Appendix 3 which provides insights into partial correlation between the involved variables.

3.2 Methodology

The quantile regressions empirical technique adopted in this study is consistent with the elements of style adopted in the introduction. Accordingly, as argued in the corresponding section, the underlying estimation technique is adopted in order to provide nexuses between mobile money innovations, female unemployment and female self-employment with particular emphasis on initial levels of the outcome variable or female self-employment. It is relevant to also highlight that the attendant estimation approach is adopted because of the departure from Ngono (2021) which is the paper in the literature that is closest to the positioning of this research. The insights provided above are in accordance with the corresponding quantile-centric literature (Billger & Goel, 2009; Asongu, 2017; Tchamyou & Asongu, 2017b; Boateng *et al*., 2018).

Another relevant point needing clarification is the premise that, relative to OLS that is based on the hypothesis that the error are substantially distributed normally, with the quantile regression approach, such a hypothesis does not hold. Furthermore, parameters are examined at various points of the conditional distribution of the outcome variable of female economic empowerment. This narrative is in line with both non-contemporary and contemporary studies on the estimation approach (Koenker & Bassett, 1978; Keonker & Hallock, 2001; Asongu, 2017).

Given the underlying, in the adopted empirical strategy, the θ^{th} quantile estimator of female self-employment is obtained by solving for the optimization problem in Equation (1), that is disclosed in absence of subscripts for the purpose of simplicity in presentation.

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

where $\theta \in (0,1)$. Relative to the OLS approach that considered within the framework of reducing the sum of squared residuals, the quantile technique is engaged by adding the absolute deviations of all related quantiles. For instance, in the attendant literature, a multitude of quantiles are considered. For instance, the 25$^{\text{th}}$ quantile (θ=0.25) is minimised by weighing the residuals. The related conditional quantile of female self-employment or y_i given x_i is:

$$Q_y(\theta / x_i) = x_{i'}\beta_\theta \quad (2)$$

where for the comparative θ^{th} quantile that is examined, parameters that feature unique slopes are modelled. The related formulation is parallel to $E(y / x) = x_{i'}\beta$ in the OLS slope within which remit, parameters are assessed exclusively at the mean of the conditional distribution of female self-employment. For the model in Eq. (2), the dependent variable y_i is the female self-employment indicator while x_i contains a constant term, *female unemployment, mobile money innovations, secondary female high school enrollment rate, trade openness, the cost it takes for a woman to set up a business, the time for women to set up a business and the procedures a woman has to go through to start a business.*

4. Empirical results

4.1 Presentation of results

The empirical findings are provided in this section in three main sub-sections, respectively in Tables 1, 2, 3 and 4. Table 1 show findings related to nexuses between female unemployment, registered mobile money agents (i.e. registered mobile money agents per 100 000 adults and registered mobile money agents per 1000 km2) and female self-employment while Table 2 is concerned with nexuses between female unemployment, active mobile money agents (i.e. active mobile money agents per 100 000 adults and active mobile money agents per 1000 km2) and female self-employment. Table 3 shows results on nexuses between female unemployment, registered mobile money accounts (i.e. number of registered mobile money accounts per 1000 adults and balances in the mobile accounts active money as a percentage of GDP) and female self-employment whereas Table 4 focuses on connections between female unemployment, number and volume of transactions (i.e. number of transactions per 1000 adults and volume of transactions via mobile money as a percentage of GDP) and female self-employment.

It is important to articulate that in the light of the presented findings, the choice of the quantile regression approach seems relevant because when the estimated coefficients of the OLS and quantiles are compared across mean values of the outcome variables and throughout the conditional distribution of the outcome variables, differences are apparent in terms of significance, signs of significance and magnitude of significance.

4.1.1 Female unemployment registered mobile money agents and female self-employment.

Table 1 presents the findings of this section with the left-hand side showing findings on nexuses between female unemployment, registered mobile money agents per 100 000 adults and female self-employment and the right-hand side displaying results on the linkages between female unemployment, registered mobile money agents per 1000 km2 and female self-employment. In order to assess the hypothesis being tested, the research is in accordance with contemporary literature by computing net effects which entail both the unconditional and the conditional effects of the main channel (Nchofoung *et al*., 2022; Nchofoung & Asongu, 2022a, 2022b). Hence, in order to assess the role of mobile money innovations in the incidence of female unemployment on female self-employment, net effects are computed accordingly. This is consistent with Brambor *et al*. (2006) on the pitfalls of interactive regressions. In essence, the net effect is an embodiment of both the unconditional impacts and conditional or interactive effects.

In order to put the above highlighted computation insight into more perspective, an illustrative example is worthwhile. For instance, in the penultimate specification of the last column in the left-hand side of Table 1 or the 75^{th} quantile, the net effect from the role of registered mobile

money agents per 100 000 adults in moderating female unemployment to affect female self-employment is -0.679 = ([0.001 × 237.012] + [-0.917]). In the corresponding computation, -0.917 is the unconditional effect of female unemployment, 237.012 is the mean or average value of registered mobile money agents per 100 000 adults while 0.001 is the interactive or conditional effect between female unemployment and registered mobile money agents per 100 000 adults. From the findings in Table 1, the validity of Hypothesis 1 can be assessed exclusively in the top quantiles of the left-hand side and the highest quantile in the right-hand side. This is an indication that such nexuses can be significantly examined for the most part in countries in which female self-employment is already high (i.e. top quantiles of the outcome variable). The net effects in the top quantiles are consistently negative and most of the control variables are significant. While negative net effects are apparent, the corresponding conditional effects are positive, which implies that there are critical masses or thresholds of the corresponding mobile money innovations needed to transform female unemployment to female self-employment.

Table 1: Female unemployment, registered mobile money agents and female self-employment

	Dependent variable: Female Self-Employment (1)											
	Registered mobile money agents per 100 000 adults (Oae1)						**Registered mobile money agents per 1000 km2 (Oae2)**					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	131.78***	129.74***	134.24***	130.30***	106.19***	115.39***	131.94***	129.74***	135.81***	129.77***	110.59***	120.93***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FUmpl	-1.325***	-0.815***	-0.855***	-1.662***	**-0.917*** **	**-1.213*** **	-1.291***	-0.809***	-0.846***	-1.635***	-0.874***	**-1.196*** **
	(0.000)	(0.000)	(0.000)	(0.000)	**(0.000)**	**(0.000)**	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	**(0.000)**
Oae1	-0.005	-0.0001	-0.002	-0.007	-0.010**	-0.010***	---	---	---	---	---	---
	(0.215)	(0.963)	(0.679)	(0.366)	(0.048)	(0.000)						
Oae2	---	---	---	---	---	---	-0.004***	-0.0005	-0.001	-0.004	-0.005**	-0.006***
							(0.006)	(0.727)	(0.504)	(0.167)	(0.045)	(0.000)
FUmpl× Oae1	0.0007	-0.00007	-0.0001	0.0003	**0.001** **	**0.001*** **	---	---	---	---	---	---
	(0.344)	(0.895)	(0.834)	(0.817)	**(0.024)**	**(0.000)**						
FUmpl× Oae2	---	---	---	---	---	---	0.0003	-0.0001	-0.0005	-0.0007	0.002	**0.001* **
							(0.802)	(0.862)	(0.700)	(0.693)	(0.187)	**(0.073)**
SES	-0.627***	-0.771***	-0.784***	-0.446***	-0.285***	-0.324***	-0.617***	-0.769***	-0.729***	-0.414***	-0.367***	-0.369***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	-0.204***	-0.292***	-0.272***	-0.191**	0.006	-0.081***	-0.201***	-0.294***	-0.297***	-0.189***	-0.014	-0.103***
	(0.000)	(0.000)	(0.000)	(0.022)	(0.904)	(0.001)	(0.000)	(0.000)	(0.000)	(0.006)	(0.802)	(0.000)
CostBusiness	-0.043	-0.063**	-0.065	0.019	0.009	-0.006	-0.040	-0.061**	-0.045	0.013	0.006	-0.015
	(0.228)	(0.036)	(0.159)	(0.772)	(0.817)	(0.733)	(0.253)	(0.029)	(0.303)	(0.809)	(0.899)	(0.428)
TimeBusiness	-0.008	0.222***	0.169	-0.051	-0.078	-0.149***	-0.023	0.214***	0.149	-0.049	-0.116	-0.170***
	(0.899)	(0.002)	(0.126)	(0.749)	(0.427)	(0.002)	(0.708)	(0.002)	(0.160)	(0.717)	(0.312)	(0.001)
Startupprocd	0.021	-0.491	-0.586	-0.834	0.132	0.709***	-0.047	-0.492	-0.900*	-0.951	0.205	0.619**
	(0.954)	(0.175)	(0.291)	(0.304)	(0.791)	(0.004)	(0.893)	(0.140)	(0.091)	(0.163)	(0.712)	(0.010)
Net Effects	na	na	na	na	-0.679	-0.975	na	na	na	na	na	-1.027
Thresholds	na	na	na	na	917	1213	na	na	na	na	na	1196
R^2/Pseudo R^2	0.834	0.811	0.652	0.481	0.399	0.409	0.654	0.812	0.661	0.507	0.419	0.427
Fisher	73.58***						63.22***					
Observations	104	104	104	104	104	104	104	104	104	104	104	104

*,**,***: significance levels of 10%, 5% and 1% respectively. OLS: Ordinary Least Squares. R^2 for OLS and Pseudo R^2 for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where female self-employment is least. FUmpl: Female Unemployment. Oae1: Number of registered mobile money agents per 100 000 adults. Oae2: Number of registered mobile money agents per 1000 km2. SES: Secondary female high school enrollment rate. Trade: trade openness. CostBusiness: The cost it takes for a woman to set up a business. TimeBusiness: The time of women to set up a business. Startupprocd: The procedures a woman has to go through to start a business. The mean value of Oae1 is 237.012 while the mean value of Oae2 is 168.559. na: not applicable because at least one estimated coefficient needed for the computation of net effect and threshold is not significant.

4.1.2 Female unemployment, active mobile money agents and female self-employment

Table 2 presents the results of this section with the left-hand side showing findings on nexuses between female unemployment, active mobile money agents per 100 000 adults and female self-employment and the right-hand side displaying results on the linkages between female unemployment, active mobile money agents per 1000 km2 and female self-employment. In order to assess the hypothesis being tested, the research is in accordance with contemporary literature by computing net effects, in line with the discussion in the previous section.

From the findings in Table 2, the validity of Hypothesis 1 can be assessed exclusively in the top quantiles of the left-hand side and the right-hand side. This is an indication that such nexuses can be significantly examined for the most part in countries in which female self-employment is

already high (i.e. top quantiles of the outcome variable). The net effects in the top quantiles are consistently negative and most of the control variables are significant. While negative net effects are apparent, the corresponding conditional effects are positive, which implies that there are critical masses or thresholds of the corresponding mobile money innovations needed to transform female unemployment to female self-employment.

Table 2: Female unemployment, active mobile money agents and female self-employment

	Dependent variable: Female Self-Employment (1)											
	Active mobile money agents per 100 000 adults (Oaa1)						**Active mobile money agents per 1000 km2 (Oaa2)**					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	133.46***	129.35***	139.09***	147.15***	131.61***	125.12***	135.15***	127.71***	137.88***	136.08***	131.37***	128.33***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FUmpl	**-1.743*** **	-0.778***	-0.852**	**-1.917*** **	**-1.804*** **	**-1.362*** **	**-1.448*** **	-0.790***	-0.760***	-1.323***	**-1.333*** **	**-1.246*** **
	(0.000)	(0.000)	(0.017)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	(0.000)	(0.009)	(0.000)	**(0.000)**	**(0.000)**
Oaa1	-0.015**	-0.0008	-0.006	-0.027**	-0.021**	-0.012***	---	---	---	---	---	---
	(0.011)	(0.778)	(0.508)	(0.028)	(0.014)	(0.002)						
Oaa2	---	---	---	---	---	---	-0.011***	-0.0005	-0.001	-0.008*	-0.012***	-0.011***
							(0.000)	(0.762)	(0.746)	(0.076)	(0.000)	(0.000)
FUmpl× Oaa1	**0.004*** **	-0.00002	0.0008	**0.005** **	**0.005*** **	**0.002*** **	---	---	---	---	---	
	(0.005)	(0.969	(0.669)	**(0.015)**	**(0.002)**	**(0.004)**						
FUmpl× Oaa2	---	---	---	---	---	---	**0.004***	-0.0005	-0.0002	0.001	**0.005** **	**0.003*** **
							(0.081)	(0.629)	(0.928)	(0.645)	**(0.011)**	**(0.001)**
SES	-0.565***	-0.764***	-0.756***	-0.558***	-0.450***	-0.435***	-0.621***	-0.780***	-0.772***	-0.563***	-0.459***	-0.581***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	-0.378***	-0.301***	-0.350***	-0.485***	-0.348***	-0.108**	-0.337***	-0.276***	-0.320***	-0.351***	-0.351***	-0.089***
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.012)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.006)
CostBusiness	-0.074	-0.034*	-0.036	-0.121	-0.016	-0.069**	-0.058	-0.044	-0.032	-0.017	0.065	-0.063***
	(0.146)	(0.086)	(0.601)	(0.153)	(0.785)	(0.014)	(0.283)	(0.108)	(0.629)	(0.808)	(0.180)	(0.006)
TimeBusiness	0.103	0.166***	0.164	0.110	-0.185	-0.110	0.028	0.162**	0.145	-0.122	-0.378***	-0.242***
	(0.350)	(0.004)	(0.402)	(0.644)	(0.266)	(0.158)	(0.805)	(0.036)	(0.443)	(0.533)	(0.007)	(0.000)
Startupprocd	1.182**	-0.420	-1.044	0.739	1.866**	0.846**	0.866	-0.186	-1.110	0.662	1.354**	1.299***
	(0.046)	(0.125)	(0.275)	(0.522)	(0.023)	(0.028)	(0.101)	(0.603)	(0.218)	(0.475)	(0.039)	(0.000)
Net Effects	-1.057	na	na	-1.060	-0.947	-1.019	-0.871	na	na	na	-0.612	-0.813
Thresholds	435.75	na	na	383.40	360.80	681	362	na	na	na	266.60	415.33
R^2/Pseudo R^2	0.887	0.814	0.721	0.576	0.479	0.487	0.890	0.817	0.726	0.581	0.515	0.513
Fisher	134.19***						149.30***					
Observations	69	69	69	69	69	69	69	69	69	69	69	69

*,**,***: significance levels of 10%, 5% and 1% respectively. OLS: Ordinary Least Squares. R^2 for OLS and Pseudo R^2 for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where female self-employment is least. FUmpl: Female Unemployment. OAA1: Number of active mobile money agents per 100 000 adults. OAA2: Number of active mobile money agents per 1000 km2. SES: Secondary female high school enrollment rate. Trade: trade openness. CostBusiness: The cost it takes for a woman to set up a business. TimeBusiness: The time of women to set up a business. Startupprocd: The procedures a woman has to go through to start a business. Bankaccount: dummy variable who takes the value 1 if women can open bank accounts like men, 0 otherwise. Contract: dummy variable who takes the value the value 1 if women can sign contracts like men, 0 otherwise. Business: dummy variable who takes the value the value 1 a woman can register a business in the same way as a man, 0 otherwise. The mean value of Oaa1 is 171.339 while the mean value of Oaa2 is 144.217. na: not applicable because at least one estimated coefficient needed for the computation of net effect and threshold is not significant.

4.1.3 Female unemployment, registered mobile money accounts and female self-employment.

The narrative of this sub-section pertaining to linkages between female unemployment, registered mobile money accounts and female self-employment is consistent with the narrative in Table 2, not least because the net effects are consistently negative and the quantiles at which the tested hypothesis is validly assessed are the same, notably: (i) the median, 75 quantile and 90th quantile of the left-hand side linked to the number of registered mobile money accounts per 1000 adults and (ii) the 75th and 90th quantiles linked to balances in the mobile accounts active money as a percentage of GDP.

Table 3: Female unemployment, registered mobile money accounts and female self-employment

	Dependent variable: Female Self-Employment (1)											
	Number of registered mobile money accounts per 1000 adults						Balances in the mobile accounts active money as a percentage of GDP					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	136.07***	136.19***	139.62***	140.91***	128.28***	118.03***	130.14***	125.04***	128.24***	161.64***	108.86***	121.74***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FUmpl	**-1.497*** **	-0.863***	-0.891**	**-1.645*** **	**-1.721*** **	**-1.332*** **	-1.763***	-1.010***	-1.152***	-1.523***	**-2.622*** **	**-2.750*** **
	(0.000)	(0.000)	(0.010)	**(0.000)**	**(0.000)**	**(0.000)**	(0.000)	(0.000)	(0.007)	(0.000)	**(0.000)**	**(0.000)**
CA	-0.019**	-0.005	-0.007	-0.036**	-0.043***	-0.024***	---	---	---	---	---	---
	(0.034)	(0.456)	(0.571)	(0.020)	(0.000)	(0.000)						
Balance	---	---	---	---	---	---	-5.666	3.988	1.592	-2.615	-17.692**	-19.417***
							(0.617)	(0.359)	(0.903)	(0.880)	(0.012)	(0.000)
FUmpl× CA	**0.003***	0.001	0.001	**0.005** **	**0.006*** **	**0.003*** **	---	---	---	---	---	
	(0.056)	(0.218)	(0.451)	**(0.023)**	**(0.000)**	**(0.000)**						
FUmpl× Balance	---	---	---	---	---	---	2.192	-0.370	-0.319	0.432	**3.639*** **	**3.479*** **
							(0.123)	(0.539)	(0.860)	(0.858)	**(0.000)**	**(0.000)**
SES	-0.582***	-0.417***	-0.378***	-0.321***	-0.284***	-0.131***	-0.703***	-0.803***	-0.842***	-0.909***	-0.151**	-0.170***
	(0.000)	(0.000)	(0.001)	(0.009)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.045)	(0.000)
Trade	-0.331***	-0.699***	-0.735***	-0.569***	-0.351***	-0.284***	-0.250***	-0.263***	-0.273**	-0.344**	-0.021	-0.033
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.000)	(0.015)	(0.022)	(0.710)	(0.330)
CostBusiness	-0.054	-0.019	-0.031	-0.089	-0.018	-0.013	-0.205***	-0.170***	-0.227***	-0.273**	0.008	-0.008
	(0.259)	(0.569)	(0.468)	(0.248)	(0.728)	(0.350)	(0.006)	(0.000)	(0.007)	(0.015)	(0.848)	(0.729)
TimeBusiness	-0.018	0.182**	0.175	0.021	-0.202	-0.139***	0.200*	0.313***	0.320**	0.271	-0.043	-0.065
	(0.809)	(0.030)	(0.293)	(0.910)	(0.117)	(0.000)	(0.067)	(0.000)	(0.044)	(0.196)	(0.591)	(0.187)
Startupprocd	0.555	-1.026**	-1.161	0.223	1.334*	0.835***	1.671*	0.591	1.341	0.008	-0.029	-0.781**
	(0.277)	(0.031)	(0.220)	(0.832)	(0.068)	(0.000)	(0.075)	(0.124)	(0.243)	(0.995)	(0.960)	(0.035)
Net Effects	-1.497	na	na	-0.670	-0.551	-0.747	na	na	na	na	-1.901	-2.061
Thresholds	499	na	na	329	286.833	444	na	na	na	na	0.720	0.790
R^2/Pseudo R^2	0.862	0.804	0.692	0.541	0.451	0.460	0.896	0.803	0.762	0.597	0.572	0.584
Fisher	139.36***						116.31***					
Observations	81	81	81	81	81	81	54	54	54	54	54	54

*,**,***: significance levels of 10%, 5% and 1% respectively. OLS: Ordinary Least Squares. R^2 for OLS and Pseudo R^2 for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where female self-employment is least. FUmpl: Female Unemployment. CA: number of registered mobile money accounts per 1000 adults. Balance: balances in the mobile accounts active money as a percentage of GDP. SES: Secondary female high school enrollment rate. Trade: trade openness. CostBusiness: The cost it takes for a woman to set up a business. TimeBusiness: The time of women to set up a business. Startupprocd: The procedures a woman has to go through to start a business. Bankaccount: dummy variable who takes the value 1 if women can open bank accounts like men, 0 otherwise. Contract: dummy variable who takes the value the value 1 if women can sign contracts like men, 0 otherwise. Business: dummy variable who takes the value the value 1 a woman can register a business in the same way as a man, 0 otherwise. The mean value of CA is 194.949 while the mean value of Balance is 0.198. na: not applicable because at least one estimated coefficient needed for the computation of net effect and threshold is not significant.

4.1.4 Female unemployment, number and volume of transactions and female self-employment

The narrative of this sub-section focusing to nexuses between female unemployment, number and volume of transactions and female self-employment is consistent with the narrative in Table 1, not least because the net effects are consistently negative and the quantiles at which the tested hypothesis is validly assessed are the same, notably: (i) 75^{th} and 90^{th} quantiles of the left-hand side on the number of transactions per 1000 adults and (ii) the 90^{th} quantile linked to the volume of transactions via mobile money as a percentage of GDP.

Three main common characteristics are apparent in the Tables 1-4: (i) the tested hypothesis is valid exclusively at the top quantiles of female self-employment; (ii) the net effects are consistently negative and (iii) the corresponding conditional or interactive effects upon which the net effects are based are consistently positive. This is an indication that critical masses at which mobile money innovations have an overall positive net effect on female self-employment are apparent. This is the focus of the next section on mobile money innovation thresholds.

Table 4: Female unemployment, number and volume of transactions and female self-employment

	Dependent variable: Female Self-Employment (1)											
	Number of transactions per 1000 adults						Volume of transactions via mobile money as a percentage of GDP					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Constant	130.75***	129.21***	131.60***	130.95***	109.71***	120.67***	126.59***	125.05***	129.29***	123.10***	110.10***	117.05***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FUmpl	-1.254***	-0.877***	-0.881***	-1.520***	**-0.886*** **	**-1.244*** **	**-1.311*** **	-0.809***	-0.887***	-1.603***	-0.994***	**-1.230*** **
	(0.000)	(0.000)	(0.000)	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	(0.000)	(0.000)	(0.000)	(0.000)	**(0.000)**
Ntran	-0.00007	-0.00003	-0.00005	-0.0003	-0.0002**	-0.0001***	---	---	---	---	---	---
	(0.607)	(0.716)	(0.683)	(0.127)	(0.033)	(0.001)						
Vtran	---	---	---	---	---	---	-0.070	0.070	-0.103	-0.226	-0.124	-0.159***
							(0.633)	(0.574)	(0.539)	(0.349)	(0.450)	(0.001)
FUmpl×Ntran	0.00001	1.17e-06	6.87e-06	0.00005	**0.00003** **	**0.00002*** **	---	---	---	---	---	---
	(0.489)	(0.922)	(0.740)	(0.068)	**(0.018)**	**(0.000)**						
FUmpl× Vtran	---	---	---	---	---	---	**0.036***	-0.006	0.039	0.050	0.029	**0.029*** **
							(0.079)	(0.736)	(0.111)	(0.154)	(0.225)	**(0.000)**
SES	-0.678***	-0.767***	-0.748***	-0.527***	-0.361***	-0.416***	-0.648***	-0.831***	-0.795***	-0.472***	-0.391***	-0.369***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	-0.183***	-0.298***	-0.310***	-0.217**	-0.013	-0.086***	-0.198***	-0.249***	-0.270***	-0.182**	-0.061	-0.105***
	(0.001)	(0.000)	(0.000)	(0.029)	(0.783)	(0.000)	(0.000)	(0.000)	(0.000)	(0.023)	(0.253)	(0.000)
CostBusiness	-0.058	-0.072**	-0.047	-0.002	0.010	-0.046**	-0.060*	-0.102***	-0.065	-0.007	0.013	-0.015
	(0.134)	(0.018)	(0.366)	(0.977)	(0.788)	(0.010)	(0.097)	(0.008)	(0.199)	(0.922)	(0.778)	(0.246)
TimeBusiness	-0.002	0.226***	0.174	-0.036	-0.138	-0.164***	-0.012	0.088	0.162	-0.046	-0.191*	-0.207***
	(0.966)	(0.001)	(0.137)	(0.831)	(0.114)	(0.000)	(0.846)	(0.307)	(0.160)	(0.781)	(0.092)	(0.000)
Startupprocd	0.255	-0.281	-0.408	-0.328	0.357	0.979***	0.645	0.596	0.006	0.091	1.013*	1.195***
	(0.532)	(0.415)	(0.496)	(0.710)	(0.423)	(0.000)	(0.171)	(0.197)	(0.991)	(0.918)	(0.096)	(0.000)
Net Effects	na	na	na	na	-0.512	-0.995	-0.865	na	na	na	na	-0.871
Thresholds	na	na	na	na	29533.33	62200	36.416	na	na	na	na	42.413
R^2/Pseudo R^2	0.844	0.810	0.665	0.471	0.425	0.444	0.849	0.805	0.670	0.500	0.418	0.444
Fisher	83.01***						102.72***					
Observations	93	93	93	93	93	93	99	99	99	99	99	99

*,**,***: significance levels of 10%, 5% and 1% respectively. OLS: Ordinary Least Squares. R^2 for OLS and Pseudo R^2 for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where female self-employment is least. FUmpl: Female Unemployment. Ntran: Number of transactions per 1000 adults. Vtran: Volume of transactions via mobile money as a percentage of GDP. SES: Secondary female high school enrollment rate. Trade: trade openness. CostBusiness: The cost it takes for a woman to set up a business. TimeBusiness: The time of women to set up a business. Startupprocd: The procedures a woman has to go through to start a business. Bankaccount: dummy variable who takes the value 1 if women can open bank accounts like men, 0 otherwise. Contract: dummy variable who takes the value the value 1 if women can sign contracts like men, 0 otherwise. Business: dummy variable who takes the value the value 1 a woman can register a business in the same way as a man, 0 otherwise. The mean value of Ntran is 12450.05 while the mean value of Vtran is 12.375. na: not applicable because at least one estimated coefficient needed for the computation of net effect and threshold is not significant.

4.2 Mobile money innovation policy thresholds

The importance of this section is premised on the pertinence of extending the discourse in the previous section with more actionable thresholds of mobile money innovations at which the overall incidence on female self-employment is transformed from negative to positive. As apparent from the interactive regressions, the mobile money innovation proxies become both a sufficient and necessary condition for an overall positive incidence on female self-employment when some critical masses of mobile money innovations have been attained. In essence, the present study is in line with contemporary interactive regression studies on providing thresholds in order to enable room for more policy implications (Nchofoung & Asongu, 2022a, 2022b) by computing thresholds of mobile money innovation that produce overall positive effects on female self-employment. According to the related literature, in order for the compute thresholds to have any relevance to policy makers, such thresholds should be between the minimum and maximum values of the corresponding variables disclosed in the summary statistics.

Consistent with the same example provided on Table 1 in the preceding section, in the penultimate specification of the last column in the left-hand side of Table 1 or the 75^{th} quantile, the mobile money innovation threshold is 719 (0.719/0.001). In the computation, 0.719 is the

absolute value of the unconditional effect of female unemployment, while 0.001 is the interactive or conditional effect between female unemployment and registered mobile money agents per 100 000 adults. It follows that 719 registered mobile money agents per 100 000 adults is the threshold needed to have an overall positive incidence on female self-employment. The threshold is policy-relevant and within policy range because it is situated between 0.115 and 2160.727 respectively, the minimum and maximum values of registered mobile money agents per 100 000 adults disclosed in the summary statistics or Appendix 2. Given these insights, the corresponding mobile innovation thresholds are disclosed in the bottom of tables reporting the findings. To avoid repetition owing to space constraint, the interested reader can refer to the tables for the corresponding mobile money innovation policy thresholds.

4.3 Further discussion of results

This section is discussed in three main strands, especially as it pertains to comparing the findings with respectively, Ngono (2021), the extant theoretical literature and corresponding empirical studies. The strands are engaged in chronological order. First, it is worthwhile to articulate that whereas Ngono (2021) has concluded that mobile money innovation promotes female self-employment, the present study which is premised within the remit of assessing the nexuses throughout the conditional distribution of female self-employment has shown that mobile money innovations can be employed to transform unemployed women into self-employed women. Moreover, contrary to Ngono (2021), the findings are not blanket but contingent on initial levels of female self-employment such that blanket female self-employment policies are unlikely to succeed unless they are contingent on initial levels of female self-employment and thus, tailored differently across countries with various initial levels of female self-employment. For brevity and the purpose of avoiding repetition, the similarities and differences between the positioning of the present study and Ngono (2021) are clearly articulated in the introduction.

Second, with respect to the theoretical literature, the thresholds from the tested hypothesis are consistent with the extensive and intensive margin theories disclosed in Section 2. Accordingly, contingent on initial levels of female self-employment, the findings confirm the intensive margin theory on the premise that existing female users of mobile phones who are unemployed can leverage on mobile money innovations in order to improve their employment conditions especially as it pertains to becoming self-employed through *inter alia*, entrepreneurial activities. Moreover, the extensive margin theory is also confirmed on the premise that contingent on initial levels of female self-employment, females who did not previously benefit from mobile phone services can leverage on the opportunities of mobile money innovations to become self-employed.

Third, the tested hypothesis confirmed in the previous section, is in line with the extant contemporary empirical studies on the nexus between new technology and employment linkages, especially as it pertains to the promotion of female self-employment by the mitigation of female unemployment. Accordingly, Freeman (2005) has established that new technologies such as mobile money innovations are fundamental in the mitigation of income inequality. According to the narrative, those that are excluded-economically such as the female gender can leverage on extant technologies (i.e. such as mobile money innovations) to improve their social mobility prospects (Whittall *et al*., 2009). In summary, assessing whether the testable hypothesis withstands empirical scrutiny is consistent with the corresponding literature on the relevance of leveraging on extant technologies such as mobile money innovation to promote working opportunities, including self-employment for women (Geelan, 2021; Staples & Whittall, 2021; Flanagan & Walker, 2021; Hennebert *et al*., 2021). Accordingly, relative to initial levels of female self-employment, the established findings are consistent with the empirical literature on

the benefits of mobile money innovations in financial inclusion (Lashitew *et al*., 2019; Asongu *et al*., 2020, 2021b; Koomson *et al*., 2021; Coffie *et al*., 2021; Serbeh *et al*., 2022; Awel & Yitbarek, 2022), especially female financial and economic inclusion (Asongu & Odhiambo, 2018a; Osabuohien & Karakara, 2018; Mndolwa & Alhassan, 2020; Kim, 2022).

5. Concluding implications and future research directions

The study examines how mobile money innovations transform unemployed women to self-employed women. The empirical evidence is based on interactive quantile regressions focusing on data from 44 countries in sub-Saharan Africa for the period 2004 to 2018. The hypothesis that mobile money innovations transform female unemployment to female self-employment is tested. Eight mobile money innovation variables provided in four main categories are employed, namely: (i) registered mobile money agents (i.e. registered mobile money agents per 100 000 adults and registered mobile money agents per 1000 km2); (ii) active mobile money agents (i.e. active mobile money agents per 100 000 adults and active mobile money agents per 1000 km2); (iii) registered mobile money accounts (i.e. number of registered mobile money accounts per 1000 adults and balances in the mobile accounts active money as a percentage of GDP) and (iv) number and volume of transactions (i.e. number of transactions per 1000 adults and volume of transactions via mobile money as a percentage of GDP).

Three main common findings are apparent from interactions between female unemployment, eight mobile money innovation dynamics and female self-employment: (i) the investigated hypothesis is valid exclusively at the top quantiles of female self-employment; (ii) the net effects are consistently negative and (iii) the corresponding conditional or interactive effects upon which the net effects are based are consistently positive. This is an indication that critical masses at which mobile money innovations have an overall positive net effect on female self-employment are apparent. The corresponding mobile money innovation policy thresholds at which the net effects on female self-employment change from negative to positive are provided. In what follows, policy implications are discussed.

In terms of policy implications, four policy perspectives are worth articulating. First, the finding that mobile money innovations are exclusively relevant in transforming female unemployment into female self-employment is an indication of the fact that sampled countries have to work towards improving their initial conditions of female self-employment before the attendant countries can benefit from the role of mobile money innovations in promoting female self-employment. Improving the initial conditions can include the formulation and implementation of policy measures that are favorable to female entrepreneurship.

Second, the negative net effects which invalidate the tested hypothesis are an indication that, mobile money innovations are not a sufficient and necessary condition to transform female unemployment into female self-employment. For favorable effects in terms of female self-employment to be apparent, complementary policies are worthwhile and/or certain thresholds of mobile money innovations are necessary.

Third, the suggested mobile money innovation thresholds should be reached by sampled countries in the top quantiles of the female self-employment distribution in order for the corresponding countries to benefit from the role of mobile money innovations in promoting self-employment through a reduction in female unemployment. Such mobile money innovation penetration levels can thus be improved in sampled countries by implementing innovation-friendly policies in the information and communication technology and banking sectors.

Fourth, SDG5 on gender economic empowerment can be achieved if governments of sampled countries understand that a sustainable way of fighting unemployment is to empower women to engage in entrepreneurial activities and by extension, be self-employed. Such self-employment avenues can be made more apparent by providing females with the much needed sensitization frameworks and opportunities surrounding to use of mobile money innovations for entrepreneurship.

Future studies can extend the present study by assessing other mechanisms and policy channels via which SDG5 pertaining to gender socio-economic and political inclusion can be promoted. Moreover, the main channels and moderating variables (i.e. female unemployment and mobile money innovations) can be considered within remit of other SDGs in order to assess how tendencies provided in this research withstand empirical scrutiny when other SDGs are considered.

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Appendices

Appendix 1: Definitions and sources of variables

Variables	Definitions	Sources
Female Self-Employment	Self-employed, female (% of female employment)	WDI (World Bank)
Female Unemployment	Unemployment, female (% of female labor force)	WDI (World Bank)
Education	School enrollment, high, female (% gross)	WDI (World Bank)
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI (World Bank)
Cost to start business	The cost it takes for a woman to set up a business.	Gender and parity statistics for men and women (2020)
Time to start business	The time it takes for a woman to set up a business.	Gender and parity statistics for men and women (2020)
Start up procedure	The procedures a woman has to go through to start a business	Gender and parity statistics for men

		and women (2020)
Registered agents 1	Number of registered mobile money agents per 100 000 adults	Financial Access Survey (2020)
Registered agents 2	Number of registered mobile money agents per 1000 km2	Financial Access Survey (2020)
Active agents 1	Number of active mobile money agents per 100 000 adults	Financial Access Survey (2020)
Active agents 2	Number of active mobile money agents per 1000 km2	Financial Access Survey (2020)
Registered accounts 1	Number of registered mobile money accounts per 1000 adults	Financial Access Survey (2020)
Registered accounts 2	Balances in the mobile accounts active money as a percentage of GDP	Financial Access Survey (2020)
Transactions 1	Number of transactions per 1000 adults	Financial Access Survey (2020)
Transactions 2	Volume of transactions via mobile money as a percentage of GDP	Financial Access Survey (2020)

WDI: World Development Indicators.

Appendix 2: Summary Statistics

	Mean	**S.D**	**Min**	**Max**	**Obs**
Female Self-Employment	76.840	22.988	11.816	99.081	645
Female Unemployment	9.206	8.512	0.218	38.265	645

Education	43.377	26.076	6.542	112.824	391
Trade	74.769	34.486	19.100	225.023	604
Time to start business	40.416	39.625	4.000	261	635
Cost to start business	108.518	140.472	0.200	1229.100	635
Start up procedure	9.468	3.089	3.000	18.000	635
Registered agents 1(Oae1)	237.012	314.561	0.115	2160.727	199
Registered agents 2(Oae2)	168.559	475.494	0.004	4372.031	199
Active agents 1(Oaa1)	171.339	227.829	0.000	1046.332	125
Active agents 2(Oaa2)	144.217	425.719	0.000	3141.954	125
Registered accounts 1(CA)	194.949	214.717	0.000	803.635	149
Registered accounts 2(Balance)	0.198	0.280	0.000	1.748	114
Transactions 1(Ntran)	12450.05	21601.30	0.000	195972.7	190
Transactions 2 (Vtran)	12.375	19.519	0.000	142.391	197

SD: Standard Deviation. Min: Minimum. Max: Maximum. Obs: Observations. Oae1: Number of registered mobile money agents per 100 000 adults. Oae2: Number of registered mobile money agents per 1000 km2. Oaa1: Number of active mobile money agents per 100 000 adults. Oaa2: Number of active mobile money agents per 1000 km2. CA: number of registered mobile money accounts per 1000 adults. Balance: balances in the mobile accounts active money as a percentage of GDP. Ntran: Number of transactions per 1000 adults. Vtran: Volume of transactions via mobile money as a percentage of GDP.

Appendix 3: correlation matrix (uniform sample size: 45)

	FSE	FUmpl	SES	Trade	Cost	Time	StartP	Oae1	Oae2	Oaa1	Oaa2	CA	Balan	Ntran	Vtran
FSE	1.000														
FUmpl	-0.858	1.000													
SES	-0.849	0.691	1.000												
Trade	-0.637	0.644	0.423	1.000											
Cost	0.538	-0.420	-0.744	-0.324	1.000										
Time	-0.203	0.426	0.041	0.176	0.411	1.000									
StartP	0.262	-0.117	-0.264	-0.031	0.517	0.401	1.000								
Oae1	0.099	-0.160	-0.051	-0.121	-0.163	-0.346	-0.302	1.000							
Oae2	0.067	-0.227	-0.100	-0.242	-0.054	-0.327	-0.309	0.867	1.000						
Oaa1	0.103	-0.185	-0.050	-0.141	-0.147	-0.364	-0.273	0.988	0.875	1.000					
Oaa2	0.070	-0.241	-0.105	-0.257	-0.047	-0.340	-0.298	0.860	0.996	0.878	1.000				
CA	0.082	-0.208	0.007	-0.157	-0.235	-0.455	-0.353	0.929	0.774	0.939	0.784	1.000			
Balan	0.276	-0.188	-0.166	-0.066	-0.149	-0.318	-0.299	0.540	0.219	0.549	0.225	0.604	1.000		
Ntran	0.092	-0.129	-0.034	-0.076	-0.175	-0.340	-0.282	0.941	0.724	0.944	0.726	0.948	0.715	1.000	
Vtran	0.234	-0.181	-0.076	-0.098	-0.174	-0.349	-0.303	0.695	0.364	0.708	0.368	0.746	0.943	0.839	1.000

FSE: Female Self Employment. FUmpl: Female Unemployment. SES: Secondary female high school enrollment rate. Trade: trade openness. Cost: The cost it takes for a woman to set up a business. Time: The time of women to set up a business. StartP: The procedures a woman has to go through to start a business. Account: dummy variable who takes the value 1 if women can open bank accounts like men, 0 otherwise. Oae1: Number of registered mobile money agents per 100 000 adults. Oae2: Number of registered mobile money agents per 1000 km2. Oaa1: Number of active mobile money agents per 100 000 adults. Oaa2: Number of active mobile money agents per 1000 km2. CA: number of registered mobile money accounts per 1000 adults. Balance: balances in the mobile accounts active

money as a percentage of GDP. Ntran: Number of transactions per 1000 adults. Vtran: Volume of transactions via mobile money as a percentage of GDP.