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INEQUALITY AND GENDER INCLUSION: MINIMUM ICT POLICY THRESHOLDS FOR PROMOTING FEMALE EMPLOYMENT IN SUB-SAHARAN AFRICA [1]

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INEQUALITY AND GENDER INCLUSION: MINIMUM ICT POLICY THRESHOLDS FOR PROMOTING FEMALE EMPLOYMENT IN SUB-SAHARAN AFRICA

Simplice A. Asongu[2] and Nicholas M. Odhiambo[3]

Abstract

The study assesses how ICT modulates the effect of inequality on female economic participation in a panel of 42 countries in sub-Saharan Africa over the period 2004-2014. Three inequality indicators are used, namely: the Gini coefficient, the Atkinson index and the Palma ratio. The adopted ICT indicators are mobile phone penetration, internet penetration and fixed broadband subscriptions. Three gender economic inclusion indicators are also used for the analysis, namely: female labour force participation, female unemployment and female employment. The Generalised Method of Moments is employed as empirical strategy. The findings show that enhancing ICT beyond certain thresholds is necessary for ICT to mitigate inequality in order to enhance gender economic participation. First, for female labour force participation, a minimum threshold of 165.714 mobile phone penetration per 100 people is required for the Palma ratio. Second, minimum ICT thresholds for the reduction of female unemployment are: (i) 87.783, 107.486 and 152.500 mobile phone penetration per 100 people for respectively, the Gini coefficient, the Atkinson index and the Palma ratio; (ii) 39.618 internet penetration per 100 people for the Atkinson index and (iii) 4.500 fixed broadband subscriptions for the Palma ratio. Third, the corresponding ICT thresholds for the promotion of female employment are: (i) 120.369 and 85.533 mobile phone penetration per 100 people for respectively, the Gini coefficient and the Atkinson index and (ii) 30.005 internet penetration per 100 people for the Gini coefficient. The established thresholds make economic sense and can be feasibly implemented by policy makers in order to induce favourable effects on gender economic inclusion dynamics.

Keywords: Africa; ICT; Gender; Inclusive development

JEL Classification: G20; I10; I32; O40; O55

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1. Introduction

In Africa, gender inequality costs approximately 2.5 trillion USD according to a World Bank report (Nkurunziza, 2018; World Bank, 2018). In line with the narrative, in nations that are poor, women mostly work in the informal sector of the economy in occupations that range from self-employment in petty trading to agricultural activities that are fundamentally devoted to subsistence. Recommendations are made to involve more women in the formal economic sector because such involvement is associated with a multitude of positive economic and welfare externalities. The engagement of the female gender in the formal economic sector can be enhanced through, *inter alia*: education, reduction of income inequality, improvements in financial services and provision of basic infrastructure[4]. This research partly builds on the policy recommendations and focuses on how information and communication technology (ICT) infrastructure can be used to moderate the effect income inequality on gender participation in the formal economic sector in sub-Saharan Africa (SSA). There are also three complementary elements of motivation that merit critical expansion, notably: (i) the dual concerns of income inequality and gender exclusion in the post-2015 development era of Sustainable Development Goals (SDGs); (ii) the importance of information technology in the promotion of inclusive development in contemporary literature and (iii) gaps in recent literature pertaining to inclusive human development.

First, in accordance with recent inequality literature, income inequality and female economic participation are crucial in the achievement of SDGs in SSA (Robinson, 2015; Bicaba, Brixiova and Ncube, 2017; Efobi, Tanakem and Asongu, 2018; Tchamyou, 2019, 2020). Inequality is a critical policy concern because according to Asongu and le Roux (2019) and Asongu and Kodila-Tedika (2017), the African poverty tragedy is not being solved because economic growth experienced by SSA over the recent two decades of resurgence in economic prosperity did not trickle down to the poorer factions of the population. A consequence of this inequitable distribution of the fruits of economic prosperity is that close to half of the countries in SSA did not reach the threshold of extreme poverty reduction related to the Millennium Development Goal (MDG) extreme poverty target.

[4] The terms "gender inclusion", "gender economic participation", "female labour force participation", "female employment", "female economic participation" and "gender economic inclusion" are used interchangeably throughout the study.

In the light of the SDGs, the concern of reducing extreme poverty to a benchmark of below 3% is even more concerning because Bicaba *et al*. (2017) have concluded that unless inequality is addressed significantly, SSA will not achieve the underlying SDG extreme poverty target. Drawing on the high gender exclusion in SSA, it is apparent that gender inequality is a dimension of inequality that will further dampen the negative responsiveness of extreme poverty to economic growth. Gender equality in the formal economic sector is fundamental in poverty alleviation because it provides women with a plethora of opportunities that help in the improvements of household and economic wellbeing (Efobi *et al*., 2018). Robinson (2015) maintains that gender equality is central in the achievement of SDGs, not only because of improvements in the rights of the female gender but also because the enhancement of economic opportunities for women and girls engenders positive human welfare and economic ramifications. According to the author, beyond the factor of human rights, gender inclusion is important because no economy can grow sustainably if majority of its population is marginalized in the informal economic sector. It is important to recall that SSA has the highest female poverty rate in the world (Hazel, 2010) and the underlying poverty rate is substantially traceable to non involvement of women in formal economic activities. A policy instrument that can be leveraged upon to in order to involve more women in the formal economic sector is the burgeoning ICT phenomenon.

Second, an important body of literature has been recently devoted to articulating the relevance of ICT in mitigating socio-economic differences across and within countries. From the perspective of Africa, ICT is documented to improve economic and human wellbeing on the plethora of fronts, including: improvement of agricultural productivity, enhancement of corporate performance, reduction of income disparities between the rich and the poor, facilitation of improved health outcomes and availment of financial access. Some of the contemporary studies supporting these highlighted ICT externalities are: Afutu-Kotey, Gough and Owusu (2017); Minkoua Nzie, Bidogeza and Ngum (2018); Abor, Amidu and Issahaku (2018); Asongu and Nwachukwu (2018a); Gosavi (2018); Humbani and Wiese (2018); Asongu and Boateng (2018) and Isszhaku, Abu and Nkegbe (2018). It is also worthwhile to emphasize that information technology is particularly important in promoting inclusive economic and human development in SSA because the sub-region has a high potential for ICT penetration, compared to other regions of the world which are characterised by higher levels of economic inclusion and saturation in the penetration of information technology. According to the attendant literature, the high potential for ICT penetration in Africa implies that it can be leveraged as a policy instrument to address growing needs for more human inclusion and socio-economic development (Asongu, 2013; Penard, Poussing, Yebe and Ella, 2012; Tchamyou, 2017; Asongu and Odhiambo, 2019a). In the light of these insights, this research is positioned on the relevance of ICT in modulating the effect of inequaliuty on female economic participation because of a gap in contemporary literature.

Third, to the best of our knowledge, the contemporary development literature with emphasis on gender inclusion in Africa has largely focused on, *inter alia*: connections between access to finance and mobile money with moderations from social and gender networks (Bongomin, Ntayi, Munene and Malinga, 2018); the involvement of rural women and rural farmers in programs that are oriented towards ICT-driven agricultural expansion (Uduji and Okolo-Obasi, 2018a; Uduji, Okolo-Obasi and Asongu, 2019a, 2019b, 2019c, 2019d, 2019e); linkages beween gender disparities and inclusive finance (Kairiza, Kiprono and Magadzire, 2017); the imperative of promoting females in scientific fields (Elu, 2018); gender involvement in informal and financial sectors of production (Bayraktar and Fofack, 2018); the relationship underlying financial inclusion and gender exclusion in microfinance (Mannah-Blankson, 2018); gender involvement in agricultural production that is sustainable (Theriault, Smale and Haider, 2017) and the importance of information technology in gender inclusion in the formal economic sector (Efobi *et al*., 2018).

Among the engaged studies, the study closest to this research is Efobi *et al*. (2018) which has investigated how ICT affects the participation of the female gender in the formal economic sector. Using data from 1990 to 2014, the study has established a positive nexus between ICT penetration and gender inclusion in SSA. It is worthwhile to emphasise that Efobi *et al*. (2018) use three: (i) gender inclusion proxies (female unemployment, female labour force participation and female employment); (ii) ICT dynamics (fixed broadband subscriptions, mobile phone penetration and internet penetration) and (iii) regression techniques (i.e. fixed effects, ordinary least squares and generalized method of moments estimations).

This research extends Efobi *et al*. (2018) from two main standpoints. On the one hand, in line with the motivational strands discussed in the preceding paragraphs, instead of focusing directly on the connection between ICT and female economic participation, ICT is tailored to moderate the effect of inequality on female economic participation. Accordingly, ICT is considered as a policy instrument for female economic participation while inequality is acknowledged as a policy syndrome in gender economic inclusion because the response of inclusive economic development decreases with increasing levels of inequality (Fosu, 2008, 2009, 2010a, 2015). To this end, the estimation approach is tailored such that the ICT policy variables moderate the effect of the policy syndrome (or inequality) on female economic participation. This interactive specification departs from Efobi *et al*. (2018) with the argument that it is not enough to provide policy makers and scholars with simple nexuses among macroeconomic variables. In essence, going further to assess how policy variables interact with policy syndromes to affect the outcome variables is more informative to policy makers.

On the other hand, as opposed to Efobi *et al*. (2018) who have presented findings based on signs and magnitude of ICT impacts on gender economic inclusion, this paper is tailored to provide ICT policy thresholds that can be leveraged by policy makers to induce the targeted effects on gender inclusion. Accordingly, this study argues that it is not enough to simply provide nexuses between ICT variables and macroeconomic outcomes: research should go beyond such linkages by disclosing specific ICT policy thresholds that are important in modulating the effect of policy syndromes (such as inequality) for gender inclusiveness in the formal economic sector.

The rest of the paper is organised in the following structure. The theoretical underpinnings are highlighted in Section 2 while the data and methodology are discussed in section 3. Section 4 discloses the empirical results whereas section 5 concludes with implications and future research directions.

2. Theoretical highlights and intuition

The theoretical foundation consolidating the nexus between ICT, inequality and gender economic inclusion fundamentally builds on the relevance of knowledge diffusion in human and socio-economic developments (Kwan and Chiu, 2015). In essence, neoclassical models are supportive of the perspective that ICT is essential for politico-economic and social progress in countries, especially when these nations are at the beginning of industrialisation (Abramowitz, 1986; Bernard and Jones, 1996; Asongu, Nwachukwu and Aziz, 2018). Examples of contemporary studies that have built on these neoclassical theoretical insights to establish the importance of ICT in inclusive development are: Bongomin *et al*. (2018); Uduji and Okolo-Obasi (2018a, 2018b); Muthinja and Chipeta (2018) and Asongu, le Roux, Nwachukwu and Pyke (2019).

The theoretical literature is consistent with the position that ICT provides opportunities of inclusive development because, it, *inter alia*: (i) avails networks that reduce distances between economic operators and entrepreneurs who may need to physically displace themselves (Ureta, 2008; Shaikh and Karjaluoto, 2015; Efobi *et al*., 2018). (ii) ICT also mitigates asymmetric information that is associated with economic activities (Asongu and Nwachukwu, 2018b). Such reduction in information asymmetry decreases economic costs and increases the timely availability of information that is essential for the smooth and effective implementation of entrepreneurial operations. Moreover with ICT, developmental inputs are more affordable and possibility frontiers are also enlarged (Smith, Spence and Rashid, 2011). (iii) The inclusive development opportunities from ICT are more apparent in poorer fractions of the population compared to their rich counterparts. This theoretical insight is consistent with Asongu (2015) who has concluded that ICT reduces inequality in Africa. It is also important to recall that Efobi *et al*. (2018) have established that ICT enhances female economic participation. Hence: the intuition motivating this study on the role of ICT in modulating the effect of inequality on female economic participation.

It is relevant to also emphasize that while this study builds on the discussed theoretical underpinnings, it is equally framed as an evidence-based applied economics study in the light of the policy relevance motivating the problem statement. As recently argued by Asongu and Odhiambo (2020a), applied economics for policy purpose is not exclusively buttressed on the imperative to accept or reject prevailing theoretical underpinnings. It follows that this study is positioned within the context and evolving literature which supports the perspective that applied economics can also be relevant in theory-building (Narayan, Mishra & Narayan, 2011; Costantini & Lupi, 2005; Asongu & Nwachukwu, 2016a). Following insights from the relevant literature, evidence-based applied economics that is also a useful scientific activity should be based on sound intuition. In line with the narratives throughout the introduction, the intuition underpinning this study is quite easy to follow: levels of inequality influence female economic participation and ICT can be leveraged as a policy instrument to mitigate the negative influence of existing levels of inequality on female economic participation. The interactive analytical framework is therefore suggestive of the fact that some minimum levels of ICT penetration are needed in order for ICT penetration to mitigate the negative incidence of inequality on female economic inclusion.

The discussed intuition can also be substantiated by providing empirical evidence on the negative role of existing levels of inequality on inclusive economic development. Accordingly, the existing literature supports the perspective that inclusive economic development (which includes inclusive economic participation) is negatively affected by inequality. To put these empirical insights into more perspective: "*The study finds that the responsiveness of poverty to income is a decreasing function of inequality*" (Fosu, 2010b, p. 818); "*The responsiveness of poverty to income is a decreasing function of inequality, and the inequality elasticity of poverty is actually larger than the income elasticity of poverty*" (Fosu, 2010c, p. 1432); and "*In general, high initial levels of inequality limit the effectiveness of growth in reducing poverty while growing inequality increases poverty directly for a given level of growth*" (Fosu, 2011, p. 11). The conclusions of Fosu broadly apply to mainstream measurements of inequality used in the attendant inclusive development literature, namely: the Gini coefficient, the Atkinson index and the Palma ratio. These three inequality indicators are used in this study. The conclusions of Fosu are also important in justifying this research because, as we seen from theoretical highlights in this section, ICT policies from governments are designed to reduce income inequality and by extension improve inclusive human development which entails gender inclusive economic participation.

Given the above insights, the corresponding research question this inquiry aims to tackle is the following: what minimum ICT policy thresholds are needed to mitigate inequality and promote female economic participation in sub-Saharan Africa? To address this question, two hypotheses have to be tested, notably: inequality should affect female economic inclusion negatively while the interaction between inequality and ICT should have the opposite incidence on female economic inclusion.

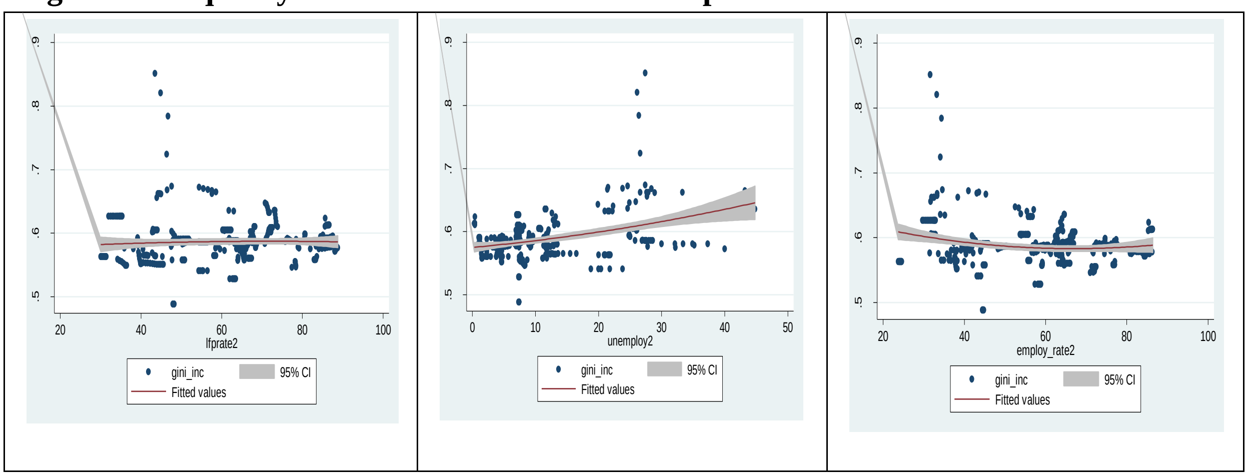
Hypothesis 1: there are negative unconditional impacts from the incidences of inequality on female economic inclusion.

Hypothesis 2: there are positive conditional impacts from the interaction between ICT dynamics and inequality on female economic participation[5].

It follows that inequality unconditionally reduces female employment and increases female unemployment while ICT modulates the unconditional incidence of inequality for a positive effect on female economic participation.

The discussed hypotheses are in line with stylized facts pertaining to linkages between the dynamics of inequality and female economic participation. In Figure 1, below, associations between an inequality variable (i.e. the Gini coefficient) and female economic participation variables are presented. On the figure, from the left hand-side to the right hand-side are respectively, nexuses between: (i) inequality and the female labour force participation rate; (ii) inequality and female unemployment and (iii) inequality and female employment. It is apparent from the attendant graphs that inequality is negatively associated with female employment (i.e. third graph) and positively linked with female unemployment (i.e. second graph).

Figure 1: Inequality and Female Economic Participation



Notes: The y axes represent inequality or the Gini coefficient while the x axes denote female economic participation dynamics. The first graph is the relationship between the Gini coefficient (*gini_inc*) and female labour force participation rate (*lfprate2*). The second graph is the relationship between the Gini coefficient (*gini_inc*) and female unemployment (*unemploy2*). The third graph is the nexus between the Gini coefficient (*gini_inc*) and female employment (*employ_rate2*).

[5] The use of the word "conditional" is generic and not specific to the choice of authors. This is essentially because estimates from interacted variables are considered as "conditional effects" in the standard literature on interactive regressions (Tchamyou, Asongu and Odhiambo, 2019a; Asongu and Odhiambo, 2020b). Moreover, as discussed prior to stating the hypothesis, the hypothesis on the positive conditional effect builds on the discussed literature on the role of ICT in reducing inequality. "ICT dynamics" represent the ICT variables used in the study, notably: mobile phone penetration, internet penetration and fixed broadband subscriptions.

3. Data and methodology

3.1 Data

This research is focused on 42 countries in SSA using data from 2004 to 2014[6]. The adopted sample of countries and periodicity of investigation are constrained by issues of data availability at the time of the study. Four main sources are used to obtain the data, notably: (i) the three inequality indicators (i.e. the Gini coefficient, the Atkinson index and the Palma ratio) are obtained from the Global Consumption and Income Project (GCIP). (ii) Three gender-inclusive indicators on female economic participation come from the International Labor Organization (i.e. female labor force participation, female unemployment and female employment). (iii) The ICT variables are sourced from World Development Indicators of the World Bank (i.e. mobile phone penetration, internet penetration, fixed broadband subscriptions). Moreover a control variable is also obtained from the same source (i.e. remittances). The use of selected ICT indicators is motivated by contemporary ICT literature (Tchamyou, 2017; Karakara and Osabuohien, 2019; Ejemeyovwi and Osabuohien, 2020; Asongu and Tchamyou, 2020). (iv) Another control variable (i.e. political stability) is obtained from the World Governance Indicators of the World Bank.

The motivation for adopting three control variables is consistent with contemporary inequality literature (Meniago and Asongu, 2018; Tchamyou, 2019, 2020). While the Gini coefficient reflects the manner in which income is distributed across the population, Naceaur and Zhang (2016) have argued that the measurement fails to capture extremities of the inequality distribution (i.e. the lowest and highest bounds of inequality). It is therefore for the purpose of providing robust estimations that the Gini coefficient is complemented with two measurements that are tailored to capture extreme ends of the inequality distribution, namely: the Atkinson index and the Palma ratio. The Atkinson index measures income inequality based on the percentage of total income that a specific society is willing to forego in order to enhance income equality among its citizens. The Palma ratio reflects national income shares of the top 10% of households to the bottom 40%.

[6]The 42 countries include: "Angola, Benin, Botswana, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda and Zambia".

The ICT variables that are adopted align with the contemporary literature which has argued for the relevance of involving many ICT indicators in empirical analyses in order to provide findings with greater room for policy implications (Tchamyou, 2017; Asongu and Odhiambo, 2018; Efobi *et al*., 2018; Asongu, Amankwah-Amoah, Nting & Afrifa, 2019). The adoption of the control variables is also motivated by contemporary inclusive development literature, notably: Meniago and Asongu (2018), Tchamyou, Erreygers and Cassimon (2019b) and Asongu and Odhiambo (2019). These control variables are: remittances and political stability. In the following passages, the expected signs from the control variables are discussed.

First, in line Tchamyou *et al*. (2019b) and Meniago and Asongu (2018), this research argues that remittances promote exclusive development in Africa because majority of the citizens from the continent going abroad are from wealthier segments of society. By deduction, money remitted from abroad for the most part, ends-up in richer households compared to poor households. By extension, as recently argued and empirically established by Asongu and Odhiambo (2018), remittances promote gender exclusion in Africa. Hence, this research expects remittances to increase female unemployment and reduce female participation in the formal economic sector (and/or female employment). Second, while political stability is anticipated to promote an atmosphere that is enabling for economic prosperity, investment and associated externalities such as employment (i.e. including female economic participation), the overall incidence of political stability is contingent on whether it is negatively or positively skewed. Accordingly, a distribution of political stability that is negatively skewed may also be construed as political instability. It follows that the expected signs of this element in the conditioning information set cannot be established with certainty. It is important to clarify that the political instability indicator is negatively skewed because as shown in Appendix 2: (i) its mean value is negative and (ii) the minimum negative value is about as twice as high as the maximum positive value.

This research devotes some space to clarifying why only two variables are involved in the conditioning information set. Accordingly, the two control variables used in this study are in accordance with the attendant empirical literature based on the generalised method of moments (GMM). For instance, in order to avoid concerns about instrument proliferation that are likely to bias estimated coefficients, Osabuohien and Efobi (2013) and Asongu and Nwachukwu (2017) have not used any control variable. An example of a study that has employed two control variables (as in this study) is Bruno, De Bonis and Silvestrini (2012). The definitions and sources of variables are provided in Appendix 1, whereas the summary statistics is disclosed in Appendix 2. The correlation matrix is covered by Appendix 3.

2.2 Methodology

2.2.1 GMM Specification

Borrowing from contemporary empirical literature (Asongu and Nwachuwku, 2016a; Tchamyou, 2019, 2020; Asongu and Odhiambo, 2019c; Tchamyou *et al*., 2019b; Fosu and Abass, 2019), this research motivates the choice of the GMM empirical strategy on four main justifications. (i) A prime condition for the adoption of the technique is that the number of cross sections should exceed the time periods pertaining to each cross section. This condition is fulfilled in our study because the research is dealing with 42 countries based on 11 periods in each country. (ii)The engaged measurements of gender economic participation reflect persistence because the correlations between their level and first lag values are higher than the threshold of 0.800 which is the established rule of thumb for assessing persistence in an economic indicator (Tchamyou *et al*., 2019b). In essence, from a preliminary analysis, the corresponding correlations are respectively 0.998, 0.982 and 0.999 for the female employment rate, the female unemployment rate and the female labour force participation rate. (iii) Given the data structure used in this research, the underlying estimation process does not eliminate cross- country differences because they are inherent in panel data analyses. (iv) Endogeneity is taken on board because it is controlled from two main angles. On the one hand, the issue of reverse causality is controlled with the employment of internal instruments. On the other, the unobserved heterogeneity is controlled by means of accounting for time invariant omitted variables in the estimation exercise.

The extension by Roodman (2009a, 2009b) of Arellano and Bover (1995) has been established in contemporary empirical literature to produce more efficient estimates compared to traditional GMM approaches (Asongu and Nwachukwu, 2016b; Boateng *et al*., 2018). Hence, the empirical approach adopted in this study is the GMM technique with forward orthogonal deviations.

The following equations in level (1) and first difference (2) summarise the standard *system* GMM estimation procedure.

$$FE_{i,t} = \sigma_0 + \sigma_1 FE_{i,t-\tau} + \sigma_2 T_{i,t} + \sigma_3 I_{i,t} + \sigma_4 TI_{i,t} + \sum_{h=1}^{2} \delta_j W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$FE_{i,t} - FE_{i,t-\tau} = \sigma_1 (FE_{i,t-\tau} - FE_{i,t-2\tau}) + \sigma_2 (T_{i,t} - T_{i,t-\tau}) + \sigma_3 (I_{i,t} - I_{i,t-\tau}) + \sigma_4 (TI_{i,t} - TI_{i,t-\tau}) + \sum_{h=1}^{2} \delta_j (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \quad (2)$$

where, $FE_{i,t}$ denotes a gender economic inclusion indicator (i.e. female employment, female unemployment and female labor force participation) of country i in period t, σ_0 is a constant. T is an ICT indicator (i.e. mobile phone penetration, internet penetration and fixed broadband subscriptions) of country i in period t. I denotes an inequality measurement (i.e. the Gini coefficient, the Atkinson index and the Palma ratio) of country i in period t. TI reflects interactions between ICT and inequality indicators ("mobile phone penetration" × "the Gini coefficient"; "mobile phone penetration" × "the Atkinson index"; "mobile phone penetration"× "the Palma ratio"; "internet penetration" × "the Gini coefficient"; "internet penetration" × "the Atkinson index"; "internet penetration"× "the Palma ratio"; "fixed broadband subscriptions" × "the Gini coefficient"; "fixed broadband subscriptions" × "the Atkinson index" and "fixed broadband subscriptions"× "the Palma ratio"), W is the vector of control variables (remittances and political stability), τ represents the coefficient of auto-regression which is one within the framework of this study because a year lag is enough to capture past information, ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ the error term.

2.2.2 Identification and exclusion restrictions

It will be unsound to specify a GMM technique without engaging the corresponding identification and exclusion restrictions properties. Such properties are relevant for a robust estimation. Within the framework of this research, following recent empirical literature, the "years" are considered as strictly exogenous while the conditioning information set (i.e. control variables) and independent variables of interest (inequality and ICT dynamics) are acknowledged to be endogenous explaining indicators (Asongu and Nwachukwu, 2016c; Tchamyou and Asongu, 2017; Boateng *et al*., 2018; Tchamyou *et al*., 2019b). The strategy of identification is consistent with the argument of Roodman (2009b) which maintains that years are ideal strictly exogenous variables because it is unlikely for years to become endogenous after a first difference[7].

Cognizant of the identification above, the assumption of exclusion restriction is assessed with the Difference in Hansen Test (DHT) for the exogeneity of instruments. The alternative hypothesis of this test is the position that the identified strictly exogenous variables do not exhibit strictly exogeneity because they do not affect the outcome indicators (i.e. gender economic inclusion variables) exclusively via the predetermined variables (i.e indicators in the conditioning information set and independent variables of interest). In the light of this narrative and clarification, the null hypothesis of the DHT should not be rejected in order for the assumptions underpinning the identification strategy and corresponding exclusion restrictions to be valid. Such assumptions and corresponding criteria for the assessment of their validity are consistent with other instrumental variable (IV) techniques which require the rejection of the alternative hypothesis of the Sargan/Hansen test in order for the identified instruments to influence the dependent variable exclusively through the exogenous components of the explaining variables (see Beck, Demirgüç-Kunt and Levine, 2003; Asongu and Nwachukwu, 2016d).

In the light of the above, the role of the exogenous instruments is assessed with the DHT whose null hypothesis should not be rejected in order for the strict exogeneity of instruments to be established. As argued by Roodman (2009a, 2009b), the DHT test should be reported for the exogeneity of instruments. The attendant strictly exogenous variables adopted in this study are years because as argued by Roodman (2009b), this indicator can be plausibly considered to exhibit strict exogeneity because in first difference, the attendant indicator cannot be endogenous[8].

It is also worthwhile to articulate that four main information criteria as employed to assess the validity of the estimations, in the light extant GMM-centric literature: "*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and*

[7]Hence, the procedure for treating *ivstyle* (years) is 'iv (years, eq(diff))' whereas the *gmmstyle* is employed for predetermined variables.

[8] Discussing the test in detail implies that we reproduce most of the content of the papers of Roodman (2009a, 2009b) cited in the study. The interested reader can get more insights from the attendant references because engaging the test in detail may be out of scope because this is not an econometrics paper. What is relevant is that: (i) we discuss the relevance of the test to our study, (ii) inform the reader of the information criterion for the validity of the test and (iii) engaged our findings in the light of this information criterion for the validity of instruments.

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

4. Empirical results

4.1 Presentation of results

The empirical results are provided in this section in Tables 1-3. The first columns of respective tables provide the definitions of variables. Moreover, for the respective tables, the first row discloses the dependent variables; the second provides insights into ICT variables under consideration while the third shows the corresponding inequality variables. Table 1 discloses findings on linkages between inequality, ICT and formal economic participation. In Table 2, the results pertain to nexuses between inequality, ICT and female unemployment while Table 3 provides findings on linkages between inequality, ICT and female employment. The presentation of results in the tables is designed such that there are three types of specifications pertaining to each ICT dynamic. The first relates to mobile phone penetration, the second focuses on internet penetration while the last is concerned with fixed broadband subscriptions. In each sub-specification pertaining to an ICT dynamic, three more specifications are apparent: each focusing on one of the three inequality indicators (i.e. the Gini coefficient, the Atkinson index and Palma ratio, in this order). For all the engaged specifications, the research uses the four principal information criteria (discussed in the last paragraph of the pervious section) to assess the overall validity of estimated models. Based on these criteria, the models are overwhelmingly valid.

In order to assess the overall incidence of ICT in modulating the effect of inequality on female economic participation, net impacts are calculated as apparent in the contemporary empirical literature (see Asongu & Odhiambo, 2019). For instance, in the fourth column of Table 1, the net impact from the role of mobile phone penetration in moderating the effect of the

Palma ratio on female labour force participation is -0.0842 ([0.0007× 45.330] + [-0.116]). In this calculating, the mean value of mobile phone penetration is 45.330; the unconditional impact of the Palma ratio is -0.116 while the interactive effect between mobile phone penetration and the Palma ratio is 0.0007.

The following findings can be established from Tables 1-3. There are net negative effects in the role of mobile phone penetration in moderating the effect of the Palma ratio on female labour force participation in Table 1. In Table 2 there are consistent net positive effects from the relevance of ICT in the effect of inequality on female unemployment. Only three exceptions are apparent, notably insignificant findings are in: (i) the role of internet penetration in moderating the effect of the Gini coefficient and Palma ratio on female unemployment and (ii) the relevance of fixed broadband subscriptions in moderating the impact of the Atkinson index on female unemployment.

In Table 3, the significant net negative effects on female employment are apparent in: (i) the role of mobile phone penetration in moderating the impacts of all inequality indicators and (ii) the importance of internet penetration in dampening the unconditional negative effect of the Gini coefficient on female employment. The significant control variables have the expected signs.

Table 1: ICT, Inequality and Female Labour Force Participation

	Dependent variable: Female Labour Force Participation(FLFP)								
	Mobile Phone Penetration			**Internet Penetration**			**Fixed BroadBand Subscriptions**		
	Gini	Atkinson	Palma	Gini	Atkinson	Palma	Gini	Atkinson	Palma
FLFP(-1)	**0.969*** **	**0.954*** **	**0.968*** **	**0.973*** **	**0.972*** **	**0.966*** **	**0.974*** **	**0.977*** **	**0.973*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile Phone(Mob)	0.001	**-0.021*** **	**-0.009*** **	---	---	---	---	---	---
	(0.960)	**(0.002)**	**(0.004)**						
Internet	---	---	---	0.009	-0.015	**-0.012***	---	---	---
				(0.568)	(0.182)	**(0.050)**			
BroadBand	---	---	---	---	---	---	**2.138*** **	**1.586*** **	**0.431*** **
							(0.000)	**(0.004)**	**(0.000)**
Gini Coefficient (Gini)	0.672	---	---	-1.701	---	---	0.702	---	---
	(0.817)			(0.174)			(0.635)		
Atkinson Index (Atkinson)	---	0.350	---	---	-0.759	---	---	1.155	---
		(0.664)			(0.457)			(0.243)	
Palma Ratio(Palma)	---	---	**-0.116*** **	---	---	**-0.073*** **	---	---	0.004
			(0.000)			**(0.001)**			(0.705)
Mob × Gini	-0.006	---	---	---	---	---	---	---	---
	(0.870)								
Mob × Atkinson	---	**0.022*** **	---	---	---	---	---	---	---
		(0.004)							
Mob × Palma	---	---	**0.0007** **	---	---	---	---	---	---
			(0.035)						
Internet × Gini	---	---	---	-0.036	---	---	---	---	---
				(0.144)					
Internet × Atkinson	---	---	---	---	0.001	---	---	---	---
					(0.922)				
Internet × Palma	---	---	---	---	---	-0.0006	---	---	---
						(0.275)			
BroadBand × Gini	---	---	---	---	---	---	**-3.902*** **	---	---
							(0.000)		
BroadBand × Atkinson	---	---	---	---	---	---	---	**-2.482*** **	---
								(0.003)	
BroadBand × Palma	---	---	---	---	---	---	---	---	**-0.094*** **
									(0.000)
Political Stability	**0.164** **	0.165	**0.407*** **	0.153	0.138	**0.392*** **	**0.169*** **	0.040	**0.120***
	(0.042)	(0.116)	**(0.000)**	(0.169)	(0.358)	**(0.000)**	**(0.001)**	(0.432)	**(0.072)**
Remittances	**-0.068*** **	**-0.062*** **	-0.012	**-0.059*** **	**-0.042*** **	-0.012	-0.009	**-0.029** **	-0.009
	(0.000)	**(0.000)**	(0.395)	**(0.000)**	**(0.000)**	(0.437)	(0.317)	**(0.012)**	(0.559)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	na	-0.0842	na	na	na	na	na	na
Thresholds	na	na	165.714	na	na	na	na	na	na
AR(1)	(0.049)	(0.036)	(0.058)	(0.067)	(0.066)	(0.073)	(0.090)	(0.082)	**(0.103)**
AR(2)	**(0.316)**	**(0.287)**	**(0.131)**	**(0.210)**	**(0.213)**	**(0.126)**	**(0.238)**	**(0.332)**	**(0.226)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	**(0.540)**	**(0.254)**	**(0.201)**	**(0.264)**	**(0.439)**	**(0.220)**	**(0.396)**	**(0.340)**	**(0.295)**
DHT for instruments									
(a)Instruments in levels									
H excluding group	**(0.348)**	(0.081)	**(0.142)**	**(0.341)**	**(0.160)**	**(0.230)**	**(0.148)**	**(0.257)**	(0.095)
Dif(null, H=exogenous)	**(0.572)**	**(0.501)**	**(0.313)**	**(0.262)**	**(0.624)**	**(0.267)**	**(0.585)**	**(0.400)**	**(0.535)**
(b) IV (years, eq(diff))									
H excluding group	**(0.299)**	**(0.235)**	(0.042)	**(0.383)**	**(0.294)**	**(0.157)**	**(0.182)**	**(0.173)**	**(0.359)**
Dif(null, H=exogenous)	**(0.663)**	**(0.332)**	**(0.675)**	**(0.239)**	**(0.533)**	**(0.373)**	**(0.618)**	**(0.548)**	**(0.289)**
Fisher	**191432.25 *** **	**9725.21*** **	**4930.40 *** **	**213898.87 *** **	**213898.87 *** **	**22088.49 *** **	**4.41e+06 *** **	**10560.31 *** **	**35457.86 *** **
Instruments	32	32	32	32	32	32	32	32	32
Countries	39	39	39	39	39	39	37	37	37
Observations	366	366	366	361	361	361	314	314	314

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. 45.330, 7.676 and 0.643 are respectively mean values of mobile phone penetration, internet penetration and fixed broadband subscriptions. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant.

Table 2: ICT, Inequality and Female Unemployment

	Dependent variable: Female Unemployment(FU)								
	Mobile Phone Penetration			**Internet Penetration**			**Fixed BroadBand Subscriptions**		
	Gini	Atkinson	Palma	Gini	Atkinson	Palma	Gini	Atkinson	Palma
FU(-1)	**0.936*** **	**0.943*** **	**0.943*** **	**0.913*** **	**0.940*** **	**0.915*** **	**0.958*** **	**0.972*** **	**0.966*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile Phone(Mob)	**0.102*** **	**0.049*** **	0.015	---	---	---	---	---	---
	(0.009)	**(0.004)**	(0.141)						
Internet	---	---	---	0.023	**0.095** **	0.031	---	---	---
				(0.741)	**(0.017)**	(0.147)			
BroadBand	---	---	---	---	---	---	**-1.038*** **	-0.171	**0.339*** **
							(0.001)	(0.569)	**(0.000)**
Gini Coefficient (Gini)	**15.011*** **	---	---	**4.743** **	---	---	**2.760*** **	---	---
	(0.001)			**(0.019)**			**(0.000)**		
Atkinson Index (Atkinson)	---	**7.739*** **	---	---	**5.190** **	---	---	**4.242*** **	---
		(0.001)			**(0.011)**			**(0.000)**	
Palma Ratio(Palma)	---	---	**0.305*** **	---	---	**0.268*** **	---	---	**0.234*** **
			(0.001)			**(0.000)**			**(0.000)**
Mob × Gini	**-0.171*** **	---	---	---	---	---	---	---	---
	(0.006)								
Mob × Atkinson	---	**-0.072*** **	---	---	---	---	---	---	---
		(0.001)							
Mob × Palma	---	---	**-0.002** **	---	---	---	---	---	---
			(0.035)						
Internet × Gini	---	---	---	-0.030	---	---	---	---	---
				(0.790)					
Internet × Atkinson	---	---	---	---	**-0.131** **	---	---	---	---
					(0.015)				
Internet × Palma	---	---	---	---	---	-0.003	---	---	---
						(0.304)			
BroadBand × Gini	---	---	---	---	---	---	**1.885*** **	---	---
							(0.001)		
BroadBand × Atkinson	---	---	---	---	---	---	---	0.326	---
								(0.473)	
BroadBand × Palma	---	---	---	---	---	---	---	---	**-0.052** **
									(0.023)
Political Stability	0.293	0.077	0.122	**0.842*** **	0.208	**0.619* **	-0.009	-0.064	-0.118
	(0.118)	(0.712)	(0.521)	**(0.004)**	(0.480)	**(0.060)**	(0.926)	(0.569)	(0.341)
Remittances	0.011	**0.034** **	**0.044*** **	0.015	**0.057*** **	0.024	**0.051*** **	**0.057*** **	**0.072*** **
	(0.241)	**(0.029)**	**(0.001)**	(0.267)	**(0.007)**	(0.154)	**(0.000)**	**(0.000)**	**(0.000)**
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	7.259	4.475	0.214	na	4.184	na	3.972	na	0.200
Thresholds	87.783	107.486	152.500	na	39.618	na	nsa	na	4.500
AR(1)	**(0.194)**	**(0.198)**	**(0.198)**	**(0.192)**	**(0.199)**	**(0.197)**	**(0.190)**	**(0.193)**	**(0.190)**
AR(2)	**(0.379)**	**(0.385)**	**(0.385)**	**(0.303)**	**(0.390)**	**(0.330)**	**(0.174)**	**(0.178)**	**(0.200)**
Sargan OIR	(0.011)	(0.005)	(0.014)	(0.050)	(0.007)	(0.024)	(0.012)	(0.029)	(0.038)
Hansen OIR	**(0.164)**	**(0.367)**	**(0.180)**	**(0.304)**	**(0.865)**	**(0.415)**	**(0.123)**	**(0.110)**	**(0.267)**
DHT for instruments									
(a)Instruments in levels									
H excluding group	**(0.206)**	**(0.204)**	**(0.274)**	**(0.376)**	**(0.408)**	**(0.330)**	**(0.130)**	**(0.249)**	**(0.082)**
Dif(null, H=exogenous)	**(0.208)**	**(0.479)**	**(0.195)**	**(0.290)**	**(0.902)**	**(0.439)**	**(0.202)**	**(0.121)**	**(0.520)**
(b) IV (years, eq(diff))									
H excluding group	**(0.135)**	**(0.593)**	**(0.524)**	**(0.514)**	**(0.408)**	**(0.226)**	(0.084)	(0.083)	**(0.181)**
Dif(null, H=exogenous)	**(0.303)**	**(0.245)**	**(0.108)**	**(0.219)**	**(0.947)**	**(0.580)**	**(0.308)**	**(0.279)**	**(0.417)**
Fisher	**11598.14*** **	**13844.00*** **	**6961.12*** **	**5151.24*** **	**12687.18*** **	**5787.44*** **	**36054.87*** **	**24433.04*** **	**96081.15*** **
Instruments	32	32	32	32	32	32	32	32	32
Countries	37	37	37	37	37	37	35	35	35
Observations	346	346	346	341	341	341	295	295	295

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. 45.330, 7.676 and 0.643 are respectively mean values of mobile phone penetration, internet penetration and fixed broadband subscriptions. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. nsa: not specifically applicable because the conditional and unconditional effects have the same sign.

Table 3: ICT, Inequality and Female Employment

	Dependent variable: Female Employment(FE)								
	Mobile Phone Penetration			Internet Penetration			Fixed BroadBand Subscriptions		
	Gini	Atkinson	Palma	Gini	Atkinson	Palma	Gini	Atkinson	Palma
FE(-1)	**0.994*** **	**0.987*** **	**0.984*** **	**0.990*** **	**0.978*** **	**0.981*** **	**0.990*** **	**0.989*** **	**0.986*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Mobile Phone(Mob)	**-0.047** **	**-0.029*** **	**-0.010* **	---	---	---	---	---	---
	(0.028)	**(0.004)**	**(0.079)**						
Internet	---	---	---	**-0.111*** **	-0.049	**-0.022* **	---	---	---
				(0.003)	(0.131)	**(0.051)**			
BroadBand	---	---	---	---	---	---	0.269	0.367	-0.039
							(0.346)	(0.176)	(0.253)
Gini Coefficient (Gini)	**-10.111*** **	---	---	**-5.731*** **	---	---	**-3.619*** **	---	---
	(0.000)			**(0.000)**			**(0.001)**		
Atkinson Index (Atkinson)	---	**-3.849*** **	---	---	-0.965	---	---	**-1.455** **	---
		(0.004)			(0.557)			**(0.025)**	
Palma Ratio(Palma)	---	---	**-0.195*** **	---	---	-0.066	---	---	**-0.107*** **
			(0.000)			(0.195)			**(0.000)**
Mob × Gini	**0.084** **	---	---	---	---	---	---	---	---
	(0.017)								
Mob × Atkinson	---	**0.045*** **	---	---	---	---	---	---	---
		(0.001)							
Mob × Palma	---	---	**0.001*** **	---	---	---	---	---	---
			(0.003)						
Internet × Gini	---	---	---	**0.191*** **	---	---	---	---	---
				(0.001)					
Internet × Atkinson	---	---	---	---	0.062	---	---	---	---
					(0.156)				
Internet × Palma	---	---	---	---	---	**0.003** **	---	---	---
						(0.011)			
BroadBand × Gini	---	---	---	---	---	---	-0.498	---	---
							(0.334)		
BroadBand × Atkinson	---	---	---	---	---	---	---	-0.571	---
								(0.176)	
BroadBand × Palma	---	---	---	---	---	---	---	---	0.004
									(0.566)
Political Stability	0.090	-0.019	0.028	**-0.288** **	**-0.288* **	**-0.337* **	0.082	0.004	-0.021
	(0.557)	(0.883)	(0.843)	**(0.088)**	**(0.098)**	**(0.052)**	(0.359)	(0.960)	(0.818)
Remittances	-0.008	**-0.024** **	-0.013	**-0.024*** **	-0.018	-0.014	-0.008	**-0.040*** **	**-0.043*** **
	(0.347)	**(0.025)**	(0.242)	**(0.005)**	(0.102)	(0.117)	(0.100)	**(0.000)**	**(0.000)**
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	-6.303	-1.809	-0.149	-4.264	na	na	na	na	na
Thresholds	120.369	85.533	195	30.005	na	na	na	na	na
AR(1)	**(0.144)**	**(0.138)**	**(0.140)**	**(0.136)**	**(0.142)**	**(0.143)**	**(0.144)**	**(0.146)**	**(0.144)**
AR(2)	**(0.292)**	**(0.292)**	**(0.293)**	**(0.223)**	**(0.290)**	**(0.285)**	**(0.168)**	**(0.184)**	**(0.175)**
Sargan OIR	(0.040)	(0.080)	**(0.119)**	**(0.114)**	**(0.103)**	(0.080)	(0.056)	**(0.249)**	**(0.254)**
Hansen OIR	**(0.676)**	**(0.450)**	**(0.457)**	**(0.414)**	**(0.453)**	**(0.409)**	**(0.242)**	**(0.172)**	**(0.136)**
DHT for instruments									
(a)Instruments in levels									
H excluding group	**(0.229)**	**(0.386)**	**(0.310)**	**(0.549)**	**(0.351)**	**(0.334)**	**(0.204)**	**(0.695)**	**(0.344)**
Dif(null, H=exogenous)	**(0.814)**	**(0.446)**	**(0.502)**	**(0.336)**	**(0.470)**	**(0.430)**	**(0.315)**	**(0.097)**	**(0.124)**
(b) IV (years, eq(diff))									
H excluding group	**(0.232)**	**(0.107)**	**(0.111)**	**(0.157)**	**(0.145)**	**(0.173)**	**(0.620)**	**(0.618)**	**(0.427)**
Dif(null, H=exogenous)	**(0.893)**	**(0.839)**	**(0.840)**	**(0.687)**	**(0.765)**	**(0.653)**	**(0.131)**	**(0.083)**	**(0.094)**
Fisher	**21158.74*** **	**93116.01*** **	**96585.01*** **	**8016.75*** **	**130597.65*** **	**8629.41*** **	**140747.55*** **	**18680.90*** **	**26425.54*** **
Instruments	32	32	32	32	32	32	32	32	32
Countries	37	37	37	37	37	37	35	35	35
Observations	346	346	346	341	341	341	295	295	295

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. 45.330, 7.676 and 0.643 are respectively mean values of mobile phone penetration, internet penetration and fixed broadband subscriptions. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant.

4.2 Extension with policy thresholds

It is worthwhile to note that the net effects of the role of ICT in modulating inequality for enhanced female economic participation are consistently unfavorable, notably: (i) a net effect in Table 1 pertaining to female labour force participation is negative; (ii) six net impacts in Table 2 relating to female unemployment are positive and (iii) the first-four net effects in Table 3 which focuses on female employment are negative. Whereas these net effects are quite detrimental to the promotion of gender inclusion in the formal economic sector, the corresponding conditional or interactive effects overwhelmingly have signs which indicate that the unexpected net effects on gender economic inclusion are traceable to low ICT penetration rates. Accordingly, the positive conditional effects in Table 1 and Table 3 are indications of the fact that enhancing ICT will ultimately nullify the corresponding negative unconditional effects and change the signs of the negative net effects. This explanation extends to Table 2 in which negative conditional or interactive effects are associated with net positive effects on female unemployment. Hence, the negative conditional effects are indications that enhancing ICT dynamics beyond certain thresholds can completely dampen the associated positive unconditional effects and ultimately nullify the net positive effects. In the light of this narrative, positive thresholds which are associated with positive conditional effects are relevant to Table 1 and Table 3 while negative thresholds related to negative conditional impacts are relevant to Table 2. The narrative on thresholds or critical mass is in accordance with contemporary development literature that is based on interactive regressions (Ashraf and Galor, 2013; Batuo, 2015; Asongu, 2018; Asongu, le Roux and Tchamyou, 2019).

Building on the above narrative, in the fourth column of Table 1, the positive threshold is 165.714 (0.116/ 0.0007) mobile phone penetration per 100 people. Hence, at this mobile phone penetration threshold, the corresponding net effect on female labour force participation becomes 0 ([0.0007× 165.714] + [-0.116]). Therefore, above the established threshold, mobile phone penetration modulates the Palma ratio to induce a positive net effect on female labour force participation. Moreover, for this policy threshold to make economic sense and have actionable policy relevance, it should be within the statistical range (i.e. minimum to maximum) disclosed in the summary statistics. Hence, the established threshold is feasible because the minimum and maximum values of mobile phone penetrations are respectively, 0.209 and 171.375.

The negative policy thresholds in Table 2 pertaining to female unemployment are: (i) 87.783, 107.486 and 152.500 mobile phone penetration per 100 people for respectively, the Gini coefficient, the Atkinson index and the Palma ratio; (ii) 39.618 internet penetration per 100 people for the Atkinson index and (iii) 4.500 fixed broadband subscriptions for the Palma ratio. These ICT policy thresholds pertaining to female unemployment make economic sense and have policy relevance because they are within the statistical ranges of ICT dynamics. As for a policy implication, ICT penetration should be enhanced by policy makers in order for ICT to completely nullify the positive unconditional effects of inequality dynamics on female unemployment and hence, induce overall net negative effects on female unemployment.

In Table 3, positive ICT thresholds associated with female employment are: (i) 120.369, 85.533, 195 mobile phone penetration per 100 people for respectively, the Gini coefficient, the Atkinson index and the Palma ratio and (ii) 30.005 internet penetration rate per 100 people for the Gini coefficient. Only the 195 mobile phone penetration per 100 people threshold is not within statistical range because the maximum limit of mobile phone penetration in the summary statistics is 171.375 per 100 people. The remaining established thresholds are within statistical range and hence have policy relevance. Therefore, ICT should be enhanced above the established thresholds for the negative unconditional effects of inequality on female employment to be completely dampened in order to ultimately induce overall positive net effects on female employment.

5. Concluding implications and future research directions

The study assesses how ICT modulates the effects of inequality on female economic participation in a panel of 42 countries in sub-Saharan Africa over the period 2004-2014. The three inequality indicators used are: the Gini coefficient, the Atkinson index and the Palma ratio while the adopted ICT indicators are mobile phone penetration, internet penetration and fixed broadband subscriptions. Three gender economic inclusion indicators are also used for the analysis, namely: female labour force participation, female unemployment and female employment. The Generalised Method of Moments is used for the empirical analysis.

The findings overwhelmingly show unexpected net effects, notably: positive net impacts on female unemployment and negative net effects on female employment and female labour force participation. Fortunately, the corresponding conditional or interaction effects are favorable and indicate that enhancing ICT beyond given thresholds can nullify the unfavorable unconditional effects of inequality on gender economic inclusion in order to change the signs of established net effects. Hence, with the established ICT thresholds, further enhancing ICT has an overall effect in modulating inequality dynamics to reduce female unemployment and increase female employment and female labour force participation. First, for female labour force participation, a minimum threshold of 165.714 mobile phone penetration per 100 people is required for the Palma ratio. Second, minimum ICT thresholds for the reduction of female unemployment are: (i) 87.783, 107.486 and 152.500 mobile phone penetration per 100 people for respectively, the Gini coefficient, the Atkinson index and the Palma ratio; (ii) 39.618 internet penetration per 100 people for the Atkinson index and (iii) 4.500 fixed broadband subscriptions for the Palma ratio. Third, the corresponding ICT thresholds for the promotion of female employment are: (i) 120.369 and 85.533 mobile phone penetration for respectively, the Gini coefficient and the Atkinson index and (ii) 30.005 internet penetration per 100 people for the Gini coefficient. The established thresholds make economic sense and can be feasibly implemented by policy makers in order to induce favourable effects on gender economic inclusion because they are within the statistical ranges disclosed in the summary statistics.

Overall from the findings, it can be concluded that ICT penetration needs to be enhanced in order to effectively mitigate inequality for the enhancement of the participation of women in the formal economic sector. The need to enhance ICT may also be traceable to the high inequality level prevailing in the sampled countries. Hence, a policy framework of promoting ICT could be accompanied by corresponding policies designed to reduce inequality. With such complementary policy actions, the ICT penetration thresholds may not be as high as established. Ceteris paribus, the established ICT thresholds are based on the fact that: (i) inequality levels remain unchanged and (ii) in the light of the unconditional effects of inequality dynamics on gender inclusion variables, inequality should be reduced concurrently with the enhancement of ICT, especially when/if financial resources needed to enhance ICT to certain critical masses are more than the corresponding funds relevant for reducing inequality.

Future studies should engage relevant estimation techniques in order to assess if the established findings in this study withstand empirical scrutiny when the problem statement is viewed from country-specific settings. The policy recommendation is motivated by the caveat that cross-specific effects are eliminated in the panel regressions as it is required in GMM specifications in order to avoid endogeneity resulting from the correlation between country-specific effects and the lagged dependent variable. Moreover, in the suggested future research directions, considering alternative ICT indicators from the International Telecommunications Union (ITU) is also worthwhile. This consideration should clearly separate the effects of "active mobile-broadband subscriptions" from those of "fixed broadband subscriptions" used in this study.

Appendices

Appendix 1: Definitions of Variables

Variables	Signs	Definitions of variables (Measurements)	Sources
Female Economic Participation	FLFpart	Labor force participation rate, female (% of female population ages 15+) (modeled ILO estimate)	ILO
	FU	Unemployment, female (% of female labor force) (modeled ILO estimate)	ILO
	FE	Employment to population ratio, 15+, female (%) (modeled ILO estimate)	ILO
Mobile Phones	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Internet	Internet	Internet users (per 100 people)	WDI
Fixed Broad Band	BroadB	Fixed broadband subscriptions (per 100 people)	WDI
Gini Index	Gini	"*The Gini index is a measurement of the income distribution of a country's residents*".	GCIP
Atkinson Index	Atkinson	"*The Atkinson index measures inequality by determining which end of the distribution contributed most to the observed inequality*".	GCIP
Palma Ratio	Palma	"*The Palma ratio is defined as the ratio of the richest 10% of the population's share of gross national income divided by the poorest 40%'s share*".	GCIP
Political Stability	PolS	"Political stability/no violence (estimate): measured as the perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional and violent means, including domestic violence and terrorism"	WGI
Remittances	Remit	Remittance inflows to GDP (%)	WDI

WDI: World Bank Development Indicators of the World Bank. FDSD: Financial Development and Structure Database of the World Bank. WGI: World Governance Indicators of the World. ILO: International Labour Organisation. GCIP: the Global Consumption and Income Project.

Appendix 2: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Obs
Female Labor Force participation	62.515	15.685	30.00	88.80	451
Female Unemployment, female	10.831	8.736	0.300	44.800	429
Female Employment	57.201	15.828	23.700	86.400	429
Mobile Phone Penetration	45.330	37.282	0.209	171.375	558
Internet Penetration	7.676	10.153	0.031	54.26	453
Fixed BroadBand	0.643	1.969	0.000	14.569	369
Gini Index	0.586	0.034	0.488	0.851	461
Atkinson Index	0.705	0.058	0.509	0.834	461
Palma Ratio	6.457	1.477	3.015	14.434	461
Political Stability	-0.471	0.905	-2.687	1.182	462
Remittances	4.313	6.817	0.00003	50.818	416

S.D: Standard Deviation.

Appendix 3: Correlation matrix (uniform sample size: 305)

Gender Inclusion			ICT Dynamics			Inequality			Control variables		
FLFpart	FU	FE	Mobile	Internet	BroadB	Gini	Atkinson	Palma	PolS	Remit	
1.000	-0.282	0.947	-0.226	-0.354	-0.254	-0.046	-0.012	-0.059	0.082	-0.187	FLFpart
	1.000	-0.565	0.272	0.260	0.107	0.379	0.490	0.505	0.317	0.261	FU
		1.000	-0.277	-0.433	-0.250	-0.152	-0.169	-0.208	-0.041	-0.252	FE
			1.000	0.760	0.444	0.148	0.108	0.186	0.277	-0.055	Mobile
				1.000	0.600	0.071	-0.010	0.066	0.106	-0.065	Internet
					1.000	-0.010	-0.077	-0.041	0.315	-0.090	BroadB
						1.000	0.811	0.937	0.328	0.060	Gini
							1.000	0.924	0.353	0.289	Atkinson
								1.000	0.384	0.183	Palma
									1.000	0.052	PolS
										1000	Remit

FLFpart: Female Labour Force participation. FU: Female Unemployment. FE: Female Employment. Mobile: Mobile Phone Penetration. Internet: Internet Penetration. BroadB: Fixed Broadband Subscriptions. PSSE: Primary and Seconary School Enrollment. SSE: Secondary School Enrolment. TSE: Tertiary School Enrolment. PolS: Political Stability. Remit: Remittances.

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