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**ICT, Financial Access and  
Gender Inclusion in the  
Formal Economic Sector:  
Evidence from Africa**

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**ICT, Financial Access and Gender Inclusion in the Formal Economic Sector: Evidence from Africa\***

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**Abstract**

The study investigates the relevance of information and communication technology (ICT) in modulating the effect of financial access on female economic participation. Female economic participation is proxied by female labor force participation, financial access is measured with deposit and credit channels while ICT is proxied by mobile phone penetration, internet penetration and fixed broadband subscriptions. The focus of the study is on 48 African countries for the period 2004-2014 and the empirical evidence is based on Generalized Method of Moments. Policy thresholds are established at which, ICT modulates financial access to induce favourable effects on female economic participation. These policy thresholds are: (i) 160 mobile phone penetration (per 100 people) for the deposit channel and (ii) 2.166 and 0.75 fixed broadband subscriptions per 100 people for respectively, the deposit mechanism and credit channel. Overall the study supports the importance of ICT in moderating financial access for enhanced female economic participation.

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

*Keywords:* Africa; Gender; ICT; Inclusive development

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## 1. Introduction

The concepts of information and communication technology (ICT), financial access and gender inclusion are particularly relevant to concerned African scholars and policy makers for a multitude of factors that revolve around policy syndromes and policy instruments. While lack of financial access and gender exclusion are policy syndromes, ICT can be considered a policy instrument in the light of its high penetration potential in Africa, relative to other regions in the world<sup>1</sup>. These factors which motivate the positioning of this research (i.e. on the importance of ICT in modulating the effect of financial access on gender inclusion) are expanded in the following passages.

First, financial access is low in Africa compared to other regions of the world (Tchamyou, 2019a; Tchamyou *et al.*, 2019). There is a broad consensus in theoretical and empirical literature that financial access increases opportunities of investment for both households and businesses and such possibilities of investment ultimately engender positive ramifications on standards of living and socio-economic development (Odhiambo, 2010, 2013, 2014; Wale & Makina, 2017; Daniel, 2017; Chikalipah, 2017; Bocher, Alemu, & Kelbore, 2017; Osah & Kyobe, 2017; Boadi, Dana, Mertens, & Mensah, 2017; Oben & Sakyi, 2017; Ofori-Sasu, Abor & Osei, 2017; Iyke & Odhiambo, 2017; Chapoto & Aboagye, 2017). Some of the underlying benefits of financial access include the reduction of inequality (Tchamyou *et al.*, 2019).

Second, gender inequality in Africa is an important policy concern in the post-2015 sustainable development agenda. According to Efobi, Tanankem and Asongu (2018), the participation of women in the formal economic sector in Africa is considerably low. Accordingly, women in the continent are most specialized in small holding farming, domestic activities and petty trading (Ellis, Blackden, Cutura, MacCulloch & Seebens, 2007; FAO, 2011; Tandon & Wegerif, 2013).

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<sup>1</sup> The notion of policy syndrome is multifaceted. It is understood by Fosu (2013) to denote factors that are unfavorable to economic prosperity, *inter alia*: “administered redistribution”, “state breakdown”, “state controls”, and “suboptimal inter temporal resource allocation”. In the light of Asongu (2017), it reflects disparities in knowledge economy dynamics between countries. Within the context of this research, the conception and definition of policy syndrome are assimilated to two main perspectives: the lack of financial access and absence of inclusive development. These perspectives are consistent with recent financial access and inclusive development literature (Asongu & Nwachukwu, 2017a; Tchamyou, 2019a, 2019b; Asongu & Odhiambo, 2019; Tchamyou, Erreygers & Cassimon, 2019).

The scholarly views are in accordance with perspectives from the International Labour Organization (2013) and the World Bank (2015). These perspectives maintain that relative to men, women are more oriented towards the informal economic sector. Such a low female participation in the formal economic sector obviously has negative ramifications in terms of poverty reduction, especially when Africa has the highest female poverty rate (Hazel, 2010). Promoting gender equality in Africa is important because as recently posited by Efobi *et al.* (2018), gender inclusion can have a dual outcome of: (i) increasing the welfare of women and improving structural distribution in the labour market and (ii) mitigating poverty. A channel by which such gender equality can be promoted is ICT, given its high potential of penetration in Africa.

Third, relative to more technically-advanced continents in the world where the penetration of ICT is reaching levels of saturation, there is still a great deal of room for the growth of ICT in Africa (Asongu, 2013; Penard, Poussing, Yebe & Ella, 2012; Afutu-Kotey, Gough & Owusu, 2017; Asongu & Boateng, 2018; Humbani & Wiese, 2018; Gosavi, 2018; Asongu & Odhiambo, 2018a). The underlying penetration prospect has motivated a growing strand of literature on the importance of leveraging on this potential to enhance economic and human development standards (Tchamyu, 2017; Abor, Amidu & Issahaku, 2018; Minkoua Nzie, Bidogeza & Ngum, 2018; Asongu & Nwachukwu, 2018a; Gosavi, 2018; Isszhaku, Abu & Nkegbe, 2018). This research focuses on how such a penetration potential can be leveraged to increase the participation of women in the formal economic sector because of an apparent gap in the scholarly literature<sup>2</sup>.

Fourth, contemporary inclusive development literature in Africa has largely focused on, *inter alia*: relationships between inequality and foreign capital flows (Kaulihowa & Adjasi, 2018); connections between consumption, income and the wealth of the poorest factions of society (De Magalhães & Santaaulàlia-Llopis, 2018); nexuses between environmental degradation and inclusive development (Asongu & Odhiambo, 2018b); linkages between corruption and inequality (Sulemana & Kpienbaareh, 2018); the imperative of reinventing development assistance for inclusive development (Jones & Tarp, 2015; Page & Söderbom, 2015; Asongu, 2016); linkages between finance, education, information sharing and income inequality (Meniago & Asongu, 2018; Tchamyu, 2019a, 2019b) and gender inclusion (Bayraktar & Fofack, 2018; Elu, 2018; Mannah-Blankson, 2018). This last stream

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<sup>2</sup> The terms “formal economic participation”, “female economic participation” and “female labor force participation” are used interchangeably throughout the study.

of studies is closest to the present research. Elu, (2018) has argued for the importance of gender in science education for the contemporary development of Sub-Saharan Africa (SSA), Bayraktar and Fofack (2018) have provided a model for gender analysis within the financial and informal productive sectors while Mannah-Blankson (2018) has investigated the nexus between gender inequality and access to microfinance in Ghana.

The positioning of this research is also motivated by a recent stream of financial development literature which has failed to engaged connections between ICT, financial access and the enhancement of female participation in the formal economic sector (Gevorkyan & Kvangraven, 2016; Danquah, Quartey & Iddrisu, 2017; Asongu, Nwachukwu & Tchamyou, 2017; Amponsah, 2017; Boamah, 2017; Kusi, Agbloyor, Ansah-Adu & Gyeke-Dako, 2017; Bayraktar & Fofack, 2018; Tchamyou, 2019a, 2019b; Boateng, Asongu, Akamavi & Tchamyou, 2018; Kusi & Opoku-Mensah, 2018; Senga, Cassimon & Essers, 2018; Senga & Cassimon, 2018 ; Asongu, Batuo, Nwachukwu & Tchamyou, 2018a; Asongu, Raheem & Tchamyou, 2018b ; Dafe, Essers & Volz, 2018; Gyeke-Dako, Agbloyor, Turkson & Baffour, 2018; Tchamyou et al., 2019; Bokpin, Ackah & Kunawotor, 2018).

The theoretical underpinning motivating the association between ICT and the formal economic participation of women is consistent with the neoclassical models of economic development (Kwan & Chiu, 2015). In accordance with the attendant literature, these neoclassical theoretical fundamentals posit that ICT is important in socio-economic development in poor countries (Abramowitz, 1986; Bernard & Jones, 1996; Asongu Nwachukwu & Aziz, 2018c). These theoretical fundamentals align with the relevance of ICT in promoting wellbeing and socio-economic prosperity in countries at initial stages of industrialization (Bongomin, Ntayi, Munene & Malinga, 2018; Muthinja & Chipeta, 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Asongu, le Roux, Nwachukwu & Pyke, 2019a; Asongu, Nwachukwu & Pyke, 2019b). It is worthwhile to put these theoretical connections into greater perspectives.

Human and socio-economic developments can be promoted by ICT because, *inter alia*: (i) ICT provides avenues that restrict the physical movement of citizens (Ureta, 2008; Shaikh & Karjaluoto, 2015; Efobi *et al.*, 2018); (ii) information technology expands frontiers of possibility and enhances the availability of timely information which is relevant in reducing information asymmetry and other risks associated with economic activities and entrepreneurship (Smith, Spence & Rashid, 2011; Tchamyou, 2019b); (iii) the first-two positive ramifications on human and economic developments are more apparent in poorer

groups of society, including women who are economically less privileged to participate in formal economic activities (Asongu, 2015). In summary, the discussed theoretical framework broadly aligns with the position that ICT promotes inclusive development because such potential benefits are more apparent among poorer factions of the population, compared to rich factions. Having clarified the theoretical underpinnings, it is also worthwhile to further articulate why the positioning of the research has contemporary relevance in decision-making circles.

The research under consideration is particularly relevant in the post-2015 development agenda because most African countries failed to achieve the Millennium Development Goal (MDG) extreme poverty target (Asongu & le Roux, 2018). Moreover, in the light of Sustainable Development Goals (SDGs), there is a common global policy agenda of reducing extreme poverty to a below 3% threshold by 2030. Reaching this threshold is very challenging for Africa because inequality is unfavorably affecting the negative responsiveness of poverty to economic growth (Ncube, Anyanwu & Hausken, 2014; Fosu, 2015; Bicaba, Brixiova & Ncube, 2017; Asongu & Kodila-Tedika, 2017; Asongu & le Roux, 2018). The underlying concern of inequality in sustainable development is further heightened by concerns about gender inequality which have been documented to be most apparent in Africa (Efobi et al., 2018).

The concepts of inclusion and sustainable development are connected in the perspectives that, in order to inclusive development (including gender inclusion) to be sustainable, it should be sustained and for sustained development to be sustainable, it should be inclusive, which involves dimensions of gender inclusion (Amavilah, Asongu & Andrés, 2017; Asongu, 2019). The rest of the study is structured as follows. The data and methodology are discussed in section 2 while the empirical findings are covered in section 3. The study concludes in section 4 with implications and future research directions.

## **2. Data and methodology**

### **2.1 Data**

This study focuses on forty-eight countries in Africa using annual data for the period 2004-2014<sup>3</sup>. The geographical and temporal scopes of the study are motivated by data availability

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<sup>3</sup>The 48 countries include: “Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Côte d’Ivoire, Djibouti, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda,

constraints at the time of the study. The data come from four main sources, notably, the: (i) International Labor Organization for the economic participation outcome variable (i.e. female labor force participation); (ii) World Development Indicators of the World Bank for the ICT variables (i.e. mobile phone penetration, internet penetration and fixed broadband subscriptions) and a control variable (i.e. remittances); (iii) Financial Development and Structure Database (FDSD) of the World Bank for another control variable (i.e. financial stability) and financial access variables (i.e. financial system deposits and private domestic credit) and (iv) World Governance Indicators of the World Bank for a control variable (i.e. political stability).

In accordance with recent inclusive development literature (Efobi *et al.*, 2018; Asongu & Odhiambo, 2019), three main ICT indicators and one outcome variable are adopted for the study. Two main financial access dynamics are considered, namely, the: deposit channel (i.e. financial system deposits) and credit mechanism (i.e. private domestic credit). Consistent with recent inclusive development literature, three main control variables are adopted in order to control for variable omission bias, namely: financial stability, remittances and political stability (Anyanwu, 2011; Tchamyu, 2019a, 2019b; Meniago & Asongu, 2018). Concerning the expected signs, remittances are anticipated to have negative effects on the outcome variable, political stability is expected to weigh positively on female economic participation whereas the sign of financial stability is ambiguous.

As recently documented in Anyanwu (2011) and Meniago and Asongu (2018), remittances increase income inequality in Africa because majority of the population travelling abroad is from wealthier factions of society which can afford the expensive administrative and financial constraints that a visa processing project entails. Hence, remittances have negative redistributive income effects because when funds are remitted, these funds averagely end-up increasing the income of rich households that are obviously (as averagely in society) already characterised by high levels of gender inequality. Political stability is expected to promote gender inclusion because it provides enabling conditions for investment and economic prosperity which involve women in society. The overall effect of financial stability is contingent on whether men or women benefit more from financial stability.

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Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda and Zambia”.

The number of control variables is limited to three in order to avoid concerns of instrument proliferation that could severely prevent the estimated models from passing the post-estimation diagnostic tests. Conditioning the information set to three variables in a Generalised Method of Moments (GMM) specification is not uncommon because while some studies have employed less than three control variables (e.g. Bruno, De Bonis & Silvestrini, 2012), others have not used any control variable (Osabuohien & Efobi, 2013; Asongu & Nwachukwu, 2017b). 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, identification and exclusion restrictions

The adoption of the GMM empirical strategy is motivated by four main fundamentals in the scholarly literature (Tchamyou, 2019a, 2019b). First and foremost, the number of agents in the study is higher than the corresponding number of periods that each agent is characterised with. It follows that the  $N > T$  prime condition for the employment of the estimation technique is fulfilled because  $48 > 11$  (i.e. 2004 to 2014). Second, the indicator of female economic participation is persistent over time because the correlation coefficient between the level and first lags of the indicator is higher than 0.800 which is the rule of thumb in the scholarly literature for establishing persistence in an outcome variable (Tchamyou *et al.*, 2019). Third, in the light of the panel data structure of the study, cross-country differences are taken on board in the estimation exercises. Fourth, the concern about endogeneity is also considered because: (i) reverse causality or simultaneity is addressed with the help of instruments while (ii) the unobserved heterogeneity is accounted for with the control of time invariant variables.

The Roodman (2009a, 2009b) GMM approach is adopted in this research. The approach is an extension of Arellano and Bover (1995) which has been documented in recent literature to produce more efficient estimates, partly because it avoids the proliferation of instruments (Asongu & Nwachukwu, 2016a; Boateng *et al.*, 2018).

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

$$FE_{i,t} = \sigma_0 + \sigma_1 FE_{i,t-\tau} + \sigma_2 T_{i,t} + \sigma_3 FA_{i,t} + \sigma_4 TFA_{i,t} + \sum_{h=1}^3 \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$\begin{aligned}
FE_{i,t} - FE_{i,t-\tau} = & \sigma_1(FE_{i,t-\tau} - FE_{i,t-2\tau}) + \sigma_2(T_{i,t} - T_{i,t-\tau}) + \sigma_3(FA_{i,t} - FA_{i,t-\tau}) + \sigma_4(TFA_{i,t} - TFA_{i,t-\tau}) \\
& + \sum_{h=1}^3 \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau})
\end{aligned} \tag{2}$$

where,  $FE_{i,t}$  is the female economic participation indicator (i.e. female labor force participation) of country  $i$  in period  $t$ ,  $\sigma_0$  is a constant,  $T$  entails ICT (mobile phone penetration, internet penetration and broadband subscriptions),  $FA$  denotes a financial access proxy (financial system deposits and private domestic credit),  $TFA$  is the interaction between ICT indicators and financial access dynamics (“mobile phone penetration” × “financial system deposits”, “mobile phone penetration” × “private domestic credit”, “internet penetration” × “financial system deposits”, “internet penetration” × “private domestic credit”, “fixed broadband subscriptions” × “financial system deposits” and “fixed broadband subscriptions” × “private domestic credit”),  $W$  is the vector of control variables (political stability, remittances and financial stability),  $\tau$  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,  $\xi_t$  is the time-specific constant,  $\eta_i$  is the country-specific effect and  $\varepsilon_{i,t}$  the error term.

### 2.2.2 Identification and exclusion restrictions

Emphases on identification and exclusion restrictions are very vital for a robust GMM specification. In the light of contemporary empirical literature, the identification strategy of this study is such that “years” is acknowledged as the strictly exogenous variable whereas all explanatory variables are considered as predetermined or endogenous explaining (Asongu & Nwachukwu, 2016b; Tchamyou & Asongu, 2017; Boateng *et al.*, 2018; Tchamyou *et al.*, 2019). This process of identification is broadly consistent with Roodman (2009b) who has posited that it is not feasible for time invariant variables to become endogenous upon first difference<sup>4</sup>.

Cognizant of the underlying identification process, the exclusion restriction assumption is such that the identified strictly exogenous variables influence the outcome variable (i.e. female economic participation) exclusively via the predetermined variables (i.e. ICT and financial access channels). Hence, this assumption of exclusion restriction is met if the null hypothesis corresponding to the Difference in Hansen Test (DHT) is not rejected.

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<sup>4</sup>Hence, the procedure for treating *ivstyle* (years) is ‘iv (years, eq(diff))’ whereas the *gmmstyle* is employed for predetermined variables.

This null hypothesis is the position that the instruments or strictly exogenous variables are valid in that they do not affect the outcome variable beyond the proposed endogenous explaining variables. The identification process and means by which the corresponding assumptions are investigated, are consistent with the standard instrumental variable (IV) estimation approach in which, failure to reject the null hypothesis of the overidentifying restriction test is an indication that the adopted instruments affect the dependent variable exclusively via the suggested mechanisms or exogenous components of the explanatory variables (Beck, Demirgüç-Kunt & Levine, 2003; Asongu & Nwachukwu, 2016c).

### 3. Empirical results

#### 3.1 Presentation of results

The empirical findings are presented in this section in Table 1, which is partitioned into three main categories, notably, in terms of regressions pertaining to each of the ICT variables. For each typical ICT modeling, two specifications are considered in the light of the deposit and credit channels. For all specifications, four information criteria are employed to assess the validity of estimated coefficients<sup>5</sup>.

In order to investigate the overall relevance of ICT in modulating the effect of financial access on female economic participation, net effects are computed in accordance with the attendant literature on interactive regressions (Tchamyou & Asongu, 2017). For instance, in the second column of Table 1, the net effect of mobile phone penetration in modulating the effect of financial system deposits on female economic participation is  $-0.011$  ( $[0.0001 \times 45.330] + [-0.016]$ ). In this computation, the average value of mobile phone penetration is 45.330, the unconditional effect of financial system deposits is  $-0.016$  while the conditional effect from the interaction between financial system deposits and mobile phone penetration is 0.0001. With the same computational analogy, in the penultimate column of Table 1, the net effect of broadband subscriptions in modulating the influence of financial system deposits on female economic participation is  $-0.009$  ( $[0.006 \times 0.643] + [-0.013]$ ). In this computation, the average value of fixed broadband subscriptions is 0.643, the

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<sup>5</sup> “First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen 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 Fischer test for the joint validity of estimated coefficients is also provided” (Asongu & De Moor, 2017, p.200).

unconditional effect of financial system deposits is -0.013 while the conditional effect from the interaction between financial system deposits and fixed broadband subscriptions is 0.006.

**Table 1: ICT, financial access and female labor force participation**

	Dependent variable: the female labor force participation rate (FLFpart)					
	Mobile phone penetration		Internet penetration		Broadband subscription	
	Deposit Channel	Credit Channel	Deposit Channel	Credit Channel	Deposit Channel	Credit Channel
FLFpart (-1)	<b>0.934***</b> (0.000)	<b>0.937***</b> (0.000)	<b>0.958***</b> (0.000)	<b>0.949***</b> (0.000)	<b>0.953***</b> (0.000)	<b>0.963***</b> (0.000)
Mobile Phone(Mobile)	<b>-0.010***</b> (0.000)	<b>-0.007***</b> (0.004)	---	---	---	---
Internet	---	---	<b>-0.028***</b> (0.001)	<b>-0.027***</b> (0.001)	---	---
Broadband(BroadB)	---	---	---	---	<b>-0.650***</b> (0.000)	<b>-0.485***</b> (0.000)
Deposits	<b>-0.016***</b> (0.000)	---	-0.007 (0.121)	---	<b>-0.013***</b> (0.001)	---
Credit	---	<b>-0.009***</b> (0.006)	---	-0.001 (0.664)	---	-0.003 (0.378)
Mobile × Deposits	<b>0.0001***</b> (0.004)	---	---	---	---	---
Internet × Deposits	---	---	<b>0.0001*</b> (0.056)	---	---	---
BroadB × Deposits	---	---	---	---	<b>0.006***</b> (0.000)	---
Mobile × Credit	---	0.00002 (0.128)	---	---	---	---
Internet × Credit	---	---	---	0.00001 (0.857)	---	---
BroadB × Credit	---	---	---	---	---	<b>0.004***</b> (0.000)
Political Stability	<b>0.312**</b> (0.026)	0.187 (0.224)	0.261 (0.100)	0.149 (0.367)	<b>0.244***</b> (0.007)	<b>0.392***</b> (0.001)
Remittances	<b>-0.086***</b> (0.000)	<b>-0.094***</b> (0.000)	<b>-0.053**</b> (0.028)	<b>-0.062***</b> (0.000)	<b>-0.065***</b> (0.000)	-0.010 (0.171)
Financial Stability	<b>-0.022**</b> (0.018)	<b>-0.027**</b> (0.011)	0.0007 (0.994)	0.001 (0.917)	<b>-0.013*</b> (0.075)	<b>-0.021***</b> (0.001)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	-0.011	na	na	na	-0.009	na
Thresholds	160	nsa	70	nsa	2.166	0.75
AR(1)	(0.039)	(0.044)	(0.061)	(0.061)	(0.060)	(0.068)
AR(2)	<b>(0.555)</b>	<b>(0.657)</b>	<b>(0.249)</b>	<b>(0.301)</b>	<b>(0.681)</b>	<b>(0.207)</b>
Sargan OIR	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	<b>(0.364)</b>	<b>(0.394)</b>	<b>(0.313)</b>	<b>(0.244)</b>	<b>(0.620)</b>	<b>(0.562)</b>
DHT for instruments						
(a) Instruments in levels						
H excluding group	<b>(0.194)</b>	<b>(0.337)</b>	<b>(0.372)</b>	<b>(0.460)</b>	<b>(0.238)</b>	<b>(0.301)</b>
Dif(null, H=exogenous)	<b>(0.500)</b>	<b>(0.420)</b>	<b>(0.306)</b>	<b>(0.199)</b>	<b>(0.762)</b>	<b>(0.644)</b>
(b) IV (years, eq(diff))						
H excluding group	<b>(0.192)</b>	<b>(0.119)</b>	<b>(0.127)</b>	<b>(0.313)</b>	<b>(0.219)</b>	<b>(0.532)</b>
Dif(null, H=exogenous)	<b>(0.612)</b>	<b>(0.824)</b>	<b>(0.669)</b>	<b>(0.258)</b>	<b>(0.914)</b>	<b>(0.491)</b>
Fisher	<b>1.18e+07***</b>	<b>10192.63***</b>	<b>2.37e+07***</b>	<b>429736.96***</b>	<b>2.45e+07***</b>	<b>287847.41***</b>
Instruments	36	36	36	36	36	36

Countries	38	38	38	38	36	36
Observations	304	304	300	300	259	259

\*\*\*, \*\*, \*: 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 effect or the estimated interaction between ICT and financial access is not significant. Constants are included in the regressions.

The following main findings can be established from Table 1. ICT (i.e. mobile phone penetration and fixed broadband subscriptions) modulate financial system deposits for an overall net negative effect on female economic participation. These net negative effects are associated with positive conditional or interactive effects. Moreover, significant positive effects are also apparent from interactions between: (i) financial system deposits and internet penetration and (ii) private domestic credit and fixed broadband subscriptions. The significant control variables have the expected signs.

### 3.2 Extension with policy thresholds

In order to provide room for more policy implications, the analysis is extended by establishing policy thresholds of ICT penetration for the desired effect on female economic participation. It is worthwhile to articulate that ICT has a high potential of penetration in Africa, hence policy makers should be informed of actionable ICT measures that can be implemented in order to enhance the involvement of women in the formal economic sector. This relevance of threshold is consistent with the problem statement because the interactive effects are consistently positive. A direct implication of positive interactive effects is that at certain critical masses of ICT, the established negative net effect can be nullified. Hence above, the critical masses, further enhancement of ICT dynamics induce positive net effects on female economic participation.

From Table 1, a positive threshold corresponding to the second column is 160 (0.016/0.0001). Hence, when mobile penetration is 160 (per 100 people), the net effect on female economic participation is 0 ( $[0.0001 \times 160] + [-0.016]$ ). Hence, above a 160 mobile phone penetration (per 100 people) threshold, the mobile phone modulates financial system deposits to induce a positive net effect on the outcome variable. In order for the established threshold to make economic sense and have policy relevance, it should be within the policy range disclosed in the summary statistics. Accordingly, the established 160 threshold is within the disclosed minimum to maximum range (i.e. 0.209 to 171.375). In the same vein, a critical mass of 70 internet penetration (per 100 people) is required for internet penetration to nullify

the negative unconditional effect of financial system deposits on the outcome variable and for fixed broadband subscriptions, the policy thresholds for financial system deposits and private domestic credit are respectively, 2.166 and 0.75 subscriptions per 100 people. Of these established thresholds, only the internet threshold has no policy relevance because it is not within policy range.

The conception and definition of threshold underpinning this extended analysis is in accordance with the attendant literature, notably: baseline requirements for favorable effects (Cummins, 2000); thresholds at which environmental pollution can be detrimental to inclusive development (Asongu, 2018); inflexion points for desirable results (Roller & Waverman, 2001; Batuo, 2015); requirements for U-shaped and inverted U-shaped patterns (Ashraf & Galor, 2013) and information sharing thresholds for the reduction of market power in order to promote financial access (Asongu, le Roux, Tchamyu, 2019c).

#### **4. Conclusion and future research directions**

The study has investigated the relevance of information and communication technology (ICT) in modulating the effect of financial access on female economic participation. Female economic participation is proxied by labor force participation, financial access is measured with deposit and credit channels while ICT is proxied by mobile phone penetration, internet penetration and fixed broadband subscriptions. The focus of the study is on 48 African countries for the period 2004-2014 and the empirical evidence is based on the Generalized Method of Moments. The following main findings are established. ICT (i.e. mobile phone penetration and fixed broadband subscriptions) modulate financial system deposits for an overall net negative effect on female economic participation. These net negative effects are associated with positive conditional or interactive effects. Moreover, significant positive effects are also apparent from interactions between: (i) financial system deposits and internet penetration and (ii) private domestic credit and fixed broadband subscriptions.

The consistent positive conditional effects have motivated an extended analysis from which, policy thresholds have been established. At these critical masses, ICT modulates financial access to induce favourable effects on female economic participation. These policy thresholds are: (i) 160 mobile phone penetration (per 100 people) for the deposit channel: (ii) 2.166 and 0.75 fixed broadband subscriptions per 100 people for respectively, the deposit mechanism and credit channel and (iii) 70 internet penetration (per 100 people) for the deposit channel. Of these established thresholds, only the internet threshold has no policy relevance

because it is not within policy range. Overall the study supports the importance of ICT in moderating financial access for enhanced female economic participation. As a main policy implication, measures designed to enhance universal ICT access should be encouraged in order to promote the participation of women in the formal economic sector and by extension the reduction of inequality.

Future studies can improve the established findings by assessing other policy instruments that can facilitate the positive effect of financial access channels on gender inclusion in the formal economic sector. Considering information sharing offices (i.e. public credit registries and private credit bureaus) is a worthwhile direction to pursue. Moreover, assessing whether established findings in this research withstand empirical scrutiny within country-specific frameworks is also worth pursuing. This second recommendation fundamentally builds on the caveat that country-specific effects are not considered in the GMM approach because they are eliminated in order to control for endogeneity resulting from a correlation between the lagged dependent variable and country-specific effects.

## 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
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
Financial Deposits	Deposits	Financial System Deposits (% of GDP)	FDSO
Financial Credit	Credit	Privates Domestic Credits (% of GDP)	FDSO
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
Financial Stability	Z-score	Prediction of the likelihood that a bank might survive and not go bankrupt.	FDSO

WDI: World Development Indicators of the World Bank. FDSO: Financial Development and Structure Database of the World Bank. WGI: World Governance Indicators of the World Bank. ILO: International Labour Organization.

### Appendix 2: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Observations
Female Labor Force participation	130.03	83.996	1.000	287.00	462
Mobile Phone Penetration	45.330	37.282	0.209	171.375	558
Internet Penetration	7.676	10.153	0.031	54.260	453
Fixed BroadBand	0.643	1.969	0.000	14.569	369
Financial System Deposits	26.629	19.518	2.223	92.676	440
Privates Domestic Credit	20.913	24.628	0.873	150.209	440
Political Stability	-0.471	0.905	-2.687	1.182	462
Remittances	4.313	6.817	0.00003	50.818	416
Financial Stability	8.713	4.994	-12.024	25.736	404

S.D: Standard Deviation.

### Appendix 3: Correlation matrix (uniform sample size: 277)

ICT Dynamics			Financial Channels		Control Variables			FLFpart
Mobile	Internet	BroadB	Deposit	Credit	PolS	Remit	Z-score	
1.000	0.667	0.528	0.261	0.342	0.340	-0.056	0.206	-0.032
	1.000	0.674	0.288	0.400	0.187	-0.061	0.259	0.226

1.000	0.413	0.531	0.355	-0.106	0.234	0.105	BroadB
	1.000	0.856	0.376	0.0181	0.399	-0.139	Deposit
		1.000	0.327	-0.102	0.428	-0.034	Credit
			1.000	0.027	0.099	-0.064	PolS
				1.000	-0.109	-0.029	Remit
					1.000	-0.201	Z-score
						1.000	FLFpart

Mobile: Mobile phone penetration. Internet: Internet penetration. BroadB: Fixed broadband subscriptions. Deposit: Financial system deposits. Credit: private domestic credit. PolS: Political stability. Remit: Remittances. Z-score: Financial Stability. FLFpart: Female labour force participation.

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