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January 2018

A G D I Working Paper

WP/18/005

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Forthcoming: South African Journal of Economics

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2018 African Governance and Development Institute WP/18/005

Research Department

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Abstract

This study complements existing literature by investigating how the advancement in information and communication technology affects the formal economic participation of women. The focus is on 48 African countries for the period 1990-2014. The empirical evidence is based on Ordinary Least Squares, Fixed Effects and the Generalized Method of Moments regressions. The results show that improving communication technology increases female economic participation with the following consistent order of increasing magnitude: mobile phone penetration; internet penetration, and fixed broadband subscriptions. The findings are robust to the control for heterogeneities across countries. Policy implications are discussed.

JEL Classification: G20; I10; I32; O40; O55
Keywords: Africa; Gender; ICT; Inclusive development; Technology

1. Introduction

Three main issues in policy and scholarly circles motivate this study, notably: the high potential for information and communication technology (ICT) penetration in Africa, the low participation of the female gender in the labour market, and gaps in the literature on the relevance of ICT in development outcomes. The three points are substantiated in chronological order. First, in accordance with recent literature, compared to other regions of the world that are experiencing ICT saturation, there is much room for ICT penetration in Africa (see Penard *et al*., 2012; Asongu, 2015; Tchamyou, 2017). Moreover, the growing literature on the use of ICT for inclusive development is consistent with the position that policy makers in sub-Saharan Africa (SSA) countries can leverage on the ICT potential to address development policy (Mishra &

Bisht, 2013; Ojo*et al*., 2012; Alkemade & Surrs, 2012). However, the extent to which ICT can improve the gender gap in economic participation is still to be substantiated for policy implementation in SSA countries.

Second, the low participation of women in the labour market is well documented in the literature. Women in SSA countries are mostly absorbed in the informal economic sector, engage in smallholding farming, and constitute the majority of the workforce in unpaid household labour– such as home-based activities (Ellis *et al*., 2007; FAO, 2011; Tandon & Wegerif, 2013). Furthermore, according to the International Labour Organization (2013) and the World Bank (2015), in SSA countries, the percentage of women in the informal sector is higher compared to the same percentage for men[1]. This low economic participation of women is obviously associated with negative welfare externalities. The poverty consequence of low female participation in the labour market is most apparent in SSA because the sub-region has registered the highest female poverty rate compared to other regions of the world (Hazel, 2010). The narrative maintains that policies designed to improve female economic participation in SSA will produce a dual externality in poverty reduction, notably, by improving the welfare of women and ameliorating structural distribution of labour. Such policies (including ICT advancement) should also improve the competitiveness of women in the labour, capital and commodity markets. Yet, this claim also requires empirical validation.

Third, a substantial bulk of the recent literature on the relevance of ICT in development outcomes has failed to engage female economic participation. Accordingly, the recent bulk of literature on the relationship between ICT and inclusive development has largely focused on, *inter alia*: gender empowerment (Ojo *et al*., 2012); health access by the population in the low income category (Klin*eret al*., 2013); the consolidation of financial inclusion (Kirui *et al*., 2013; Mishra & Bisht, 2013; Asongu & Nwachukwu, 2016a); reduction of the rural-urban development gap and mitigation of wastes in the agricultural sector by addressing mismatches/constraints in the demand for and supply of commodities (Aker & Fafchamps, 2010; Muto & Yamano, 2009); household management efficiency (Al Surikhi, 2012; Asongu, 2016); consolidation of opportunities for small and medium-size businesses (Ondiege, 2010); development purposes (Kuada, 2009, 2014, 2015a; Afutu-Kotey *et al*., 2017) and social change (Tony & Kwan, 2015;

[1]For instance in Liberia, 65.4 percent of women are employed in the informal sector, compared to 33.4 per cent of men.

Minkoua Nzie *et al*., 2017; Gosavi, 2017). Noticeably from the highlighted literature, scholarship on the nexus between ICT and the participation of women in the labour market has not received the attention it deserves.

This study unites these three issues by investigating how ICT (covered in the first strand) can be leveraged to enhance female economic participation (engaged in the second strand) in order to bridge the noticeable gap in the literature (highlighted in the third strand). The policy relevance of the study also borders on the need for inclusive development by means of enhanced female participation in the labour market. Addressing this inequality is also relevant because SSA has been documented to reflect the highest levels of gender and income inequalities (see, IMF, 2016). This tendency is consistent with a recent report by the World Bank on achievements of the Millennium Development Goal (MDG)'s extreme poverty target which has revealed that poverty has been decreasing in all regions of the world with the exception of SSA, where close to 50% of countries in the sub-region were substantially off-track from achieving the MDG extreme poverty target (Tchamyou, 2018a, b; Asongu & Asongu, 2018a, b). Furthermore, given that the sub-region has been enjoying more than two decades of growth resurgence that began in the mid-1990s, it is apparent that the underlying extreme poverty is the result of non-inclusive growth (Tchamyou *et al*., 2018; Kuada, 2015b; Asongu & Nwachukwu, 2018). The inference on exclusive development builds on the fact that the response of poverty to growth is a decreasing function of inequality (Fosu, 2008, 2009, 2010a, 2015)[2].

The remainder of the paper is organized as follows. Section 2 reviews the literature, while the data and methodology are covered in Section 3. The empirical results are presented and discussed in Section 4. We conclude the paper in Section 5.

2. Review of Literature

ICT usage is an important driver of inclusive development at the business and national levels because they influence a plethora of economic activities, which constitute, *inter alia*, labour force dynamics. In essence, an important element for progress in ICT for human development is

[2]The response of poverty to growth as a decreasing function of inequality is also known as the Fosu conjecture. More specifically: "*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).

a characteristic that is defined by Coleman (1998) as an individual's expertise, knowledge and ability that convey positive externalities to economic prosperity. Such includes the ability of the female gender to leverage on ICT to increase her economic participation, which is the focus of this inquiry.

The vast literature on the benefit of ICT to an economic system can be categorized into three effects. The first is the industrial development effect through the improvement in total factor productivity (TFP), industrial research and development, and innovation (see Asongu, 2015; Skinner & Staiger, 2015; Du & Ouyang, 2017; Franck & Galor, 2017). These studies conclude that the rapid industrial development of countries is as a result of the growth in ICT usage, which has a significant impact on both capital and labour productivity through an enhancement in innovative business processes as well as research and development endeavors. Furthermore, the impact of ICT on the TFP of industries has received resounding attention in development literature. For instance, authors like Heshmati and Rashidghalam (2016) conclude that the Internet and communication-enhancing technologies have expanded the capacity of production resources, which boosts the society's capacity to increase the economic welfare of people.

Second, ICT usage enhances development outcomes, which include advancement in the educational system (Madge & O'Connor, 2004; Uibu & Kikas, 2008), health outcomes (Simba, 2004; Oostveen, 2014), and household income[3] (Comin & Mestieri, 2013a). These authors argue that ICT has played a significant role in service delivery within the educational and health sectors, therefore enhancing the outputs of these sectors. Moreover, it has also improved income through wage growth (for instance) and multiple income generating activities that come with its adoption. Pepper and Garrity (2015) and Asongu and Nwachukwu (2016a, c) take another look at the role of ICT in development by focusing on inclusive development – that is the development process that ensures the inclusion of all groups that hitherto have been marginalized or excluded. The authors note that mobile technology plays the important role of connecting the views of such marginalized groups within an economic system with stakeholders in the development process.

[3]Comin and Mestieri (2013b) record that over 70 percent of the variation in income per capita can be accounted for by cross-country differences in the rate of technology adoption.

Third, ICT plays an important role for economic growth. Studies that are within this framework note that mobile technology, for instance, affects growth through its direct influence on productivity growth, it also raises the efficiency of service providers, and opens new markets by reducing distances between economic agents that are in (or about to engage) in a contractual relationship (see Dutta et al., 2015). ICT also has an indirect effect on economic growth through its influence on governance (World Bank, 2013; Asongu & Nwachukwu, 2016b), which directly affects economic growth (Acemoglu, 2008).

There is, however, an evolving literature on how ICT can play an important role in individuals' economic participation within the structure of economic growth and development. The empirical evidences in these studies are within the framework of labour supply through efficient information dissemination about the labour market or other economic opportunities. As noted in Stigler (1961), information, which in reality is often costly or incomplete, is central to the functioning of the market. Therefore, appropriate technologies that can intermediate between demand and supply of labour will have a significant impact on the overall economic participation of individuals. For instance, a study by Galdo and Galdo (2015) on mobile phone technology and labour market intermediation highlights that through faster, cheaper, and up-to-date information on job vacancies via SMS and mobile technologies, individuals are able to effectively participate in the labour market. Greene and Mamic (2015) further highlight that there is a changing dynamic in the world of work, such that the proliferation of information through communication technology (like mobile technology) is playing a central role in boosting productive activities.

While the emphasis on labour supply and other forms of productive activities through communication technology adoption has been emphasized in literature, questions about how such technologies can improve women economic participation in Africa have so far largely remain without satisfactory answers. This is despite the growing literature on how to include women economic reliance and empowerment in development policies through their participation in the labour market (see Kabeer, 2012). It is precisely this knowledge gap that this study aims to address, with emphasis on Sub-Saharan African countries.

This study therefore contributes to the bulk of literature on ICT externalities for inclusive development by articulating the gender perspective. While a substantial bulk of the literature has been documented on industrial, economic growth and development outcomes of ICT, to the best of our knowledge, very little is known about how such technological advancement elicit female

economic participation in Africa. Moreover, Mpogole *et al.* (2008, p. 71) have cautioned that ICT should not be considered as a silver bullet of economic development unless it is substantiated with empirical validity. Therefore by positioning our inquiry on female economic participation and contributing to the macroeconomic literature on ICT for non-exclusive development, our paper complements an evolving strand of the literature on inclusive ICT externalities (see Cozzens, 2011), which has focused on both developed (see Thakar, 2012) and developing (Sonne, 2012) countries. Within this framework, our inquiry is closest to an evolving body of studies on the relevance of ICT for social change (Mira & Dangersfield, 2012), especially ICT improvements for inclusive development (Asongu & Nwachukwu, 2016c).

3. Data and Methodology

3.1 Data

The main explained variable (female economic participation) is measured using the female labour force participation rate. Our measure is consistent with Signorelli et al. (2012), and this measure provides a broader perspective to individuals' engagement in the economic cycle in a society since it includes individuals who are either employed or unemployed (Abdulloev *et al.*, 2014). Formally, the World Bank (2016) defines female labour force participation rate as the proportion of female in the labour force that is within the age bracket of 15 to 64. Another measure of economic participation (i.e. the female employment rate) is a restricted measure because it considers the proportion of female labour force that is available for work and currently gainfully employed. We only use the latter measure for robustness check. The data for female economic participation are obtained from the 2016 International Labour Organisation (ILO) key Indicators of the Labour Market, and the World Bank's World Development Indicators.

The ICT technology advancement variable is measured using three main indicators -fixed broadband subscription per 100 people, the Internet usage per 100 people, and the mobile phone usage per 100 people. The fixed broadband subscription per 100 people measures the total number of subscribers to broadband internet technologies (such as cable modem, fiber optic connections, and other high-speed technology) with download speeds of 256 kilobits or greater. The Internet connection describes the proportion of individuals who have access to the worldwide network, while the mobile cellular subscriber measures the number of people with access to cellular technology and the public switched telephone network. The focus on these

three measures is motivated by two main factors. (i) They are technologies that enhance labour supply by enabling access to labour market information and reducing social stereotypes on the role of women in the economy through social interactions and access to information from the rest of the world (see Mneyey, 2011; Cotten, Anderson, & McCullough, 2013); (ii) They are resounding policy variables in SSA countries because most policy documents that address the need to encourage technology advancement in Africa have considered the Internet and mobile telephones as important for social inclusion (see Hamilton & Pors, 2003; International Telecommunication Union, 2009). Data for these variables are from the World Bank's World Development Indicators

To strengthen the causal interpretations of the result and to reduce biases that may arise from variable omissions, the study controls for trade liberalization, per capita income, foreign direct investment, and the extent of democracy. The control variables are chosen to best control for a wide range of factors that influence female economic participation across countries. Following the literature, the degree of trade liberalization and the remaining three control variables are expected to have a significant and positive correlation with the level of female economic participation in SSA countries (Pampel & Tanaka, 1986; Gaddis & Peters, 2012; Efobi, 2016). Data for these variables are sourced from World Development Indicators of the World Bank. The data for democracy is sourced from the World Governance Indicators.

The summary statistics of the main variables (including the mean, standard deviation and the minimum and maximum values) are presented in Table 1. The sample is a balanced panel that consists of 48 African countries (see Appendix 1) for the period 1990-2014. Thus, it comprises 1,152 individual country-year observations. On average, about 61 percent of the women in the sampled countries are participating in the labour force. This is similar to Siba (2016) who records 64 percent female labour force participation for SSA countries. Another relevant fact from the data is that the variation of female economic participation across countries is such that the difference between the least and highest is about 61 percent, with a standard deviation of 17.50 percent. Hence, the sampled countries are not homogeneous with regards to female economic participation. This calls for a more robust analysis that includes different controls for country heterogeneities.

On the average, more people have access to mobile phone technology (20.32) than the Internet (4.29), and fixed broadband connections (about 1 person). The average trade to GDP of

the sampled countries is 78.92 percent, while the per capita GDP is about 4. The average net foreign direct investment inflow is only 4.49 percent of the sampled countries' GDP. The score for the strength of democracy is relatively high (4.46 out of 7).

Table 1: Summary Statistics

Measure by Country-year	Mean	SD	Min	Max
Female labour force participation rate	61.09	17.50	29.28	90.8
Mobile phone usage (# per 100 people)	20.32	32.84	0.00	214.75
The internet usage (# per 100 people)	4.29	7.99	0.00	54.26
Fixed broadband subscription (# per 100 people)	0.57	1.85	0.05	5.57
Trade liberalization (trade as % of GDP)	78.92	50.37	11.09	531.73
The per capita income (Constant 2010 US$) in Log form	4.06	0.33	2.91	4.50
Foreign direct investment flow (net inflows % of GDP)	4.49	10.49	-82.89	161.82
Democracy (Political right and civil liberty average, 1-low, 7-high)	4.46	1.64	1.00	7.00

Note: SD: Standard deviation. Min: Minimum. Max: Maximum.

The pairwise correlation analysis is presented in Table 2 in order to provide a clear bivariate relationship that may likely exist among the variables of interest. Two important points are observed from Table 2. First, it is evident that the three indicators of ICT technology advancement have a significant and positive association with the main outcome variable. The association is stronger for fixed broadband subscription and internet usage than it is for mobile phone usage. While these patterns of interactions do not reflect causality, they nonetheless are indicative of likely relationships that exist among the variables of interest. Second, the indicators of ICT technology advancement are highly correlated among each other, which imply that they will be included in a stepwise regression form to avoid multicollinearity problems.

Table 2: Pairwise Correlation

	lfprate	*Mobile*	*Internet*	*Fix_bband*	*Openness*	*LnGdpp*	*fdi_net*	*Demoracy*
Lfprate	1.000	----	----	----	----	----	----	----
Mobile	0.096*	1.000	----	----	----	----	----	----
Internet	0.187*	0.718*	1.000	----	----	----	----	----
Fix_bband	0.172*	0.467*	0.674*	1.000	----	----	----	----
Openness	-0.021	0.033	-0.030	-0.031	1.000	----	----	----
LnGdpp	-0.342*	-0.016	-0.094*	-0.150*	0.424*	1.000	----	----
Fdi_net	0.047	0.129*	0.060***	0.249*	0.542*	0.062**	1.000	----
Democracy	0.083*	-0.083*	-0.092*	-0.053	-0.018	-0.227*	0.022	1.000

Note: Due to space constraint, for concise presentation, abbreviations are used to represent each of the variables. For instance Lfprate, Mobile, Internet, Fix_bband, Openess, LnGdpp, Fdi_net and democracy respectively abbreviate labour force participation rate, mobile phone usage, internet usage, fixed broadband subscription, trade liberalization, per capita income, foreign direct investment inflow and democracy. *,** and *** denote significance levels of 10%, 5% and 1% respectively.

3.2 Methodology

A baseline model is first used to describe female economic participation as a function of ICT and other control variables. This model is consistent with Signorelli et al. (2012) who assessed the impact of financial crisis on female labour. The baseline model is expressed as follows:

$$Y_{i,t} = \beta + \alpha.T_{i,t-1} + \varphi.X_{i,t} + \varepsilon_{it} \quad (1)$$

The outcome variables, the indicators of ICT advancement, and the control variables are denoted as '*Y', 'T'*, and *'X'*, respectively. As usual, β is the constant, α and φ are the estimates, while the error term is depicted as ε. The country and time identifiers are *'i'* and *'t'* respectively.

Three estimation techniques were applied to estimate the baseline model, namely: the Ordinary Least Squares (OLS), Fixed Effects (FE) regression, and the Generalized Method of Moments (GMM). The second and third have some advantage in reducing the extent of endogeneity by respectively controlling for the unobserved heterogeneity (like country fixed effects) and simultaneity issues (reverse causality).

Equations corresponding to the three estimation approaches are provided below.

Ordinary Least Squares

$$Female\ Economic\ Participation_{i,t} = \beta + \alpha.ICT\ Advancement_{i,t-1} + \varphi.X_{i,t} + \varepsilon_{it} \quad (2)$$

Fixed Effects Model

$$Female\ Economic\ Participation_{i,t} = \beta + \alpha.ICT\ Advancement_{i,t-1} + \varphi.X_{i,t} + \partial.Year_t + \delta.Country_i + \varepsilon_{it} \quad (3)$$

System Generalized Method of Moments (SGMM)

Equation 3 is the dynamic panel data model from which the SGMM model is derived.

$$Female\ Economic\ Participation_{i,t} = \beta + \Phi.Female\ Economic\ Participation_{i,t-1} + \alpha.ICT\ Advancement_{i,t-1} + \varphi.X_{i,t} + \eta_i + k_t + \varepsilon_{it} \quad (4)$$

The variables in the equations 1 – 3 are as described in Table 2, while the control variables are represented as "$X_{i,t}$". The subscripts "i" and "t" denote country and time dimensions while the error term is identified as "ε".

Blundell and Bond (1998; 2000) point out that the SGMM equation is more efficient in addressing apparent endogeneity issues by using internal instruments. This technique includes reasonable stationarity restrictions on its initial conditions process and additional moment conditions unlike other dynamic estimation tools like the Difference Generalized Method of Moments - DGMM (see Oluwatobi *et al.*, 2014). Furthermore, the SGMM technique is robust to heteroscedasticity and distributional assumptions (Cheong & Wu, 2013; Bandyopadhyay *et* al., 2014; Asongu et al., 2018a, b).

To validate the efficiency of the internal instruments that are included in the SGMM technique, and to ensure that such instruments are not over-identified, the test for autocorrelation (AR (1) and AR (2)) and Sargan test for are performed for respectively the absence of autocorrelation and validity of instruments. The SGMM is a combination of the level equation (or Equation 4) with a difference equation. While country-specific effects are no longer apparent in the difference equation, time-specific effects are maintained to control for the unobserved heterogeneity in terms of time invariant omitted variables. It is important to note that the adopted SGMM satisfies the two basic requirements for its adoption, notably: (i) the outcome variable is persistent because the correlation between level observations and first-lag observations corresponding to the outcome variable is higher than the rule of thumb threshold of 0.800, necessary for the establishment of persistence in variables, and (ii) the number of countries or cross sections (i.e. 48) is higher than the number of adopted periods in each country (i.e. 25 years or 1990-2014). This narrative on basic requirements for the adoption of the GMM approach is consistent with recent literature (Tchamyou & Asongu, 2017; Asongu & Nwachukwu, 2017a).

4. Empirical results

4. 1 Presentation of results

There are several noticeable relationships from the parsimonious regression results of the indicators of Information and Communication Technology– ICT presented in Table 3. First, the coefficients of the indicators of ICT advancement variables were positive at the 1% significance level in all the regressions. This implies that ICT advancement in Africa has a favorable and robust effect on female economic participation (proxied with labour force participation). Second, in valuing the effect of the indicators of ICT advancement, it is evident that fixed broadband subscription per (100 persons) has a higher effect on female economic participation than the other competing ICT advancement indicators. Evidently, and based on the SGMM estimates, a

one standard deviation increase in fixed broad band subscription in previous year (*sd*= 1.850, see Table 1) will improve female labour force participation by about 5.308 percentage points [$^{\vartheta \text{Lfprate}}/_{\vartheta Fixed\ bband} = 2.869 \times 1.850 \approx 5.308$]. This amounts to an average increase of 3.038 in the rate of female labour force participation for a country whose fixed broadband subscription per 100 people in the previous year is 0.5724. For the Internet and mobile cellular users, a standard deviation increase will improve female labour force participation by about 4.07 and 2.95 percentage points, respectively.

Table 3: Technological Advancement and Female Economic Participation (Baseline Estimates)

	SGMM	FE	OLS	SGMM	FE	OLS	SGMM	FE	OLS
$\text{Lfprate}_{i,t-1}$	0.390*** (0.000)	----	----	0.163*** (0.000)	----	----	0.219*** (0.000)	----	----
Internet users (100 persons)	0.943*** (0.000)	0.508*** (0.000)	0.412*** (0.000)	----	----	----	----	----	----
Mobile cellular (100 persons)	----	----	----	0.090*** (0.000)	0.079*** (0.003)	0.052*** (0.001)	----	----	----
Fixedbband (100 persons)	----	----	----	----	----	----	2.869*** (0.000)	1.572*** (0.000)	1.503*** (0.000)
Constant	----	60.101*** (0.000)	60.488*** (0.000)	----	60.091*** (0.000)	60.631*** (0.000)	----	62.982*** (0.000)	63.021*** (0.000)
R Squared	----	0.035	0.035	----	0.009	0.009	----	0.029	0.029
F Test	----	33.620	45.350	----	8.570	11.170	----	12.510	23.510
Hausman	----	(0.500)	----	----	(0.206)	----	----	(0.590)	----
Hansen	0.994	----	----	0.916	----	----	0.900	----	----
Serial Correlation Test	0.731	----	----	0.923	----	----	0.970	----	----
Nos. of cross section (n)	46	----	----	46	----	----	46	----	----
Nos. of Instruments (i)	41	----	----	41	----	----	38	----	----
Instrument ratio (n/i)	1.122	----	----	1.122	----	----	1.211		

Notes: The lags of the indicators of communication technology were used in all the estimations. The superscripts '***' denote a 1 percent significance level. The Hansen and Serial Correlation tests suggest that the results are not susceptible to a Type 1 error (i.e. producing significant results despite no underlining association between the respective variables). The instrument ratio for the different estimations is expected to be greater than 1, in order to satisfy the condition that the instruments are not proliferated (see Roodman, 2007; Asiedu &Lien, 2011).

Following a similar pattern as in Table 3, Table 4 presents the results using estimations that account for more heterogeneity. The findings in Table 4 are similar to those disclosed in Table 3, Notably, the magnitude and significance of the relationship between the different indicators of ICT advancement and female economic participation are consistent as earlier discussed. The fixed broadband subscription still maintained a higher effect on female economic participation compared to internet usage and mobile cellular connections. These findings are consistent with a World Bank report that broadband subscription has a higher economic development externality when compared to other ICT indicators like the mobile phone (World Bank, 2016).

We further discuss the sign and significant values of the control variables that were reported in Table 4. While we expect that the four control variables should have a positive association with female economic participation in SSA countries, we find that Foreign Direct Investment (FDI) inflow and the extent of democracy are the only variables that consistently improve the outcome variables. For instance, an increase in the extent of democracy in the sampled countries will result in about 2 percent significant increase in the rate of female labour force participation. This kind of increase is also seen for FDI, except for the last estimation that includes fixed broadband subscription. Hence, in spite of changes in the behavior of control variables, the independent variables of interest are robust in terms of significance and magnitude of significance.

Table 4: Technological Advancement and Female Economic Participation (Including Control Variables)

Variables	SGMM	FE	OLS	SGMM	FE	OLS	SGMM	FE	OLS
$Lfprate_{i,t-1}$	0.278*** (0.000)	----	----	0.207*** (0.000)	----	----	0.217*** (0.000)	----	----
Internet users (100 persons)	0.920*** (0.000)	0.469*** (0.000)	0.430*** (0.000)	----	----	----	----	----	----
Mobile cellular (100 persons)	----	----	----	0.083*** (0.000)	0.082*** (0.003)	0.069*** (0.000)	----	----	----
Fixed bband (100 persons)	----	----	----	----	----	----	3.240*** (0.000)	1.561*** (0.001)	1.460*** (0.000)
Trade (as % of GDP)	-0.018*** (0.000)	0.029** (0.041)	0.029** (0.033)	-0.023*** (0.000)	0.034** (0.016)	0.032** (0.021)	0.020 (0.240)	0.043* (0.071)	0.031 (0.121)
GDP Per Capita (Constant 2010 US$)	0.003** (0.050)	0.003 (0.134)	0.003* (0.079)	-0.004*** (0.000)	0.005** (0.016)	0.005** (0.011)	0.007 (0.346)	0.001 (0.611)	0.002 (0.493)
Foreign direct investment, net inflows (% of GDP)	0.129*** (0.000)	0.127** (0.047)	0.126** (0.025)	0.158*** (0.000)	0.151** (0.021)	0.154*** (0.008)	0.021 (0.848)	0.015 (0.906)	0.021 (0.840)
Democracy	2.197*** (0.000)	2.157*** (0.000)	2.091*** (0.000)	2.031*** (0.000)	1.954*** (0.000)	1.820*** (0.000)	2.995*** (0.000)	1.948*** (0.000)	2.044*** (0.000)
Constant	1.225** (0.029)	54.378*** (0.000)	54.861*** (0.000)	90.853*** (0.000)	55.293*** (0.000)	55.999*** (0.000)	10.527 (0.168)	59.499*** (0.000)	58.144*** (0.000)
R Squared	----	0.0945	0.0947	----	0.0689	0.0692	----	0.0778	0.079
F Test	----	15.66	15.805	----	13.71	18.46	----	6.42	11.29
Hausman	----	0.9462	----	----	0.6143	----	----	0.5057	----
Hansen	0.214	----	----	0.161	----	----	0.934	----	----
Nos. of cross section (n)	46	----	----	46	----	----	46	----	----
Nos. of Instruments (i)	27	----	----	27	----	----	27	----	----
Instrument ratio (n/i)	1.704	----	----	1.703	----	----	1.704		

Notes: The lags of the indicators of communication technology were used in all the estimations. The superscripts '*', '**' and '***' denote 10, 5 and 1 percent significance levels, respectively. The Hansen and Serial Correlation tests suggest that the results are not susceptible to a Type 1 error (i.e. producing significant results despite no underlining association between the respective variables). The instrument ratio for the different estimations is expected to be greater than 1, in order to satisfy the condition that the instruments are not proliferated (see Roodman, 2007; Asiedu & Lien, 2011).

4. 2 Further robustness checks

We further estimate several regressions to check the consistency of our main results. For lack of space, we report (in Table 5)[4] only the SGMM estimates that concern the indicators of technological advancement.

(i) Using a different measure of female economic participation.

We run a different regression where our explained variable is measured using the female employment rate as a percentage of female labour force. Using this alternative outcome variable is motivated by the fact that studies have established that this variable is an important policy variable when considering economic participation (Ridgeway, 2011; Kabeer *et al*., 2013). The findings from the estimations are broadly consistent with those established earlier in Tables 3-4, though the significance of the positive effect from fixed broadband subscription is no longer apparent.

(ii) Controlling for countries' level of economic development.

We further include the level of economic development of each country in our estimation. This approach is consistent with Jayachandran (2014) from the perspective that gender discrimination that affects the level of female empowerment is more apparent in poor countries. The corresponding findings (which control for the income levels of countries) are consistent with those established in Tables 3-4, notably, in terms of significance and magnitude of the independent variables of interest on the outcome variable.

(iii) Using contemporary ICT advancement variables

We estimate ICT technology advancement variables within a contemporaneous framework instead of using lagged values. The findings are broadly consistent with those established in Table 3-4, notably in terms of signs. This is essentially because the effect of mobile cellular subscription is marginal compared to the other indicators of ICT advancement.

(iv) Control for countries' internal conflict and political instability

Internal conflict and political instability are important issues that confront some African countries. These policy syndromes affect the stability of the labour market, partly because

[4]We use the specification with all controls as those in Table 4.

economically active individuals are likely to seek employment elsewhere and investments (domestic, private and foreign) will diminish because investors prefer politically stable economies. These scenarios obviously affect the extent of female economic engagement. After controlling for conflicts and political instability, the findings are robust to those established in Table 3-4.

(v) Control for countries' levels of social globalization

Social globalization includes personal contacts by the nationals of a particular country with those of other countries, which culminates in information flow and cultural interaction. With increased social globalization, nationals will be subject to changing values and novel impressions that can demean societal traditional patriarchal beliefs. Therefore, it is possible that the impact of ICT technology advancement on female economic participation can be influenced by these factors of globalization encapsulated in the definition and measurement of social globalization. The control of the KOF social globalization index (Dreher, 2006) is robust to the findings established in Tables 3-4.

(vi) Control for countries' legal origins

There is some consensus on the importance of countries' legal origin in explaining social freedom. One important channel through which legal origin may influence female economic participation is through the impact on minorities in the society (Asongu & Nwachukwu, 2017b). Some legal systems support a conservative interpretation of gender roles (Henning, 2016), compared to others. Following the classification of La Porta et al. (1998) and Siems (2006), legal origins of sampled countries were accounted for to obtained results that are robust to those established in Tables 3-4.

(vii) Using instruments for ICT technology advancement variables

To further ensure the validity of our results, the study increases its bite on endogeneity by controlling for simultaneity in the effect of the independent variables of interest. Though the GMM results presented so far account for simultaneity by means of instrumentation; we consider instrumental variables, such that the second and third lags of the independent variables are used because of constraints in finding external instruments.

An endogeneity test is performed, and the results confirm the underlying endogeneity assumptions. Specifically, the ICT technology advancement indicators are endogenous because their tested residuals were found to be significant at the 1 percent level. Moreover, the results of the reduced form equation[5] suggest that previous lags of the ICT technology advancement indicators are partially correlated with the estimated indicators. Overall, the instrumental variable results are robust to those established in Tables 3-4.

(viii) Including female fertility in the model

Authors like Bloom *et al.* (2009) and Mishra and Smyth (2010) see fertility rate as an important determinant of female labor force participation. The fertility rate can be representative of the extent to which women are more or less tied to their domestic and maternal activities. Moreover, it is indicative of the extent to which women will allocate time to be actively involved in economic activities compared to other domestic activities. As apparent in the last row of Table 5, the findings disclosed in Table 3-4 are also robust to the control of the female fertility rate.

The results in Tables 3, 4 and 5 can be explained by two clear underpinnings that highlight the consequences of labour supply resulting from ICT advancement. First, our results are in line with the theoretical expectation of Bernard and Pelto (1987) that 'technology' advancement affects social desire and propel social value change through advancements in the volume and quality of information accessible to individuals. In this case, certain perspectives[6] that deprive females from participating in the workforce are dropped for a more liberal way of thinking[7]. In part, individuals also abandon patterns of recurrent behavior and thinking that favor male dominance in the workforce due to cross-cultural orientations that are propelled by the advancement of ICT. Therefore the desire for females to be economically active will increase, the information required to seek and secure opportunities will also increase, and the deprivation of females from working (as a result of social dogmas) will further reduce.

[5] The results of these analyses are available upon request.

[6] For instance, there are prevailing accepted norms in some African societies that men are the principal breadwinners and women are the primary caretakers of the family and caregivers.

[7] Tansel (2002) and Lechman and Kaur (2015) acknowledge that certain cultural beliefs, social customs and traditions hinder women's participation in the labour market.

Table 5: Results from robustness checks

Variations	Explanatory Variables	Coefficients	Comments
New explained variable: female employment rate	Internet users	0.589***	Female employment rate is measured as the female employed as % of total female labour force. The main explanatory variable remained positive, except for fixed broadband subscription.
	Mobile cellular	0.085***	
	FixedBband	1.022	
Control for level of income across countries.	Internet users	1.052***	The categorization is based on the World Bank classification of country across income groups. All variables are consistent at the 1% level in terms of sign and significant value.
	Mobile cellular	0.028***	
	FixedBband	3.240***	
Using non lag ICT advancement variables	Internet users	0.264***	The technological advancement variables are computed at contemporaneous values. The variables are consistently signed. However, mobile cellular is no longer significant.
	Mobile cellular	0.002	
	FixedBband	0.513**	
Control for the level of conflict in each country	Internet users	0.920***	Data on conflict was not readily available for the period of interest, and the World Governance Indicator data did not contain the period of our estimation. So we resolved to use Weeks (2012) and Asongu (2014) classification of African countries based on the prevalence of civil conflict and political instability. All the variables were consistently signed and maintained 1 percent significant.
	Mobile cellular	0.083***	
	FixedBband	3.240***	
Control for social globalization	Internet users	0.897***	Data for social globalization are from the KOF Index of Globalization by Dreher (2006). All the components of technology advancement maintained a positive outlook.
	Mobile cellular	0.154***	
	FixedBband	4.291***	
Control for the legal origin of countries	Internet users	0.841***	The La Porta et al. (1998) and Siems (2006) classification of countries based on their legal origins is used for our classification. 1 is for English common law and 0 for other legal origins. Similar results as in Tables 3 and 4 are observed.
	Mobile cellular	0.079***	
	FixedBband	3.577***	
Using instruments of technology advancement	Internet users	0.849**	The second and third lags of the individual technology advancement variables were used as instrumental variables. The significance and pecking order of influence, across the different components of technology advancement was maintained.
	Mobile cellular	0.093***	
	FixedBband	4.490***	
Fertility rate	Internet users	0.851***	The three components of technology advancement were positive and significant. They follow a similar pecking order.
	Mobile cellular	0.090***	
	FixedBband	2.533***	

Notes: The lags of the indicators of communication technology were used for most of the estimations except otherwise stated. The superscripts '*', '**' and '***' denote 10, 5 and 1 percent levels of significance, respectively.

Second, our results correspond to new industry creation and expansion of the service sector, and massive influx of foreign investors into Africa that must have been a consequence of communication technology advancement. For instance, since 2000 the emergence of information technology adoption in Africa has been accompanied with substantial investments in the service sector as well as a considerably increase in foreign investment inflows. To put this point into greater perspective, ICT income in Africa stood at 50 billion US$ in 2011 (Essoungou, 2011). With the income from and investment in the ICT sector projected to continue growing in the future, the demand for and supply of the female workforce is also projected to increase in other sectors including the service sector (ILO, 2016).

5. Concluding Remarks

The study has complemented existing literature by investigating how advancement in information and communication technology affects the formal participation of woman in the economy. The focus is on 48 African countries for the period 1990-2014. The empirical evidence is based on the Ordinary Least Squares, Fixed Effects and the Generalized Method of Moments regressions. The results show that improving communication technology increases female economic participation with the following consistent order of increasing magnitude: mobile phone penetration; internet penetration and fixed broadband subscriptions. The findings are robust to the control for heterogeneities across countries. In what follows, we discuss corresponding policy implications before highlighting future research directions.

In the light of the above findings, high speed internet availability and fixed wireless broadband access to the Internet are imperatives for female economic participation in SSA countries. As a policy implication, while governments of sampled countries need to formulate and implement policies that boost ICT penetration, policy priorities should focus on how to improve women access to fixed wireless broadband communication/internet access, and then the mobile phone wireless communication. Future studies can assess specific policy instruments through which the established inclusive benefits of ICT in female economic participation can be enhanced.

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Appendix 1: List of Sampled Countries

Angola	Congo Rep.	Guinea-Bissau	Namibia	South Sudan
Benin	Cote d'Ivoire	Kenya	Niger	Sudan
Botswana	Djibouti	Lesotho	Nigeria	Swaziland
Burundi	Equatorial Guinea	Liberia	Rwanda	Tanzania
Cameroon	Eritrea	Madagascar	Sao Tome	Togo
Cape Verde	Ethiopia	Malawi	Senegal	Uganda
Central African Rep.	Gabon	Mali	Seychelles	Zambia
Chad	Gambia	Mauritania	Sierra Leone	Zimbabwe
Comoros	Ghana	Mauritius	Somalia	
Congo Dem. Rep.	Guinea	Mozambique	South Africa	

Notes: Congo Dem. Rep: Congo Democratic Republic. Rep: Republic.