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Female participation in African labor markets: The role of information and communication technologies

Gaston Brice Nkoumou Ngoa [a,b,*], Jacques Simon Song [b]

[a] University of Fribourg, Department of Economics, Boulevard de Pérolles 90, 1700, Fribourg, Switzerland
[b] University of Dschang, Faculty of Economics and Management, P.O Box: 110, Dschang, Cameroon

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ABSTRACT

This article investigates the effects of information and communication technologies (ICT) on female labor force participation in a sample of 48 African countries. We specify and estimate linear regression and dynamic panel data models with fixed effects (FE) and system-generalized method of moments (SYS-GMM) estimation over the period 2001–2017. The three main results are that ICT use (mobile phone and internet) significantly stimulates female labor force participation in Africa; this effect is enhanced by financial development and female education; the effect of ICT on female employment in Africa is strongest in the industrial sector. These results remain robust to the provision of social, cultural, and institutional variables.

1. Introduction

Half of adults in the world, and therefore potentially half the labor force, are women (Pimkina & De la Flor, 2020). Their participation in the labor force is essential and an important driver of growth and development. Economies tend to grow faster as more women enter the labor force, because of higher labor inputs. At the micro level, female participation in the labor market helps families escape poverty by increasing household incomes and their consumption of goods and basic services (Verick, 2018). In addition to these benefits in terms of growth and poverty reduction, female labor force participation is seen as a marker of decreased sex discrimination and increased empowerment of women (Shirazi, 2012). Female labor force participation furthermore could be a major contributor of the demographic dividend due to declining fertility and then, the growing share of working age population relative to dependents (Klassen et al., 2012).

As information and communication technologies (ICT)[1] have proliferated over the last decades, they have emerged in African countries as a great opportunity for marginalized groups, notably women, to decrease gender inequalities as laid out in the fifth United Nation's sustainable development goal (International Telecommunication Union, 2019). Indeed, not only do ICT have an increasingly important role in empowering women and financial inclusion, they also increase the transparency of labor market information and increase female participation by making it easier for women to balance work and family duties (Chun & Tang, 2018; Roztocki et al., 2019).

* Corresponding author. University of Fribourg, Department of Economics, Boulevard de Pérolles 90, 1700, Fribourg, Switzerland.
E-mail addresses: bnkoumou@yahoo.fr, gaston.nkoumoungoa@unifr.ch (G.B. Nkoumou Ngoa), sonjacques@yahoo.fr (J.S. Song).

[1] Information and Communication Technologies (ICT) is a broader term for Information Technology (IT), which refers to all communication technologies enabling users to access, retrieve, store, transmit, and manipulate information in a digital form.

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Women can in theory gain from ICT proliferation in several ways. The most obvious is through the direct creation of jobs in the ICT sector for female specialists (Raja et al., 2013). ICT can also make labor markets more transparent, flexible, innovative and inclusive, making it easier for women to find jobs and for employers to find skilled workers among women (Buller et al., 2020; Raja et al., 2013), because better access to job market information enhances the job search process. Moreover, ICT can increase female employment through online contracting, improving women's access via internet-based employment exchanges and platforms. Another possibility is that ICT may empower women, helping them to overcome socioeconomic and cultural barriers that may otherwise have excluded them from the labor market. In addition, good ICT access provides women with greater work-life flexibility by allowing them to work remotely, from home or elsewhere and helping them overcome time or space costs (Suhaida et al., 2013). Finally, the proliferation of ICT may reduce production costs and create new investment and work opportunities (Raja et al., 2013).

However, these potential positive effects of ICT on female labor force participation may be outweighed by job destructions due to the higher labor productivity that ICT can enable within firms (Kılıçaslan & Töngür, 2019). This labor-saving effect of ICT may be concentrated in low- or middle-skilled jobs where ICT are complementary with human capital (Michaels et al., 2014). Finally, the overall effects of ICT on female employment outcomes are therefore not straightforward to determine and must be determined empirically.

Women in the developing world have been accumulating skills over the past three decades at an unprecedented pace. Fertility rates have declined in parallel, leading to smaller household sizes and reducing childcare and other domestic burdens (Klassen et al., 2021). In combination with economic growth, women should have entered the expanding labor market. However, this has not occurred everywhere and recent progress in closing the gender gap in labor force participation has been disappointing. Notwithstanding considerable regional heterogeneities, the average increase in female labor force participation has been modest (Klasen et al., 2021).

In Africa, although female labor force participation has increased over the past three decades (Fig. 1), women still have an opportunity deficit with respect to men in economic participation (WDI, 2020; Fabrizio et al., 2020). In terms of labor market productivity and growth potential, this lower female participation rate constitutes a reserve of untapped resources (Bustelo et al., 2019). Bringing more of this resource to the market should have substantial positive impacts on GDP. One way this could be achieved is through the proliferation of ICT.

Indeed, even though Africa is the continent where ICT usage rates are the lowest worldwide,[2] ICT use has grown rapidly since the end of the 1990s. Countries like Botswana, South-Africa and the Seychelles already had more than 150 mobile-cellular subscriptions per 100 inhabitants in 2018, up from just 2 per 100 up from around 2 per 100 at the turn of the century. Similarly, in countries like Tunisia, Morocco and Gabon more than 60% of individuals were using the internet in 2017 compared with less than 2% in 2000.[3] This situation is attracting attention from academics and policy makers who want to understand the ways in which ICT use affects the labor market outcomes of African women, who are often forced to drop out of the labor force because of family commitments (Cameron et al., 2019; Suhaida et al., 2014).

Several empirical studies have examined the effects of ICT on the socioeconomic and environmental dimensions of development (Avom et al., 2020; Livingstone, 2012), including on labor market outcomes (Eyike Mbongo, 2019; Hjort & Poulsen, 2018; Samargandi, 2019). However, little is known about the effect of ICT on female labor participation at the continent level, especially in Africa. The contributions of this research are threefold. First, it reveals whether and how ICT influences female labor force participation. This is important to inform economic gender inclusion policies. Second, this article adds to the literature on ICT externalities in labor markets, through the verification of transmission channels. Indeed, this study explores both direct and indirect effects of ICT on female labor force participation, with results indicating that ICT improves female employment through its positive effects on financial development and female education. Finally, this study sheds light on the sectorial employment changes associated with the spread of ICTs. This provides information on the economic activities that are most correlated with ICT use in Africa.

After estimating a panel fixed effect model and a dynamic panel data model using the system generalized method of moments over the period 2001–2017, our results based on data from 48 countries clearly show that increases in ICT use are significantly and strongly associated with increased female labor force participation in Africa, and that this effect is mediated by financial development and female education. This study also shows that the effect of ICT on female employment in Africa is strongest in the industrial sector.

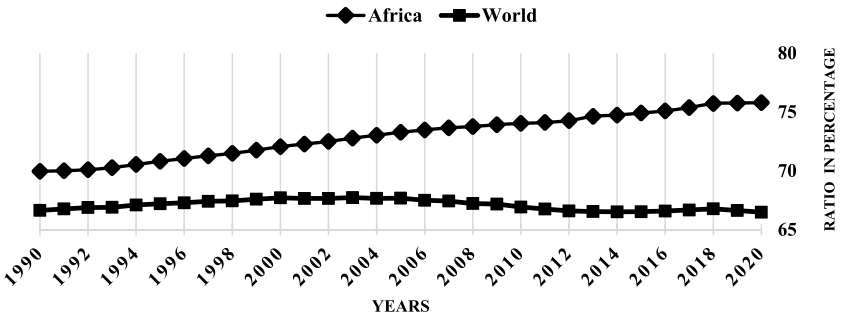
The rest of this paper is organized as follows. Section 2 explores the existing literature. Section 3 reports the variables, data sources, and methodologies. Section 4 presents the baseline results, robustness analyses and discussions. Section 5 concludes and highlights key policy implications.

2. Literature review

Female participation in the labor market has drawn considerable attention in economics since the seminal study of Mincer (1962) of the married women's labor force participation . This attempt to reinterpret the static analysis of labor supply was followed by several theories including the "theory of allocation of time" of Becker (1965), concerning the household production model and female time allocation. The aim of these theories was to identify factors associated with the participation choices of women in the labor market.

[2] According to the International Telecommunication Union (ITU), 28.2% of individuals using the internet in Africa with 34 mobile-cellular subscriptions per 100 inhabitants (ITU, 2019). In the World, more than 54% of individuals use the internet, with 108 mobile cellular subscriptions per inhabitants. In the developed countries, more than 86.6% of individuals use the internet, with 128.9 mobile cellular subscriptions per inhabitants. In developing countries, 47% of individuals use the internet with 104 mobile cellular subscriptions per inhabitants (ITU, 2019).

[3] World Development Indicators 2019.



Source: Authors, from World Development Indicators 2020

Fig. 1. Ratio of female to male labor force participation rates (%).

There have been many empirical analyses of the determinants of female labor force participation rates (He & Zhu, 2016). Early investigations at the macroeconomic level, such as those of Sinha (1967) and Boserup (1970), produced the feminization-U hypothesis that considers economic development as a determinant of differences in female labor market participation. This hypothesis posits that at low income levels, female labor force participation decreases as economies grow, but that above a certain level of development, the relationship becomes positive. In African countries however, Idowu and Owoeye (2019) suggest that the relationship between female labor participation and economic development is inverted U-shaped.

Other studies have documented the association with female labor force participation of non-economic factors such as religion, culture, social norms, democracy and governance (Bayanpourtehran & Sylwester, 2013; Chen & Suqin, 2018; Dildar, 2015; Erten & Metzger, 2019; Göksel, 2013; Lavy & Zablotsky, 2015; Priyanka, 2020; Zhike & Yang, 2018). Very recently, Klasen et al. (2021) investigated the micro-level drivers of female labor force participation in developing and emerging economies. They found that rising education levels and declining fertility were consistently associated with increased female participation rates, while rising household incomes were negatively associated in relatively poor countries, suggesting that a substantial share of women work out of economic necessity.

Despite the rapid connectivity transition over the past decades due to the general upward trends in ICT access and use, surprisingly few studies have evaluated the effects of ICT on labor market outcomes, in particular those of women. The empirical literature that has emerged on the effects of ICT on female labor force participation can be divided into two parts. The first tries to estimate the effect of using ICT for job search on individual employment outcomes. The second estimates the effect of ICT availability on employment rates. In the United States for example, Dettling (2017) has shown that high-speed internet use is associated with increased labor force participation for married women, but found no corresponding effect for single women. Focusing on developing countries, Omotoso and Obembe (2016) and Nikulin (2017) found a positive effect of internet and mobile phone penetration on female labor force participation. In the Indo-Pacific, Watson et al. (2018) also found a positive correlation between internet use and women's workforce participation. These results are consistent with those obtained by Efobi et al. (2018) and Asongu and Odhiambo (2020).

Trying to analyze the effects of technical change using micro-level data from the U.S, Coen-Pirani and Lugauer (2008) found that household appliance ownership did not increase labor force participation for single women, but accounted for about one-third of the observed increase in female labor force participation for married women. Likewise, Cardia (2007) concluded that increased adoption of these technologies did not have a significant effect on U.S. women's labor participation rates, but helped increase their participation in professional occupations.

The lack of consensus due to differences in samples and methodological approaches motivates new research into the effects of ICT diffusion on female labor force participation. Since African countries are still in the early stages of ICT adoption, and based on the above literature, the first hypothesis of this study is the following:

Hypothesis 1. ICT diffusion improves female labor force participation in African countries.

A weakness of existing empirical studies of the nexus between ICT and female labor force participation is that they do not identify the channels through which ICT improves female labor force participation. Two potential channels could usefully be considered however.

The first channel is financial development, where ICT can have dramatic effects (Owusu-Agyei, 2020). Some authors suggest that the availability of ICT services reduces information asymmetry and transaction costs in the financial market, promoting cross-border capital flow (Choi et al., 2014; Mei-Se et al., 2020). Likewise, the potential for information flow between lenders and borrowers in financial markets may be increased by ICT, reducing the effects of adverse selection and moral hazard, and increasing transparency and accountability. This likely improves financial development (Boateng et al., 2018). Assuming that financial constraints harm employment because they hinder the emergence of innovating firms and the jobs they generate, improving access to finance may allow firms to hire more labor (Dao & Lieu, 2017; Edo et al., 2019).

Financial development may also affect labor markets through economic growth. According to Okun's law, financial development

tends to be associated with faster economic growth, contributing to employment growth (Guifu & Sizhuo, 2016). To show the importance of financial development in the nexus between ICT and labor market outcomes, Samargandi et al. (2019) found that ICT diffusion was associated with reduced female labor force participation in the Kingdom of Saudi Arabia. However, when they interacted ICT with financial development the sign of the coefficient changed to be positive, meaning that the benefit of ICT diffusion is achieved when the financial sector is sufficiently developed to support the investment needs of firms, which then creates more job opportunities.

The second channel is female education. The importance and effects of education on labor force participation are well documented by economists in both developing and developed countries (Anyanwu, 2016; Doumbia & Kuepie, 2008; Kanjilal-Bhaduri & Pastore, 2017; Totououm et al., 2018). Investment in women's education increases women's opportunities to work outside the home (Ince, 2010; Michael, 1985). Indeed, higher levels of education push women's wages above the reservation wage threshold, drawing women into the labor force (Schultz, 1994). ICTs may affect female labor force participation via improved education, since they open access to a wealth of information, knowledge, and educational resources. This increases opportunities for learning in and beyond the classroom. ICT is therefore a useful tool to adapt teaching and learning methods to individual needs (Flecknoe, 2002; Internet Society, 2017). Given the above results and intuitions, a second hypothesis can be formulated as follows.

Hypothesis 2. The effects of ICTs on female labor force participation in African countries are mediated by financial development and female education.

It appears from the above survey of the empirical literature that the mechanisms through which ICT improve female labor force participation in Africa have not so far been satisfactorily explained. Studies of the labor market effects of ICT have not paid much attention to its indirect effects, that is, the channels through which ICT consolidates female labor force participation, specifically in Africa. Previous studies have also failed to investigate the effects of ICT on women's sectoral employment. Yet understanding the way ICT affects the structure of female employment reveals the complexity of these effects and is required to propose relevant recommendations. The present research aims to close these gaps in the contemporary literature by investigating the role of financial development and female education in amplifying the effects of ICT on female labor force participation.

3. Empirical methodologies and data

3.1. Empirical methodologies

In keeping with previous studies, we used a fixed effect panel data model to analyze the effects of ICT on female labor force participation. Indeed, estimating a regression model in which the dependent variable is a proportion requires econometric methods that take account of the bounded nature of the response. Considering female labor force participation (FLFP), our dependent variable, we must control for country-specific features (unobserved heterogeneity). Moreover, when a panel consists of observations on fixed and relatively small sets of cross sections, fixed effects regression is the preferred approach. However, researchers are increasingly adopting dynamic panel analysis to investigate the determinants of female labor force participation (Gaddis & Klasen, 2014), the argument being that if female labor force participation is persistent or/and the causality between female labor force participation and ICT is reversed, then the results from static models may be biased. To account for potential dynamic effects and endogeneity, we therefore also investigated the effects of ICT on female labor force participation using a system GMM dynamic panel model (Arellano & Bover, 1995; Blundell & Bond, 1998), and consider potential reverse causality and omitted variable bias.

There are three motivations for using GMM: *(i)* there are 48 countries based on 17 periods in each country; *(ii)* the underlying estimation process does not eliminate between-country differences, which are inherent in panel data analyses; *(iii)* endogeneity is accounted for in two ways: the issue of reverse causality is controlled for using internal instruments while unobserved heterogeneity is controlled for by accounting for time invariant omitted variables in the estimation. This method addresses problems of multicolinearity, endogeneity, and omitted-variable bias. Indeed, some of the independent variables may have bidirectional links with the dependent variable. In this context, endogeneity bias is suspected, which justifies the use of a dynamic panel model. Using SYS-GMM helps to ensure unbiased, convergent, and efficient estimators are obtained (Wooldridge, 2001).

Reverse causality undoubtedly leads to biased estimates in the absence of valid instruments. The instruments for level regression are the lagged differences of the corresponding variables. The baseline specification of the model is a one-step robust SYS-GMM with a collapsed set of instruments. We check the validity of the instruments using two specification tests. The first is the Sargan test of over identifying restrictions, which tests the overall validity of the instruments by analyzing the sample analog of the prevailing conditions used in the estimation process. The second test examines the hypothesis that the error term ε, is not serially correlated. In both the regression difference and the system difference-level regression, we test whether the error term difference is second-order serially correlated (by construction, the differenced residual is probably first-order serially correlated even if the original error term is not).

3.1.1. Simple regression analysis of the direct effect of ICT use on female labor force participation

In our empirical exercise, we first concentrate on the direct effect of ICT used on female labor force participation. More precisely, we exploit data on ICT diffusion in Africa to identify the impact of internet and mobile phone use on female labor force participation. In theory, more widespread ICT use should be associated with higher female labor force participation. Put differently, the theory suggests that, other things being equal, states with higher levels of ICT use should experience a greater increase in female labor force participation.

The estimated model is an extension of those in the recent empirical literature, notably Samargandi et al. (2019), Kılıçaslan and Töngür (2019), used multiple linear regression models to highlight the effects of ICT on female labor force participation in developed

and developing countries. The basic empirical model is specified below:

$$FLFP_{it} = \alpha + \beta ICT_{it} + \lambda X_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (1)$$

$FLFP_{it}$ is the level of female labor force participation in country i at time t. ICT_{it} represents ICT use (i.e. mobile phone penetration and internet penetration) in country i in period t. Internet and mobile phone access increases employment opportunities in a globalized economy and contributes to women's employment (Asongu & Odhiambo, 2020). X_{it} is the vector of control variables (female education, financial development, gross domestic product, fertility, trade, and female population). ν_i, μ_t and ε_{it} are the fixed temporal effects, the country fixed effects and the disturbance respectively.

The basic model can be augmented by adding the lagged value of female labor force participation to consider memory effects, along with cultural, institutional and religious variables (Kılıçaslan & Töngür, 2019; Dildar, 2015). The assumption of strict exogeneity of the estimator is violated in a dynamic fixed effects model because fixed effects estimation induces a downward bias in the estimated parameter (Nickell, 1981). We therefore use GMM estimation for the dynamic model given the nature of the panel data (large N, small T) and the persistence of female labor force participation. We use system rather than difference GMM because the former has better asymptotic and finite sample properties (Bond, Hoeffler, & Temple, 2001).

The augmented and dynamics female labor force participation equation is thus expressed as,

$$FLFP_{it} = \alpha_0 + \alpha_1 FLFP_{t-1} + \beta ICT_{it} + \lambda X_{it} + \gamma Z_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (2)$$

where Z is a vector of cultural, institutional and religious control variables (legal origin, democracy, female political empowerment, ethnic fractionalization, language fractionalization, religious fractionalization, control of corruption, political stability, rule of law).

3.1.2. *Exploring the possible channels from ICT to female labor force participation*

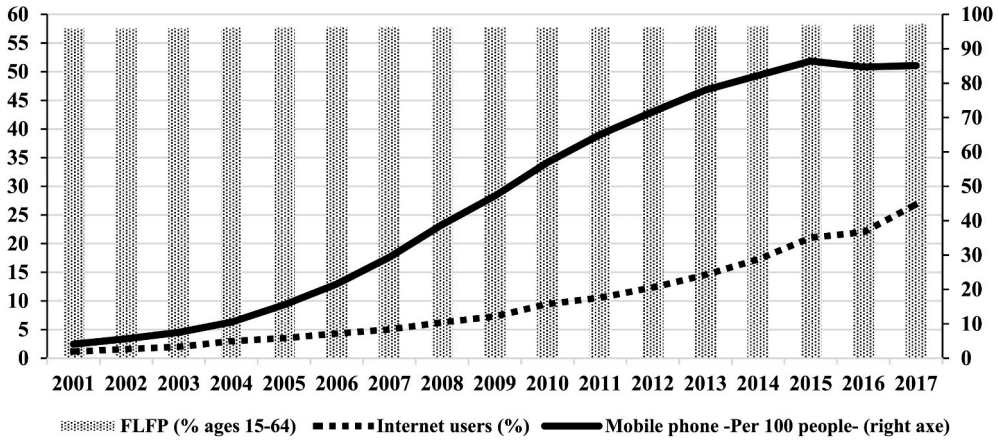
To test the second hypothesis, that the effect of ICT on female labor force participation is mediated by financial development and female education, we use Equation (3) to determine the impact of ICT on each transmission channel.

$$FLFP_{it} = \alpha_0 + \alpha_1 FLFP_{t-1} + \beta ICT_{it} + \lambda X_{it} + \gamma Z_{it} + \phi W_{it} + \nu_i + \mu_t + \varepsilon_{it} \quad (3)$$

where W_{it} is a vector of interaction terms between ICT, financial development and female education (mobile phone use*financial development, mobile phone use*female education, internet use*financial development, internet use*female education).

3.2. *Data and descriptive analysis*

The data for this study come from 48 African countries and cover the period 2001 to 2017. The sample of countries and of the periodicity of the variables were constrained by data availability at the time of the study. The included countries are listed in Appendix 1. Six main sources were used to obtain the data. The dependent variables, notably female labor force participation and sectoral female employment rates (agriculture, industry and services) were obtained from the World Bank World Development Indicators (2019), as were the interest ICT variables (mobile phone penetration and internet penetration). The socio-economic and meso-economic variables were obtained from the World Bank World Development Indicators (2019), World Governance Indicators (2019), the Database of Political Institutions (2018), V-Dem (2018), Polity IV and La Porta et al. (1999). The dependent, interest and control variables were chosen based on the contemporary literature (Priyanka, 2020; Samargandi et al., 2019). Definitions and sources



Source: Authors, from World Development Indicators 2020

Fig. 2. ICT and FLFP trends in Africa (2001–2017).

are provided in Appendix 2.

Descriptive statistics of the variables are provided in Appendix 3. The average level of female labor force participation is 57.87%, with values ranging from 12.84% (Algeria, 2001) to 80.90% (Burundi, 2014). The average proportion of individuals using the internet (as a share of total population) is 9.92%, with a minimum of 0.01147% (Democratic Republic of the Congo, 2001) and a maximum of 52.19% (Mauritius, 2016). Mobile phone subscriptions (per 100 people) range from 0 (The Comoros, 2000; Guinea-Bissau, 2001) to 147.54 (Gabon, 2016), with an average of 46.50.

Fig. 2 shows the evolution over the studied period of internet and mobile phone use alongside female labor force participation in Africa. Average female labor force participation increased from 57.56% in 2001 to 58.36% in 2017, as average internet penetration increased from 1.16 to 26.86%, and mobile phone subscriptions per 100 people jumped from 4.09 to 85.12% over the same period.

4. Results and discussion

The results obtained with the basic model are first reported and discussed before further analyses of their robustness are presented.

4.1. The baseline results

Table 1 shows the regression coefficients of the baseline model of female labor force participation estimated with fixed and random effects. We ran a Hausman test to determine which of the two models fits the data best. The p-value of the test was less than 10%, meaning that the fixed effects model is preferred. This model removes the individual heterogeneity in the data.

The results for the fixed effect model indicate that almost all the variables are significantly associated with female labor force participation. The coefficients for the ICT variables (internet and mobile phone use) are positive and the associations are significant, as expected. An increase of 1 percentage point in internet use is associated with a 0.223 percentage point increase in female labor force participation, while a 1 percentage point increase in mobile phone use is associated with a 0.046 percentage point increase in female labor force participation. This result confirms the first hypothesis of the study and is consistent with the findings of Samargandi et al. (2019) in Saudi Arabia and Nikulin (2017) in developing countries. A possible interpretation of this result is that ICT diffusion reduces informational inefficiency in the labor market by reducing the matching time for labor skills and job expectations. ICT may also help women to manage their work-life balance. The positive association between internet use and female labor force participation is stronger than that of mobile phone use. One explanation may be that the internet facilitates job creation for women more than mobile phones do, and helps them overcome the socio-economic and cultural barriers that may otherwise have excluded them from participating in the labor market.

Economic variables such as GDP per capita, financial development and trade openness are all positively and significantly associated with female labor force participation. As GDP per capita increases, various changes occur in parallel that affect women's labor force participation. Economic development generally shifts the locus of production from the family farm and business to the factory and other places of wage labor because of increased relative productivity outside family enterprises. Thus, instead of working for their

Table 1
Effects of ICT on female labor force participation.

	Dependent variable: Female Labor Force Participation (15–64)	
	Random Effects	Fixed Effects
Internet	0.068*	0.223***
	(0.041)	(0.057)
Mobile phone	0.058**	0.046*
	(0.016)	(0.028)
Female education	0.265***	0.240
	(0.176)	(0.176)
GDP per capita	0.004***	0.003***
	(0.001)	(0.013)
Fertility	−0.062***	−0.179***
	(0.011)	(0.014)
Female population	4.201*	4.587*
	(2.543)	(2.559)
Financial development	0.037***	0.159**
	(0.061)	(0.060)
Trade openness	0.006***	0.005***
	(0.001)	(0.002)
Constant	3.404***	4.100***
	(0.029)	(0.026)
Observations	884	884
Countries	48	48
R-squared		0.67
Hausman test	Prob > Chi2 = 0.001	

Notes: ***, **, *: statistical significance at 1%, 5% and 10% respectively. ( ) standard deviations robust to heteroscedasticity.
Source: Authors.

family, the rise in GDP per capita offers women the opportunity of higher (wage) remuneration in agriculture, manufacturing or services (Goldin, 1995). Even though the effect of GDP per capita on female labor force participation is small, since a 1 percent increase in GDP per capita is associated with just a 0.003 percentage point increase in female labor force participation, the coefficient is positive, as expected. Likewise for financial development, where a 1 percent increase is associated with a 0.16 percentage point increase in female labor force participation, suggesting that financial development can generate wider economic and job opportunities for women. In terms of trade openness for example, it could lead to an expansion of the traded-goods sector, generating new employment opportunities specifically for women (Cooray et al., 2017).

In contrast with the random effects model, the association between female education and labor force participation in the fixed effects model is positive but not significant. This finding is not consistent with the results obtained by Samargandi et al. (2019) and the

Table 2
Effects of ICT on female labor force participation.

	Estimation technique: GMM-System					
	Dependent variable: Labor Female Force Participation (15–64)					
	(1)	(2)	(3)	(4)	(5)	(6)
FLFP (t-1)	1.093***	0.962***	1.304***	1.227***	1.017***	1.004*
	(0.002)	(0.052)	(0.016)	(0.037)	(0.001)	(0.003)
Internet	0.083***	0.071**	0.090***	0.501***	0.049***	0.072**
	(0.018)	(0.037)	(0.054)	(0.350)	(0.002)	(0.017)
Mobile phone	0.063***	0.061*	0.030***	0.028*	0.027***	0.162*
	(0.061)	(0.095)	(0.089)	(0.062)	(0.001)	(0.004)
Female education	0.154***	0.208***	0.110***	0.148*	0.401**	0.341***
	(0.058)	(0.061)	(0.005)	(0.055)	(0.026)	(0.001)
GDP per capita	0.009***	0.005**	0.014***	0.014***	0.008**	0.006*
	(0.003)	(0.004)	(0.003)	(0.006)	(0.003)	(0.004
Fertility	−0.051*	−0.043*	−0.041	−0.053**	−0.031	−0.205*
	(0.011)	(0.016)	(0.016)	(0.018)	(0.017)	(0.076)
Female population	0.071***	0.057	0.024***	0.049*	0.060***	0.149*
	(2.543)	(2.723)	(2.434)	(2.634)	(3.318)	(0.001)
Financial development	0.043***	0.416***	0.211***	0.381***	0.028***	0.227***
	(0.061)	(0.063)	(0.053)	(0.054)	(0.350)	(0.003)
Trade openness	0.016***	0.018***	0.011	0.014***	0.042**	0.022*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.054)
Legal origin (French)		0.413***				0.363*
		(0.0032)				(0.217)
Control corruption			−0.315*			
			(0.004)			
Political stability			0.021**			0.190*
			(0.002)			(0.072)
Rule of Law			0.096*			
			(0.003)			
Ethnic Fractionalization				−0.233**		
				(0.005)		
Language Fractionalization				0.170*		0.103***
				(0.002)		(0.000)
Religious Fractionalization				−0.301***		
				(0.0741)		
Democracy					0.174**	0.051*
					(0.004)	(0.008)
Female Political Empowerment					0.078*	0.061**
					(0.011)	(2.634)
Internet*Financial development						0.011*
						(0.054)
Internet*Female education						0.021***
						(0.001)
Mobile*Financial development						0.061**
						(0.027)
Mobile*Female education						0.319***
						(0.178)
Constant	4.109*	3.101*	4.174***	4.278***	4.374***	4.301***
	(0.0628)	(0.0532)	(0.0564)	(0.0669)	(0.0749)	(0.0669)
Observations	884	884	884	884	884	884
Countries	48	48	48	48	48	48
AR(1)	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	0.766	0.890	0.631	0.641	0.519	0.670
Hansen	0.650	0.455	0.516	0.314	0.760	0.431

Notes: ***, **, *: statistical significance at 1%, 5% and 10% respectively. ( ) standard deviations robust to heteroscedasticity.
Source: Authors.

intuition that the skills acquired through education are an opportunity for women to leave home and participate in the formal job market.

Finally, fertility is negatively associated with female labor force participation in Africa. This result is consistent with the findings of Berniell et al. (2018) in Chile, that motherhood implies a drop in labor supply, both in extensive and intensive margins, and can be explained in terms of the opportunity cost of continuing in the labor market. Indeed, when childcare services are lacking or unaffordable, the opportunity cost of staying in the labor market leads one parent to specialize in earning an income for the family while the other focuses on childcare (Skadsen, 2017).

Table 3
Effects of ICT on Female sectoral employment.

	Estimation technique: GMM-System					
	Female employment in agriculture		Female employment in industry		Female employment in services	
FLFP (t-1)	0.974***	0.949**	1.003***	0.983***	1.027***	0.984***
	(0.143)	(0.442)	(0.007)	(0.020)	(0.020)	(0.029)
Internet	0.136**	0.019*	0.346**	0.225***	0.011***	0.001**
	(0.003)	(0.035)	(0.000)	(0.001)	(0.000)	(0.001)
Mobile phone	0.270*	0.012*	0.049*	0.183***	0.081**	0.001***
	(0.058)	(0.009)	(0.011)	(0.000)	(0.000)	(0.000)
Female education	0.038*	0.115**	0.067***	0.102**	0.012**	−0.001
	(0.120)	(0.000)	(0.000)	(0.031)	(0.021)	(0.061)
GDP per capita	0.007*	0.008*7	0.009*	0.0101***	0.011***	0.009***
	(0.061	(0.021)	(0.006)	(0.017)	(0.001)	(0.003)
Fertility	−0.147***	0.223***	−0.024*	−0.048**	−0.015***	0.021**
	(0.323)	(0.017)	(0.023)	(0.018)	(0.049)	(0.058)
Female population	0.180***	0.159***	0.291**	−0.107	−1.975	1.001*
	(0.425)	(0.000)	(0.491)	(0.534)	(1.515)	(0.072)
Financial development	0.192*	2.324*	0.048**	0.016	0.006	0.143**
	(0.177)	(0.744)	(0.013)	(0.019)	(0.010)	(0.064)
Trade openness	0.302*	0.110	0.411**	0.037**	0.011*	0.069***
	(0.003)	(0.006)	(0.023)	(0.000)	(0.005)	(0.000)
Legal origin (French)		−0.216**		−0.081**		−0.286***
		(0.574)		(0.017)		(0.037)
Control corruption		−0.145***		−0.109*		−0.101*
		(0.0505)		(0.0628)		(0.0532)
Political stability		0.033**		0.116***		0.295***
		(0.092)		(0.038)		(0.058)
Rule of Law		−0.109***		−0.071*		−0.321***
		(0.012)		(0.016)		(0.013)
Ethnic Fractionalization		0.011		0.108**		0.061***
		(0.017)		(0.000)		(0.000)
Language Fractionalization		0.142*		0.138*		0.348***
		(0.011)		(0.075)		(0.120)
Religious Fractionalization		0.142*		0.005***		0.005
		(0.209)		(0.006)		(0.010)
Democracy		0.279**		0.003***		0.038*
		(0.193)		(0.004)		(0.010)
Female Political Empowerment		0.158*		0.093*		0.079**
		(0.119)		(0.002)		(0.006)
Internet*Financial development		0.039		0.953*		0.035***
		(0.026)		(0.001)		(0.004)
Internet*Female education		0.279**		0.103***		0.038*
		(0.093)		(0.004)		(0.010)
Mobile*Financial development		0.158*		0.093***		0.079**
		(0.119)		(0.002)		(0.004)
Mobile*Female education		0.142*		0.115*		0.061**
		(0.209)		(0.006)		(0.013)
Constant	2.892***	5.026***	1.177***	4.640**	2.744***	4.029***
	(0.788)	(1.740)	(1.901)	(0.058)	(0.839)	(0.339)
Observations	884	884	884	884	884	884
Countries	48	48	48	48	48	48
AR(1)	0.000	0.000	0.001	0.008	0.000	0.012
AR(2)	0.443	0.670	0.131	0.094	0.119	0.229
Hansen	0.871	1.000	0.708	0.516	0.760	0.751

Notes: ***, **, *: statistical significance at 1%, 5% and 10% respectively. ( ) standard deviations robust to heteroscedasticity.
Source: Authors.

4.2. Robustness analysis

We test the robustness of our results in several ways. The first test is to use an alternative estimation method and alternative specifications, replacing the basic model with a dynamic model and using a system GMM estimator. An advantage of this estimation method is that it has good asymptotic and finite sample properties (Bond et al., 2001) and provides unbiased, convergent, and efficient estimation when endogenous bias is suspected in the model. The results obtained are presented in Table 2.

As expected, the dynamic specification is supported by Arellano-Bond test statistics for zero autocorrelation in first-differenced errors, with an AR (1) p-value equal to zero. The fact that the p-value associated with AR (2) is more than 10%, indicates that there is no evidence of a second-order serial correlation in the differenced residuals of the models. Furthermore, all the Sargan test p-values are more than 10%, meaning that the instruments in the model are valid. The association with the lagged dependent variable is positive and highly significant, indicating that female labor force participation in a given year is strongly affected by its value in the preceding year.

The first column in Table 2 gives the results of the basic dynamic model. Compared with the baseline model, all the coefficients keep their sign and are significant. However, although our main conclusion regarding the role of ICT in female labor force participation remains the same with this estimate, the effect of internet use is lower than in the country fixed effects model. Furthermore, unlike in the fixed effects model, female education is positively and significantly associated with female labor force participation, as expected. Indeed, increasing literacy rates improve women's access to better positions in the labor market (Ince, 2010).

We further test the validity of the results by including various cultural, institutional, and religious control variables in the dynamic model. These results are shown in columns 2, 3, 4 and 5 of Table 2 and are consistent with the previous estimates. The sign and significance of the associations with internet and mobile phone use are retained in all four specifications. Likewise, the coefficients for female education, GDP per capita, and financial development remain positive regardless of the specification considered.

Among the control variables, noneconomic factors such as rule of law, democracy, female political empowerment, and political stability are associated with increased female labor force participation. For example, our results show that female political empowerment is positively and significantly associated with female labor force participation, suggesting once more that countries characterized by female political participation have higher levels of female labor force participation. The explanation is that political participation is crucial in providing a voice to poor, vulnerable and marginalized groups to influence institutions and decisions that critically affect their lives. This result is consistent with those of Zhike and Yang (2018), who showed the importance of women's political status in reported levels of life satisfaction in developed and developing countries.

As a further robustness check, we included interaction terms as control variables in the dynamic model. We interacted the two ICT variables with female education and financial development, to investigate whether the effect of ICT on female labor force participation is mediated by the latter two variables. The results presented in column 5 of Table 2 show that the interactions between ICT (internet and mobile phone) with financial development and female education are statistically significant and positively associated with female labor force participation. These results support the view that while ICT diffusion reduces informational inefficiency in the labor market, financial development generates wider economic and job opportunities. In keeping with the work of Samargandi et al. (2018) and Acemoglu (2001), our results show that financial development and female education are critical to reaping the benefits of ICT diffusion in terms of female labor force participation in Africa. These findings are consistent with the second hypothesis of this study.

As a final robustness test, we use female employment in three economic sectors (agriculture, industry, and services) as dependent variables in the dynamic model, still with system GMM estimation. The results reported in Table 3 show that the dynamic specification is supported by Arellano-Bond test statistics for zero autocorrelation in first-differenced errors with an AR (1) p-value equal to zero. The p-values associated with AR (2) are greater than 10%, indicating no evidence of a second-order serial correlation in the differenced residuals of the models, and the Hansen tests do not reject the validity of the instruments (p-values > 0.1). Regardless of the specification or the sector of the economy, the internet and mobile phone variables are positively and significantly correlated with female labor force participation. These results indicate once again that ICT use improves female employment outcomes. These findings are close to those of Ndubuisi et al. (2021).

The high impact of ICT on female employment in industry may reflect the fact that Africa has seen a rapid application of recent scientific advances in new products and processes, a high rate of innovation across various countries, and a shift to more knowledge-intensive industries. Finally, economic variables such as GDP per capita, financial development, trade openness are almost all positively and significantly associated with female participation in all three economic sectors, and as expected, fertility and female education are respectively negatively and positively associated with female employment rates in these sectors.

5. Conclusion and policy implications

The purpose of this article was to examine the impact of ICT on female labor force participation in Africa. Based on the observation that drastic technological advances and innovations have significantly transformed participation trends in labor market activities and systems, notably in term of gender, we examined theoretical and empirical developments to build a model with which to test the hypothesis that ICT diffusion improves female labor force participation in African countries. Several model variants were estimated using fixed effects and system GMM, with data on a sample of 48 African countries over the period 2001 to 2017. Three interesting findings emerge.

First, ICT use, both through the internet and mobile phones, increases female labor force participation in Africa, confirming the hypothesized effect. Second, the analysis of mediation channels shows that this effect of ICT use is enhanced by financial development and female education. These results confirm the second hypothesis on the relationship between ICT, the transmission channels and

female labor force participation. Finally, the effect of ICT on female employment is strongest in the industrial sector. The findings of this study are consistent with those of other similar studies in the literature, that in addition to socioeconomic, cultural and institutional factors, technologies do influence women's decisions to participate or not in the labor market.

From a policy perspective, the following measures could be adopted to increase female labor force participation in Africa: *(i)* improve digital inclusion in parallel with financial inclusion to popularize the digital technologies and services required to develop firms and female entrepreneurship; *(ii)* improve the gender equality of the workforce, by making labor markets more inclusive and improving access to ICT to reduce information asymmetries and eliminate the gender gap in decision-making.

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Appendices.

Appendix 1. List of countries

Algeria, Angola, Benin, Botswana, Burkina-Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo, Djibouti, Gabon, Equatorial Guinea, Cote d'Ivoire, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritius, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Time and Principe, Senegal, Sierra-Leone, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

Source: Authors.

Appendix 2. Definitions of variables

Variables	Description	Sources
Female Labor Force Participation	Employment to population ratio, 15–64, female (%) (modeled ILO estimate).	WDI (2019)
Internet	Internet users (per 100 people).	WDI (2019)
Mobile phone	Mobile cellular subscriptions (per 100 people).	WDI (2019)
GDP	Log of gross domestic product per capita.	WDI (2019)
Female education	Number of girls enrolled in secondary school.	WDI (2019)
Financial development	Volume of financial resources provided to the private sector by financial institutions.	WDI (2019)
Fertility	Fertility rate, total births per woman.	WDI (2019)
Female population	Proportion of females in the total population.	WDI (2019)
Trade	Sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI (2019)
Legal origin	Identifies the legal origin of the Company Law or Commercial Code of each country. There are five possible origins: English Common Law, French Commercial Code, German Commercial Code, Scandinavian Commercial Code and, Socialist/Communist Law.	La Porta et al. (1999)
Fractionalization	Average value of five different indices of ethnolinguistic fractionalization. Its value ranges from 0 to 1. The five component indices are: (1) index of ethnolinguistic fractionalization in 1960, which measures the probability that two randomly selected people from a given country will not belong to the same ethnolinguistic. (2) probability of two randomly selected individuals speaking different languages; (3) probability of two randomly selected individuals do not speak the same language; (4) percent of the population not speaking the official language; (5) percent of the population not speaking the most widely used language.	La Porta et al. (1999)
Control of corruption	Use of public funds to achieve personal enrichment including grand and petty corruption, « capture » of the State by elites and private interests. Values range from −2.5 (low) to +2.5 (high).	WGI (2019)
Rule of Law	The confidence level of citizens, the respect of contracts, of police and courts jurisdictions, the perception of crimes and violence. Values range from −2.5 (low) to +2.5 (high).	WGI (2019)
Political stability	Perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional and violent means, including domestic violence and terrorism. Values range from −2.5 (low) to +2.5 (high).	WGI (2019)
Democracy	Provides information on the level of democracy corrected by the dictatorship. Values range from −10 (low) to +10 (high).	Polity IV Project Online (2018)
Female political empowerment	Index developed by Sundström et al. (2017), based on the legislative presence of women and the distribution of political power by gender.	V-DEM (2018)

Source: Authors.

Appendix 3. Summary statistics (2001–2017)

Variables	Observations	Mean	Std. Dev	Min	Max	Sources
Female Labor Force Participation	884	57.87167	19.26066	12.848	88.843	WDI 2019
Female employment in agriculture	884	53.09522	24.43677	2.729	96.788	WDI 2019
Female employment in industry	884	8.864012	7.536424	.35	37.524	WDI 2019
Female employment in services	884	38.04077	20.44787	2.469	84.739	WDI 2019
Internet	884	9.920532	13.25897	.0114758	64.19081	WDI 2019
Mobile phone	884	46.50274	42.40648	0	175.8727	WDI 2019
GDP Constant	884	2436.882	3245.329	194.8731	20512.94	WDI 2019
Fertility rate	884	4.677712	1.393464	1.36	7.669	WDI 2019
Female population	884	9877999	1.37e+07	40781	9.42e+07	WDI 2019
Trade	884	75.57677	41.10997	19.1008	376.2241	WDI 2019
School enrollment secondary female	884	45.02685	27.66907	3.74024	112.8249	WDI 2019
Financial development	884	.138542	.0990324	.0015849	.6266615	WDI 2019
Control of corruption	884	-.6574037	.5984596	−1.868714	1.216737	WGI 2019
Political stability	884	-.5885493	.8982119	−3.314937	1.200234	WGI 2019
Rule of law	884	-.7288802	.6101991	−2.606445	.7305223	WGI 2019
Democracy	884	−3.031863	20.38366	−88	10	Polity IV (2019)
Legal origin (Uk)	884	.3469388	.476282	0	1	La Porta et al. (1999)
Legal origin (Fr)	884	.6530612	.476282	0	1	La Porta et al. (1999)
Ethnic fractionalization	884	.6484707	.2402836	0	.930175	La Porta et al. (1999)
Language fractionalization	884	.606224	.2981391	.0102913	.9226795	La Porta et al. (1999)
Religion fractionalization	884	.4666818	.2783558	.0027548	.8602599	La Porta et al. (1999)
Female political empowerment	884	.6789566	.1626635	.2088253	.9191124	V-Dem 2018

Source: Authors.

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