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Abstract

This study investigates how technological advancement improves gender identity by means of female economic participation in a panel 48 African countries for the period 1990-2014. Two indicators are used to measure female economic participation, namely, the: female labour force participation and employment rates. Technological advancement is measured with three main indicators, notably: internet penetration, mobile phone penetration and fixed broad band subscriptions. The empirical evidence is based on Ordinary Least Squares, Fixed Effects and System Generalized Method of Moments regressions. The findings show that improvement in technology increases female economic participation with the following consistent order of increasing magnitude: mobile phone penetration; internet penetration and fixed broad band subscriptions. The findings are robust to the control for: countries' levels in economic development; the use of contemporary technology advancement indicators; internal conflicts and political stability; the level of social globalization and the use of alternative instruments. Policy implications are discussed.

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

1. Introduction

Two main trends in contemporary literature motivate this inquiry, notably, the: high potential for information and communication technologies (ICT) in Africa on the one hand and the low participation of the female gender in the labour market on the other hand. First, in accordance with recent literature, compared to other regions of the world which are experiencing ICT saturation, there is much room for ICT penetration in Africa (see Penard et al., 2012; Asongu, 2015a). Building on the evolving literature on the use of ICT for promoting inclusive development (Mishra & Bisht, 2013; Ojo et al., 2012; Alkemade & Surrs, 2012), policy makers can leverage on the ICT potential to address development issues in the continent, *inter alia*: the gender gap in economic participation.

Second, focusing on the vulnerable[1]group of labour market participation, especially women in Africa, the surrounding challenges facing their socio-economic wellbeing is evident. Certainly, this group in most African countries is mostly absorbed in the informal sector, engaged in smallholding farming and consists of the majority of the workforce in the invisible informal activities – such as home-based (non-) economic activities (Ellis et al., 2007; FAO, 2011; Ramani et al., 2013; Tandon & Wegerif, 2013). As a result, issues surrounding female unemployment and the heightened poverty rate that confront them are prevalent policy matters that face women, and raise concern for development practitioners and governments of African countries. Some facts by the International Labour Organization (2013)and World Bank (2015) show that in Sub-Saharan African Countries, the percentage of women in the informal sector is either higher than that of men[2]or their productivity is way lower than that of their male counterparts. In the same vein, more women are facing the poverty incidence more than their male counterparts, as female poverty rate in African countries is still very high. For instance, in countries like Mali, Burkina Faso, Benin and Niger, between 48 and 65 percent of women live in poverty. Moreover, female poverty is marked in Africa, compared to other regions of the World (Hazel, 2010; Women Thrive, 2014).This further corroborates the need to pay special attention to the economic prevalence of this group.

[1] The term vulnerable was used because of customs, traditions or other structural issues that make access to mainstream economic system difficult for this particular segment of the labour market.

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

Chen (2001) clearly presents a background to the origin of the problem that women are confronted with. The author notes that the challenges women face are mainly because they are less able to compete with men in the labour, capital and product markets. Of course, it is because women have relatively low levels of education and skills (apart from their likelihood to own economic resources like land) that they tend to be marginalized. More so, women are constrained by social and cultural norms that assign the responsibility for social reproduction to women and discourage investment in women's education and training (Ramani et al., 2013). This being the case, then it is possible that interventions directed at enhancing access to the labour market, especially for women on the one hand, and those directed at improving the skills, education and cultural liberalism on the other hand, will be beneficial in reducing gender inequality in access to economic opportunities.

In this study, we focus on access to technology as a possible intervention that can play a critical role in reducing the burgeoning challenges that confront women in Africa. Definitely, we clarify two concerns: first, to what extent will the rising rate of technology adoption/usage in Africa affect women's economic participation? Second, if technology has an effect on female economic participation, what are the different impacts across the indicators of technology advancement? On the one hand, we measure female economic participation by focusing on the rate of female involvement in the formal labour force. This variable is considered relevant because it captures the number of women that are involved in formal economic activities. On the other hand, we measure the level of technology advancement across countries using extent of access to mobile phone usage, access to the internet and the level of access to fixed broadband subscription. Our results suggest that though access to technology generally enhances female economic participation in Africa, the impact across the different measures of technology advancement varies. The pecking order distribution of impact is such that the estimated impact is higher for fixed broadband subscription, followed by internet access and then by mobile phone usage. The findings are robust to the control for: countries' levels in economic development; the use of contemporary technology advancement indicators; internal conflicts and political stability; the level of social globalization and the use of alternative instruments.

All three of the components of technology advancement considered in this study might have varying effect on female economic participation in Africa. This assumption is based on the fact that they capture different dimensions of technology and – as will be shown further below – are at best imperfectly correlated with each other. As a result, it is therefore important to examine the individual effect of the different components of technology advancement on female economic participation in Africa. While there exists a considerable literature which examines the impact of technology adoption/usage on women's outcome – like empowerment, inequality, poverty reduction, among others – (Asongu, 2016;Tchamyou, 2016; World Bank, 2015), the literature that considers the individual impact of technology variables on female economic participation within the Sub-Saharan Africa (SSA) region is scanty. Though, female economic participation may be both a product and a driver of technological change within the society, its linkage goes beyond the individual female, to encapsulate the overall development of the country and the region where these variables are considered. Specifically, female economic participation and technology adoption within society can be associated with increasing stock of human capital to drive industrialization, improved innovation from marginalized group that may not have had access to the economic system, improved health of the household - which will affect industrial productivity - and overall change in societal value with regards to women being involved in industrial labour force (Chambalu, 2009; Etuk et al., 2014; Moleketi, 2014). Thus, considering this relationship will have a broader development and policy impact on the African Sub-region.

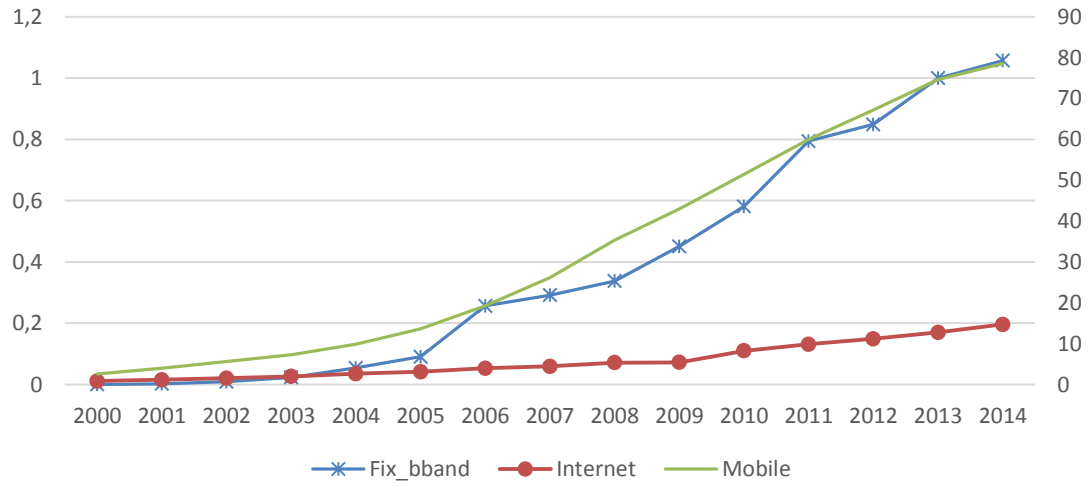
In the light of the above, this study investigates the role of technological advancement in female economic participation in Africa. This inquiry steers clear of recent literature on the use of ICT for inclusive development, notably, in: gender empowerment (Maurer, 2008; Ojo et al., 2012); health access by the population in the low income category (Kliner et al., 2013); the consolidation of financial inclusion (Singh, 2012; Kirui et al., 2013; Mishra & Bisht, 2013; Asongu & Nwachukwu, 2016a); reduction of the rural-urban development gap (Chan & Jia, 2011; Qiang et al., 2011); 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) and consolidation of opportunities for small and medium-size businesses (Ondiege, 2010). The rest of the study is structured as follows. Section 2 discusses the theoretical underpinnings and

empirical literature. The data and methodology are engaged in Section 3 while Section 4 presents the results and robustness checks. We conclude in Section 5 with implications and future research directions

2. Stylized facts, theory and empirical evidence

This section discusses three main relevant strands, namely: stylized facts, theoretical underpinnings and empirical evidence on the use of ICT for development purposes. First, with regard to the stylized facts, one of the main features of the last decade is the rise and growth in technology forms and their usage. This is especially for African countries that have experienced tremendous rise in the use of some technologies like the mobile phone, internet or even fixed broadband subscriptions (See Figure 1). The real effects of the rise in technology spans from economic to socio-cultural advancement and are always lagged. Considering the consequences of an introduction of a particular technology to a country, the outcome is that – all effects will be seen even beyond the initial year of its introduction because of the hysteresis phenomena[3]that is associated with adopting new technologies. Moreover, the extent to which technology adoption influences some segments of the labour market (including vulnerable groups and women in general) represents an interesting economic enquiry.

Figure 1: Some Technology Usage Indicators for SSA (2000-2014)



Note: The axis at the right of Figure 1 is for the fixed broadband usage, while that of the left is for both internet and mobile phone usage per 100 persons.

[3]Hysteresis phenomenon imply that ICT adoption rate is dependent on the past experience of its usage. This of course imply that current ICT adoption rate is defined by past experiences with the usage of such ICT.

Second, concerning the theoretical underpinnings, the relevance of ICT in economic prosperity has been substantially documented in both the literature on management and economic sciences (Asongu et al., 2016). According to the narrative, there is two-way causality between technological advancement and development: economic and human. Contrary to neoclassical development models that classified both technology and knowledge as public commodities that are strictly exogenous to the economic system, the new model of economic development is based on the endogenous perspectives and neo-Schumpeterian economic development views (Howells, 2005). Consistent with the new models of growth, growth in technology is the result of efforts by citizens via the mobilisation of essential resources that are associated with human capital (Romer, 1990).

The new growth theory views technology within the framework of private goods that are excludable. Furthermore, knowledge generation which is linked to the development of new intellectual property and benefits from technology is considered as a private commodity (Solow, 1994). Whereas private technologies (such as patent rights) have been supported in some economic development models, there are also positions in the literature which support the view that rents from monopolistic power are not permanent (Uzawa, 1965). Romer (1990) maintains that technological progress can take both exogenous and endogenous characteristics, essentially because some technological features determine whether a technology would be transformed into a public commodity as time unfolds. According to the narrative, because of cross-country spillovers in technology, the benefits from technology by countries vary. Hence, progress in technology could engender disequilibrium in human and economic development processes, which elucidate cross-country variations in economic prosperity (Verspagen, 1997). This position is supported by Rosenberg (1972) from the perspective that the ability to apply new technologies for the purpose of production is imperative to elucidating economic development. Therefore, technology outcome can be leveraged for the purpose of inclusive development.

ICT-related outputs translate important drivers of inclusive development at the business and national levels because they influence a plethora of features which constitute, *inter alia*, more ICT progress[4]. In essence, an important element for progress in ICT for human development is a

[4] It is important to note that, in addition to easing the doing of business (Kumar & Zahn, 2003; Kuoa &Yub, 2006; Jin & von Zedtwitz, 2008; Lee et al., 2010), the ICT-related outputs are also linked to non-exclusive development.

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 in order to increase her economic participation, which is the focus of this inquiry.

Third, by engaging the present inquiry, this study 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 the poverty-reducing externalities of ICT, to the best of our knowledge, very little is known about how such technological advancement elicit evolving gender identities by means of 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.

By positioning the inquiry on female economic participation and contributing to the macroeconomic literature on ICT management for non-exclusive development, the paper steers clear of mainstream technology management literature that is focused on microeconomic and corporate ICT innovation. In essence, some recently addressed themes are: opportunity discovery in disruptive innovation (Hang et al., 2015; Wan et al., 2015); improvement of institutional quality (Asongu & Nwachukwu, 2016b); identification of entrepreneurial avenues by scientists (Maine et al., 2015); evolving ecosystems (Overholm, 2015); involvement of innovators in entrepreneurship that build on growing resources and financial skills (Best, 2015); available business avenues owing to an ageing population (Kohlbacher et al., 2015) and innovations in technology for new opportunities as a result of patent road-mapping (Jeong & Yoon, 2015).

Our study also 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: Gupta & Jain, 2012) countries.Within this framework, this inquiry is closest to an evolving body of studies on the relevance of ICT for social change (Islama & Meadeb, 2012; Brouwer & Brito, 2012; Mira & Dangersfield, 2012),especially ICT improvements for inclusive development (Asongu & Nwachukwu, 2016c).

3. Data and Methodology

3.1 Data

The objective of this study is to assess the impact of technology advancement on female economic participation in Africa. Two indicators are used to measure female economic participation, namely, the: female labour force participation rate and female employment rate. The choice of the indicators is consistent with Signorelli et al. (2012) and Elborgh-Woytek (2013). The female labour force participation rate represents the proportion of females in the labour force that are aged 15 to 64 by the total working age population (World Bank, 2016). The female employment rate on the otherhand refers to the proportion of the female labour force that is available for work and currently gainfully employed. Both measures are used for robust checks. However, the female labour force participation rate is used as our primary outcome variable because it is generally considered a better indicator of economic participation, unlike the employment rate. Also, it is more representative of the number of women that are involved in economic activities. The data is obtained from the International Labour Organisation (ILO)key Indicators of the Labour Market and the World Bank's World Development Indicators.

The technology advancement variable is measured using three main indicators -fixed broadband subscription, the internet usage per 100 persons and the mobile phone usage per 100 persons. The fixed broad band subscription per 100 persons measures the total number of subscribers to broadband technologies (such as cable modem, fiber optic connections and other form of broadband lines) with download speeds of 256 kilobits or greater. The internet connection and mobile phone describe the proportion of individuals who have used the internet and mobile cellular subscriber from any location in the past year. We used these measures of technology advancement because of the following reasons: (i) they cover a wider and complete data span unlike other measures of technology advancement like access to personal computers, ICT imports, among others; (ii) they fit the main theme of the inquiry. In essence, the measures easily describe technologies that can reduce social stereotypes on the role of women in the economy through social interactions and can inform policy on the economic participation of women; (iii) they are resounding policy variables – for instance, most policy documents that address the need to encourage technology advancement in Africa have considered these three variables as

important (International Telecommunication Union, 2009; African Development Bank, 2014). Data for the technology advancement variables are gotten from the World Bank's World Development Indicators. It is important to state that the lag component of these variables was used in the econometric estimation because of the time lag that technology requires to diffuse (see Wang et al., 2006; Fanelli & Maddalena, 2012)

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 extent of democracy. Following arguments from the literature, the degree of trade liberalization and the remaining three control variables are expected to have a significant impact on female economic participation (Pampel & Tanaka, 1986; Gaddis &Peters, 2012; Abe et al., 2016). The control variables are chosen to best control for a wide range of factors that the literature suggests might influence female economic participation across countries. In addition, the estimation technique that is applied in this study is intended to control for time invariant differences between countries and country-invariant changes over time. These variables are sourced from World Development Indicators of the World Bank. The variable on democracy was 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 consists of 48 African countries for the period 1990-2014. Thus, it comprises of 1,152 individual country-year observations. On the average, about 61 percent of the women in the sampled countries are participating in the labour force. On the average, more persons have access to mobile phone technology than internet and the fixed broadband connection. The descriptive statistics of the other control variables are also included in Table 1.

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 persons)	20.32	32.84	0.00	214.75
The internet usage (# per 100 persons)	4.29	7.99	0.00	54.26
Fixed broadband subscription (# per 100 persons)	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

The pairwise correlation analysis is further presented in Table 2 in order to provide a clear bivariate relationship that may likely exist among the variables of interest. More so, the pairwise correlation helps to identify possible issues of multicollinearity that might exist among the variables. Two important points are observed from the table. First, it is evident that the three indicators of technology advancement have a significant and positive association with the main explained variable. The association is stronger for fixed broadband subscription and internet usage than it is for mobile phone usage. Although the correlation analysis is a bivariate estimation, it suggests that fixed broadband subscription and internet usage may have a stronger effect on female economic participation compared to mobile phone usage. This prediction will be verified in further econometric estimations. Second, there are no issues of multicollinearity that exist among the explanatory variables. This is except for the technology advancement indicators that have high correlation coefficients among themselves. In order to take account of this correlation, the technology advancement variables will be included in the regression model in a stepwise form.

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 the length of the variable names and 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 imply labour force participation rate, mobile phone usage, internet usage, fixed broadband subscription, trade liberalization, per capita income, foreign direct investment inflow and democracy.

3.2 Methodology

Three estimation techniques are adopted in order to assess the relationship between technology advancement and female economic participation, namely: a baseline Ordinary Least Squares (OLS); Fixed Effects (FE) and the Generalized Method of Moments (GMM). The second and third have some bite on endogeneity by respectively controlling for the unobserved heterogeneity (or country fixed effects) and simultaneity (reverse causality). Equations corresponding to the three estimation approaches are provided below.

Ordinary Least Square

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

Fixed Effects Model

$$Female\ Economic\ Participation_{i,t} = \beta + \alpha.Technology\ Advancement_{i,t-1} + \partial.Year_t + \delta.Country_i + \varepsilon_{it} \quad (2)$$

System Generalized Method of Moments

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

$$Female\ Economic\ Participation_{i,t} = \beta + \Phi.Female\ Economic\ Participation_{i,t-1} + \alpha.Technology\ Advancement_{i,t-1} + \eta_i + k_t + \varepsilon_{it} \quad (3)$$

Equation 4 is the SGMM equation with additional moment conditions: it entails computing the first difference of equation (3), which eliminates the time- and country- specific fixed effects. The equation will take the following form:

$$Female\ Economic\ Participation_{i,t} - Female\ Economic\ Participation_{i,t-1} = \alpha + \acute{\alpha}(Technology\ Advancement_{i,t} - Technology\ Advancement_{i,t-1}) + \partial(Female\ Economic\ Participation_{i,t-1} - Female\ Economic\ Participation_{i,t-2}) + \theta(k_t - k_{t,1}) \quad (4)$$

The specifications use an OLS framework with both country and year fixed effects or system GMM (SGMM), which mitigate many of the concerns of potential omitted variable bias. The advantage of using this battery of methods over analyzing cross-sectional variation with a single method is to enable control for country-specific, time-invariant, unobserved heterogeneity issues that could lead to bias in standard estimators like OLS. Country fixed effects help control for any time-invariant and country-specific factors. The system GMM eliminates country-specific, time invariant factors and it has an additional benefit of alleviating concerns that are related to serial correlation. Specifically, the two-step SGMM estimator is applied: this technique is asymptotically efficient and robust to all forms of heteroscedasticity. The SGMM takes the first difference of the variable and the lagged values of the endogenous[5] variables as instruments. Additional moment conditions are used to ensure the efficiency of the instruments applied. To

[5]The endogeneity problem is expected since the model will likely contain unobserved panel-level effects that are correlated with the lagged dependent variable.

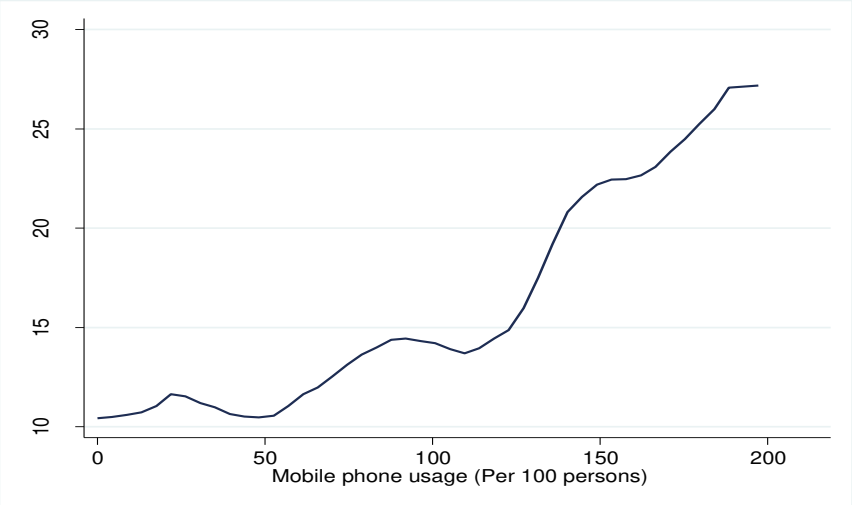
check for the presence of instrument proliferation, which is a major weakness of the SGMM estimation, the Hansen and serial correlation tests are performed, as well as the instrument ratio.

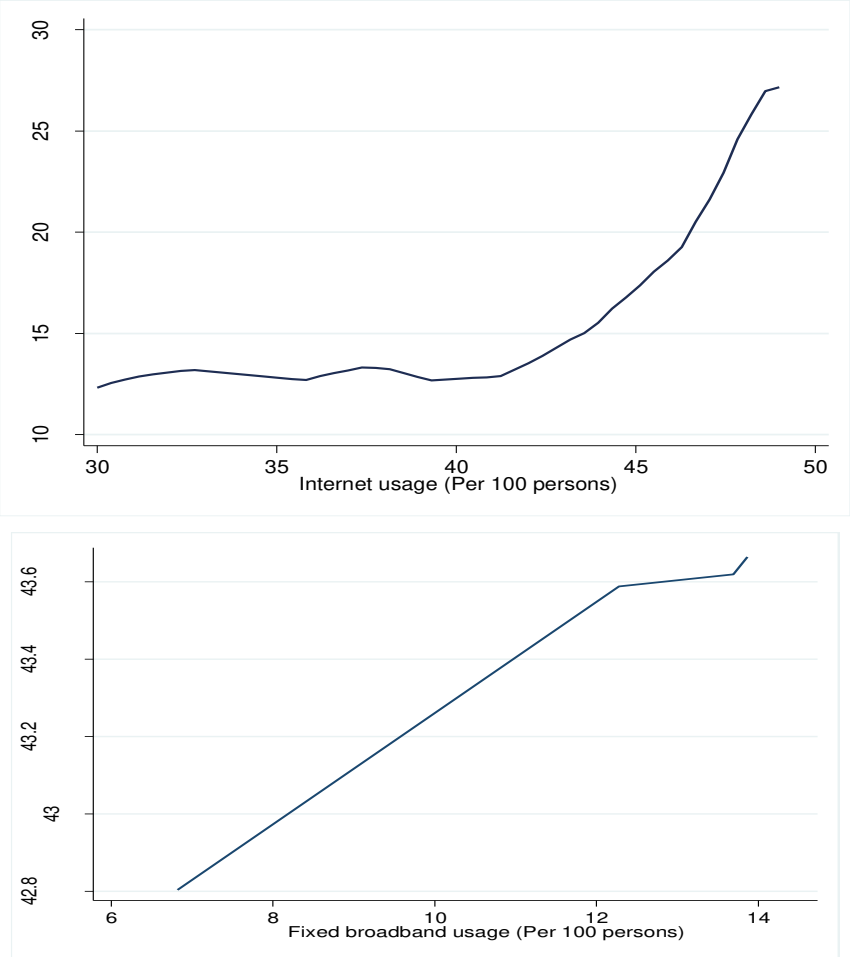
4. Empirical results

4. 1 Presentation of results

The presentation of the empirical results begins with Figures 2a-c that displays the non-parametric regressions (based on the local polynomial regression). This preliminary analysis fits the relationship between the different components of technology advancement and female economic participation for our sampled countries. These figures reveal that the relationship appears positive, quite pronounced and mostly linear for the fixed broadband subscription. For mobile phone usage and internet usage, the relationship seems quite strong, but not at the same magnitude as fixed broadband subscription. In the former two cases, it seems that the association is flat for the least technology advanced countries, before becoming strongly positive.

Figure 2: Different Components of Technology and Female Economic Participation (1990-2014)





The baseline parsimonious regression of the individual variables that represent different aspects of technological advancement without controlling for other control variables are presented in Table 3. The estimates in Table 3 are gotten from a battery of estimation techniques to enhance comparison and for sensitivity checks. There are several noticeable facts from the estimation: first, the coefficients of each of the technological advancement variables are positive at the 1 percent level in all the regressions. In addition, these coefficients are stable across the estimation techniques, suggesting that all else equal, technological advancement has a favorable and robust effect on female economic participation (proxied with labour force participation). Second, in case of ranking the effect, it is evident that fixed broad band subscription per (100 persons) has a higher effect on female economic participation than its *contemporaries*. From Table 3, a one standard deviation increase in fixed broad band subscription in previous year (*sd* = 1.850, see Table 1)will increase female labour force participation by about 5.308 percentage points based

on the SGMM estimates [$^{\vartheta \text{Lfprate}}/_{\vartheta Fixed\ bband} = 2.869 \times 1.850 \approx 5.308$]. These amounts to an increase of 3.038 female labour force participation rate for the average sample country, whose fixed broad band subscription per 100 persons in the previous year is 0.5724. For the internet and mobile cellular users, as tandard deviation increase will improve female labour force participation by about 4.07 and 2.95 percentage points, respectively.

An example is used in this study to provide a clearer perspective on the importance of technology advancement in female economic participation. Specifically, two African countries are considered "Sudan" and "Mauritius", because they are at the extremes of highest and lowest technological advancement in terms of fixed broad band subscription per 100 inhabitants. The average (1990-2014) fixed broad band subscription per 100 inhabitants in Sudan is about 0.049, compared to Mauritius that has about 6 individuals with access to this kind of technology. The estimation results (for fixed broad band subscription) as in Table 3 shows that an increase in the level of technological advancement from the level of Sudan to that of Mauritius will increase female economic participation by about 20.27 percentage points in the long run.[6]This increase in female economic participation is quite important, because the female economic participation for Sudan over the period 1990-2014is about 29.276 (see Table 1).

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		

[6] This computation follows the reasoning of Asiedu (2013) and from the fact that a long-run effect of a Δ (change) in technological advancement on female economic participation is given by $(\hat{\alpha} \times \Delta)/(1 - \hat{\rho})$, where $\hat{\alpha}$ is the estimated coefficient of technological advancement and $\hat{\rho}$ is the estimated coefficient of the lag of female economic participation. Δ is the difference in average technological advancement between Sudan (0.049) and Mauritius (5.567) and $\hat{\alpha}$ from the Table is 2.869, while $\hat{\rho}$ is 0.219.

Note: The superscripts '***' imply 1 percent level of significance. The Hansen and Serial Correlation test suggest that the results are not susceptible to a type 1 error (i.e. producing significant results despite there are 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 that the instruments are not proliferated (see Roodman, 2007; Asiedu &Lien, 2011).

This study goes further to consider the relationship between the main variables of interest when controlling for other heterogeneities (see Table 4). It is important to note that we follow a similar pattern as in Table 3 by separately including the main explained variables in our regression analysis in order to reduce possible multicollinearity problems[7] among the three technological advancement variables.

We now turn our attention to the signs and significant values of the coefficients corresponding to the technological advancement variables. Three mainpoints are apparent from Table 4: (i) there were not many changes observed in the coefficients of the individual variables – internet subscription, mobile cellular subscription and fixed broad band subscription (all per 100 persons) – when all the control variables are added. (ii) The coefficient of each of the variables of interest still maintains the pecking order that fixed broad band subscription and internet subscription are the most important technology variables that positively affect female economic participation in Africa. They both have the largest point estimate and retain their statistical significance. The mobile cellular subscription maintains its positive impact; however, the size of the coefficient is marginal. Interestingly, the World Bank (2016) report maintains this pecking order; the report notes that broad band subscription and the internet have the highest impact on the economy compared to mobile cellular. (iii) As expected, the control variables carry the expected signs and significant in most of estimations. For instance, openness of a country (trade as a % of GDP), the income per capita, the volume of foreign direct investment, and the strength of a country's democracy have positive and significant impacts on female economic participation. Thus, these variables are important to drive the level of female economic participation in Africa.

The results in Tables 3 and 4 can be explained with three clear underpinnings. First, the result matches the theoretical expectation of Bernard and Pelto (1987) that technology advancement affects social desire and propel social value change through advancement in the volume and

[7] The presence of multicollinearity will definitely bias our result.

quality of information accessible to individuals. In this case, certain perspectives[8] that deprive females from participating in the workforce are dropped for a more liberal way of thinking[9]. In part, individuals abandon patterns of recurrent behavior and thinking that favor male dominance in the workforce due to cross cultural orientations that are propelled by technology advancement. Therefore the desire for females to be involved in economic activity will increase and the deprivation of females from working (as a result of social dogmas) will further reduce. Second, the result corresponds to new industry creation and expansion of the service sector, and a massive influx of foreign investors into Africa that must have been a consequence of technology advancement. For instance, since 2000 at the emergence of information technology adoption in Africa, there has been huge growth in the investment in the service sector and even foreign investment inflow. It is estimated that annual ICT revenue in Africa was 50 billion US$ in 2011, acquisition of assets worth 8.8 billion US$ and 10.7 billion US$ was observed for France Telecom company and India's Bharti PLC (Essoungou, 2011). With this massive investment in technology-driven sectors, it is pertinent to note that apart from the agricultural sector, the service sector in Africa has largely absorbed female workforce (for details, see ILO, 2016).

Third and important is the rise in small businesses that come with increased technology. Grater et al. (2016) also note that the rise in technology has created booming small businesses, which is a key driver of job creation and inclusive growth. In this sense, technology advancement (like ICT and internet speed) provides economic opportunities to both urban and rural populations and increases the productivity of small businesses in these areas and as well as increase market efficiency. It is apparent that technology advancement informs growth, productivity and enlargement of small business investment (World Bank, 2016).Therefore, a boost in the technology and the massive investment that comes with it will naturally explain the increase in female economic participation through social conception change, foreign investment inflow and small business expansion.

[8] 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.

[9]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 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		

Note: The superscripts '*', '**' and '***' imply 10, 5 and 1 percent level of significance, respectively. The other information at the bottom of Table 3 are also applicable here.

4. 2 Robustness Checks

We run several regressions to test the consistency of our main results: that the extent of female economic participation in Africa will improve with the level of technological advancement. For lack of space, we report only the values of $\hat{\beta}$(i.e. indicators of technological advancement) in Table 5 in order to keep the discussion focused. The tables contain the estimates from the SGMM technique, while the OLS and fixed effect estimates were not reported because the signs and coefficient of the variables of interest were consistent across the techniques in Tables 3 and 4. More so, the discussion of this paper was based on the SGMM technique due to its merit over the OLS and FE (especially with regards to endogeneity and simultaneity issues).We use the specification with all controls (that is, corresponding to those in Table 4). A brief preview of the outcome from the robustness checks shows that our results are robust: the three indicators of technological advancement maintained a consistent positive and significant relationship with female economic participation. Despite this outcome, an interesting pattern to note is: controlling for the level of social globalization, country income level and internal conflict, will result in a very high impact of technology advancement variables on female economic participation. This suggests that these three variables are important indicators that can improve the outcome from technology advancement on female economic participation.

(i) Using a Different Measure for Female Economic Participation: we run a different regression where our explained variable was measured using a different indicator –female employment rate as a percentage of female labour force. This variable is considered as the rate of females who are members of the economically active population, but with work and are available for work. The choice of this variable as an alternative measure of female economic involvement is motivated based on two reasons: it is an important policy variable that can easily be influenced for policy actions. Thus, it will be more relevant to test the stability of our results with this kind of variable. Second, this variable has gained credence in some studies focused on female economic involvement: they find that the employment status of women is a key mechanism for promoting gender equity, which can leverage change in other domains (Seguino, 2007; Ridgeway, 2011; Kabeer et al., 2013). Also, Signorelli and Marelli (2012) considered unemployment status of women in addressing the impact of the global economic crisis on female economic participation, using a global dataset. Clearly, the results of the robustness test are the

same as in the earlier estimation, as most of the variables of interest maintain a positive and significant relationship with the new explained variable. The significant level is at one percent (see Table 4.4).

(ii) Control for Countries' Level of Economic Development: another important sensitivity check was performed where the level of economic development of each country was controlled for in the estimation. Jayachandran (2014) notes that gender discrimination that affects the level of female empowerment is more apparent in poor countries. This therefore suggests that the level of female economic participation will most likely vary across a country's income level and this supposedly would explain the level of gender discrimination. Therefore it is possible that our result may change if we control for the income level of countries in our regression analysis. Evidently, our results are robust to controlling for the level of income in the regression model. The signs and significant values of the three indicators of technology advancement maintained a consistent outlook as in Tables 3 and 4. Attention should be drawn to the probability value of fixed broadband subscriptions, which was not significant in this test. However, we are not concerned about this because the sign and magnitude of the coefficient was not too different as in Tables 3 and 4.

(iii) Using Non-lag (or Contemporary) Technology Advancement Variables: the third robustness concerns the use of non-lag technology advancement variables, where the variables are estimated at contemporaneous values instead of lagged values. The essence of this check is to ensure that the results from our study are not informed by the lagged component of the technology advancement variables. In this case, the result remained stable. The signs and value of the coefficient maintains that fixed broadband subscription and internet users are the most important technologies that spur female economic engagement. Mobile cellular subscription was positive, however, the value of the coefficient was lower than the former in Tables 3 and 4.

(iv) Control for Internal Conflict and Political Instability: internal conflict and political instability are important issues that confront some African countries. As a result, there will be rising labour market instability and those individuals who may be economically active will likely get displaced. This situation will obviously affect the extent of female economic engagement. To

address this issue and ensure that our results are not driven by country's specific conflict and political instability, we will be controlling for this variable in our SGMM estimations. Internal conflict and political instability are measured based on Asongu (2014) and Weeks (2012) classification of countries based on the occurrence of internal conflict. Their classification was preferred because it was based on a strong argument that reflects peculiar African countries' experiences. For instance, the authors' classification took into cognizance episodes of civil war and the severity of internal strife that helps to determine the degree of significance and periodicity of instability within a country. The result did not change; the magnitude of the coefficients and their respective significant values still maintain a positive and significant relationship between female economic participation and technology advancement.

(v) Control for the Level 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 traditional patriarchal beliefs upheld by societies. Therefore, it is possible that the impact of technology advancement diminishes when this important variable is included in the regression model. We try this robustness by including the KOF social globalization index (Dreher, 2006). The multidimensional nature of this index and its longer periodicity are the merits for choosing this index. The results from the robustness estimations in Table 5 suggest that the estimates are robust; the values of technological advancement are significant at the one percent level and have the correct signs as in Tables 3 and 4.

(vi) Control for Countries' Legal Origin: consensus is reached with regards to 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, 2016d). Some legal system supports a conservative interpretation of gender roles (Henning, 2016), compared to others. Following the classification of La Porta et al. (1998) and Siems (2006), the legal origin status of our sampled countries was included in the econometric model, and then the SGMM technique was re-

estimated. The results of this process are in Table 5. Evidently, the technology advancement variable maintained similar sign and significant values as in Tables 3 and 4.

(vii) Using Instruments for Technology Advancement Variables

To further ensure the validity of our results, this study takes the assumption of endogeneity concerns further, especially through our technology advancement indicators. Intuitively, the extent of technology development in respective countries and in a particular period, are more likely to have economic and innovative effects. For instance, it may influence the springing-up of some other industries that can use current technology to create other forms of technology. However, it will be unrealistic to assume the relationship between technology and female economic participation without considering these other effects. Despite the use of SGMM estimation in dealing with possible endogeneity issues, we delight in considering specific instrumental variable estimations (IV), where the second and third lag of the individual technology advancement variable was used as our instrumental variables. The instruments were chosen due to the general difficulty in identifying efficient instruments and based on the intuition that they effectively capture past specific issues that affects technology within the countries. To confirm the endogeneity assumptions, the study performs tests for endogeneity, which assuages some of the concerns related to the need to further perform instrumental variable estimations. Specifically, the technology advancement indicators were endogenous because their tested residuals were found to be significant at the 1 percent levels of significance. More so, the results of the reduced form equation[10]suggest that previous lags of the technology advancement indicators are partially correlated with the estimated indicators. Clearly, the results from the IV estimations in Table 5 show similar results as in earlier estimations and robustness checks. The indicator for the fixed broadband subscription maintained its significance and the highest coefficient compared to the other two technology advancement variables.

[10] The results of these analyses can be obtained from the authors on request.

Table 5: Results from Robustness Checks

Variation	Explanatory Variables	Coefficient.	P values	Comments
New Explained Variable Female employment rate	Internet users	0.589***	(0.000)	Female employment rate is measured as the female employed as % of total female labour force. The main explanatory variable remained positive, except for fixed broad band subscription.
	Mobile cellular	0.085***	(0.000)	
	FixedBband	1.022	(0.154)	
Control for level of income across countries.	Internet users	1.052***	(0.000)	The categorizationis based on the World Bank classification of country across income groups. Asongu (2014 and 2015) applied this classification in checking heterogeneity across countries. All variables were consistent at the 1% level in terms of sign and significance.
	Mobile cellular	0.028***	(0.008)	
	FixedBband	3.240***	(0.001)	
Using non lag technology advancement variables	Internet users	0.264***	(0.000)	The technological advancement variables were computed at contemporaneous values. The variables were consistently signed. However, mobile cellular was no longer significant.
	Mobile cellular	0.002	(0.491)	
	FixedBband	0.513**	(0.049)	
Control for the level of conflict in each country	Internet users	0.920***	(0.000)	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 significance.
	Mobile cellular	0.083***	(0.000)	
	FixedBband	3.240***	(0.001)	
Controlfor Social Globalization	Internet users	0.897***	(0.000)	Data for social globalization was gotten from the KOF Index of Globalization by Dreher(2006). All the components of technology advancement maintained a positive outlook.
	Mobile cellular	0.154***	(0.000)	
	FixedBband	4.291***	(0.001)	
Control for Legal origin of Countries	Internet users	0.841***	(0.000)	Asongu (2014) classification of African countries based on their legal origin was used for our classification. Where 1 is for English common law and 0 for other legal origins. Similar result as in Tables 3 and 4 were observed.
	Mobile cellular	0.079***	(0.000)	
	FixedBband	3.577***	(0.006)	
Using Instrumental Variable for the Technology Advancement Variables	Internet users	0.849**	(0.013)	The second and third lag of the individual technology advancement variableswere used as instrumental variables. The significance and pecking order of influence, across the different components of technology advancement was maintained.
	Mobile cellular	0.093***	(0.000)	
	FixedBband	4.490***	(0.635)	

Note: The superscripts '*', '**' and '***' imply 10, 5 and 1 percent level of significance, respectively.

5. Concluding implications and future research directions

This study has investigated how technological advancement improves gender identity by means of female economic participation in a panel 48 African countries for the period 1990-2014. Two indicators are used to measure female economic participation, namely, the: female labour force participation and employment rates. Technological advancement is measured with three main indicators, notably: internet penetration, mobile phone penetration and fixed broad band subscriptions. The empirical evidence is based on Ordinary Least Squares, Fixed Effects and System Generalized Method of Moments regressions. The findings show that improvement in technology increases female economic participation with the following consistent order of increasing magnitude: mobile phone penetration; internet penetration and fixed broad band subscriptions. The findings are robust to the control for: countries' levels in economic development; the use of contemporary technology advancement indicators; internal conflicts and political stability; the level of social globalization and the use of alternative instruments.

In the light of the above findings, the comparatively high positive effects from fixed broadband and the internet imply that a mobile phone is a necessary but not a sufficient ICT condition for women economic participation. Hence, high speed internet availability and fixed wireless broadband access to the internet are also imperative in order for the female gender to benefit in terms of economic participation as much as possible. As a main policy implication, while governments of sampled countries need to formulate and implement policies that boost ICT penetration, policy priorities are the following in order of increasing relevance: mobile phone penetration, internet penetration and fixed wireless broadband access. The selective policy recommendation is motivated by two main factors. On the one hand, in terms of the magnitude of ICT relevance in increased female economic participation, the same order has been established in the findings. On the other hand, from the summary statistics, the mobile penetration is low (20.32 per 100 persons); the internet penetration is lower (4.29 per 100 persons) whereas fixed wireless broadband access is lowest (0.57per 100 persons). Apart from the ICT-specific policies, universal ICT coverage schemes are necessary through the provision of the much needed infrastructure and low pricing mechanisms. Moreover, the role of wireless internet connection as an interface between the mobile phone and female entrepreneurs can be

consolidated by designing ICT policies to facilitate, *inter alia*: interactions, cost effectiveness, adoption, efficiency, reach and access.

The principal contribution of this inquiry to theoretical literature is the role of information sharing in mitigating information asymmetry that is associated with the low participation of women in economic activities. In essence, the engaged ICT channels are valuable information sharing mechanisms that help reduce costs and increase benefits associated with the search for employment, extension of existing business structures and development of new enterprises by the female gender. Hence, the ICT channels can reduce informational rents that previously prevented the female gender from engaging in economic activities. Ultimately, it is reasonable to infer that ICT channels improve the efficiency of economic participation by the female gender. The theoretical underpinnings of such efficiency is broadly consistent with the role of information sharing offices (public credit registries and private credit bureaus) in ensuring financial intermediation efficiency within the banking sector (see Claus & Grimes, 2003). With this analogy in mind, the theoretical perspective of increasing banking sector efficiency by means of information sharing offices may be similar to the view ofincreasing efficiency in the female gender's economic participation by means of information sharing ICT devices. The underlying theoretical standpoints have a common denominator of reducing information asymmetry in the banking market and labour market respectively.

Future studies can assess how the established findings withstand empirical scrutiny when viewed within broader frameworks of youth unemployment and entrepreneurship. This recommendation for future research builds on the factthat the population of the African continent is projected to double by 2036 and represent about 20% of the population in the world by 2050 (UN, 2009). Leveraging on the ICT penetration potential in Africa may go a long way to addressing the apparent policy syndrome of unemployment because such unemployment has been documented to be more associated with the private sector in the long term (see Asongu, 2013). In other words, in the long run unemployment resulting from the burgeoning African population would not be accommodated by the public sector.

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