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Empirical verification of the link between the digital divide and women's economic participation in Africa

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Abstract

This article examines the link between the digital divide and women's economic participation. We use a cross-sectional model based on a panel of 45 African countries. Our results show that the digital divide (cell phone, bandwidth and Internet) worsens women's economic participation. The negative influence of the digital divide on women's economic participation tends to be amplified in countries with low democracy and in the industrial sector. Our results remain stable when we add cultural variables and when we use the alternative measure of the digital divide. However, after using the quantile regression approach, we find that these influences vary at different intervals along the distribution of women's economic participation.

JEL classification: I21, J21, O55

Keywords: Digital divide, Women's economic participation, OLS, Quantile regression

1. Introduction

For several decades, the issue of women's economic participation has been at the heart of the concerns of governments and international bodies, due to its impact on increasing economic growth (Pimkina and De la Flor, 2020) and reducing poverty and inequality (Verick, 2018). Indeed, between 1970 and 1990, several attempts were made to improve issues related to women's economic participation, and this period is known as the "pioneering" period. The conferences in Mexico City in 1975, Copenhagen in 1980, Nairobi in 1985 and Beijing in 1995 are among the key events of this period (United Nations, 1996). During this period, women in developing countries acquired

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skills at an unprecedented rate. At the same time, they had to enter the labour market (UN Women, 2020). Unfortunately, more than twenty years after the Beijing conference, the status of women still seems depressing (Klasen et al., 2021).

The United Nations report (2021) states that digital inclusion is one of the priorities for gender equality and women's empowerment. This is particularly true in some countries, where mobile phones and the internet are seen as promising ways of tackling major challenges such as equal access to the labour and political markets (Stamps, 1990; Raja et al., 2013; Dencik and Leistert, 2015) and financial inclusion (Asongu and Odhiambo, 2018). Indeed, ICTs provide women with access to information on job offers, training and professional development opportunities. They can use online platforms, social networks and search engines to search and apply for jobs (McKinsey Global Institute, 2015; International Labour Organisation, 2017). In addition, ICTs enable women to set up their own businesses and become entrepreneurs. They can use e-commerce platforms, social networks and digital financial services to start and develop their business. (World Bank, 2019a).

Although the emergence of ICTs in some countries has offered many opportunities to marginalised women, in Africa the digital revolution has resulted in unequal access to new technologies, leading to what is now known as the "digital divide" (Moolman et al., 2007). According to Gurumurthy (2004), the digital divide is a persistent reality, with structural barriers limiting access to technological tools, to digital education and socio-economic opportunities. Castells (2002) defines the "digital divide" as the difference in access to and use of ICTs between individuals.

With this in mind, several authors, including Tiemtoré (2008), assert that a significant proportion of the population is excluded from the appropriation of ICTs. Not everyone has access to these digital tools, and their distribution between social groups is highly unequal (Granjon et al., 2009). According to a report by the United Nations Development Programme (UNDP, 2012), women in Africa have more difficulty than men in accessing and using these technologies in the long term because of a patriarchal social structure that encourages these practices. Indeed, the digital divide can exclude women from employment opportunities that require digital skills or access to technology. This can confine them to low-paid, low-skilled jobs (World Economic Forum, 2017). The digital divide can hinder women's entrepreneurship by limiting women’s access to the online information, tools and resources needed to start and run a business (International Center for Research on Women, 2016). In addition, the digital divide can limit women’s access to online training and professional development, hindering their career advancement (International Telecommunication Union, 2019).

What’s more, research on the gender digital divide (Mottin-Sylla, 2005; Taran, 2011) establishes that women have a lower overall probability of benefiting from the information society than men. Women’s inability to take advantage of the opportunities offered by ICTs is hampered by a number of factors, including illiteracy, poverty, language barriers and inadequate access to technological tools due to the low representation of women in positions of responsibility in ICT development programmes (Mefalopulos, 2008). Even when women have the necessary skills to use ICTs, “persistent cultural barriers, such as stereotypical definitions of the roles of women and men in Africa, continue to hinder their full participation in the information age” (UN, 2005).

Gender disparities around the world are also reflected in the digital domain. Globally, around 52% of women are not connected, compared with 44% of men (International Telecommunication Union, 2020). Yet the digital gender gap is even more pronounced in developing countries, where women are 7% less likely to own a cell phone and 18% less likely to own a smartphone (Global System for Mobile Communication, 2022). Access to computers remains limited in these regions, with only 54% of urban households equipped, compared with just 17% in rural areas (Amber & Chichaibelu, 2023). There are marked regional differences when it comes to digital inequalities between men and women. Africa is the region where this digital gender gap is most pronounced, particularly in terms of cell phone ownership and mobile internet use. This gap influences women's participation in the labor market in Africa, where their participation rate stands at 57.56%, and 71.8% of them are more dependent on the lower-paid informal sector (Global Entrepreneurship Monitor, 2020/2021).

However, in developing countries in general, and in Africa in particular, there is a great deal of interest in women's economic participation. Unfortunately, very few studies have been published on the determinants of women's economic empowerment, including the link between the digital divide and women's economic empowerment in the macro case. However, the work of Omotoso et al (2020) which analyzes gender differences in broadband internet use and its effects on women's labor market participation. Using an instrumental variable approach, the results suggest that exogenous broadband internet use leads to increases of around 14.1 and 10.6 percentage points in labor market participation for single and married women with some level of education in South Africa. For Amber & Chichaibelu (2023) using the Pakistan Social and Living Standards Measurement Survey (2019-2020), they examine the digital divide between genders and between rural and urban areas. They use an instrumental variable approach to investigate the effect of cell phone or smartphone ownership on women's labor market participation. The results indicate that institutional and socio-cultural norms explain most of the gap in cell phone or smartphone ownership between men and women. The instrumental variable approach demonstrates that cell phone or smartphone ownership increases women's participation in the labor market.

However, while our results confirm certain aspects of previous studies, our study appears to complement existing work by offering a more contextual and nuanced analysis of the effects of the digital divide on women's economic participation in Africa, while using econometric methods that reveal complex dynamics that previous approaches have been unable to capture. Firstly, we have opted for both parametric and non-parametric analysis. The choice of the cross-sectional panel-based model is appropriate, as it allows us to capture intra- and inter-country variations, as well as the effect of political and sectoral variables, which has not been the case in previous studies, and also the use of quantile regression as a means of better understanding how the effect of the numerical divide varies at different levels of women's economic participation. This responds to methodological limitations in previous studies that would not have captured this heterogeneity in effects.

Secondly, this study provides new insights, notably by showing how the effects vary according to the political context and women's sector of activity. Finally, this paper makes a contribution to the literature on the digital divide and women's economic participation in Africa. After estimating a dynamic panel data model using the OLS method over the period 2000-2021, our results clearly show that the digital divide decreases women's economic participation in Africa. The remainder of the paper is structured as follows: the following section gives a brief overview of the literature review (2); section (3) describes the data used and the estimation strategy; section (4) presents the empirical results.

2. Literature review

Women's participation in economic life has attracted considerable attention in economic literature since Mincer's (1962) seminal study of married women's participation in the labour market. This attempt to reinterpret the static analysis of labour supply was followed by several theories, including Becker's (1965) "time allocation theory", concerning the household production model and the allocation of women's time. The aim of these theories was to identify the factors associated with women's choices of economic participation. However, most empirical analyses of the micro and macro determinants of women's economic participation have focused on digital technology.

The empirical literature that has emerged on the effects of the digital divide and women's participation in the workforce can be divided into two parts. The first highlights that women can theoretically benefit from the proliferation of ICTs in a number of ways, including making labour markets more transparent, flexible, innovative and inclusive, making it easier for women to find jobs and for employers to find skilled workers among women (Nikulin, 2017; Hafeez et al., 2020), as better access to labour market information improves the job search process (Raja et al., 2013). In the United States, for example, Dettling, (2017), shows that broadband internet use is associated with increased labour market participation for married women, but found no corresponding effect for single women. Focusing on developing countries, Omotoso and Obembe (2016) and Nikulin (2017), find a positive effect of internet and mobile phone penetration on women's labour market participation. In the Indo-Pacific, Watson et al (2018), also found a positive correlation between internet use and women's labour market participation. In Africa, Nkoumou and Song (2021) found that ICTs increase women's participation in the labour market. These results are consistent with those obtained by Mainuddin et al. (2015); Efobi et al. (2018) and Asongu and Odhiambo (2020).

Secondly, not all individuals have access to and benefit from the potential of ICTs (Boutilier, 2019; Cummings & O'Neil, 2015). These inequalities indicate that the potential effects of ICT can be offset by the 'digital divide' (Ragnedda & Muschert, 2013; Mariscal, et al., 2020). The digital divide can have a significant impact on women's different activities, and in particular on their integration into the labour market (McKinsey Global Institute, 2015; Alozie and Akpan-Obong, 2017). Coen-Pirani and Lugauer (2008), using microdata from the US, found that owning technological devices did not increase the labour market participation of single women compared to married women, yet they represented around a third of the observed population. Similarly, Cardia (2007) concluded that increased adoption of these technologies had no significant effect on female labour force participation rates in the US, but did increase their participation in the professions. The gender gap in economic participation is significant in Africa (Fabrizio et al., 2020). Studies by Jiang and Luh (2017) and Antonio and Tuffley (2014) show that women in these countries have a much lower rate of access to technology than men, which justifies their low representation in the labour market.

The lack of consensus in the literature on the effects of ICTs on women's empowerment, as well as the lack of measurement of ICTs, motivate further research on the effects of the digital divide on women's economic participation. Given that African countries are still in the early stages of ICT adoption, and based on the aforementioned literature. Nor have previous studies examined the effects of the digital divide on women's sectoral activities. This research aims to fill these gaps in the literature. The hypothesis of this study is as follows: The digital divide handicaps women's economic participation in African countries.

3. Methodology

3.1. Variable and data

Our sample is composed of 45 African countries. We chose the period 2000-2021 because of the availability of continuous data for a large number of countries. Table A1 in the Appendix lists the countries, while Tables A2 and A3 define the descriptive statistics for all variables, and present the correlation matrix respectively. Four main sources were used to obtain the data. The dependent variables, including women's economic participation and women's economic activity sectors (agriculture, industry and services) were obtained from the ILO database, the digital divide indicators were obtained from the World Bank's WID (2022), as were some economic control variables such as women's education, GDP per capita and natural resources. Global governance indicators are taken from the Political Institutions database and Polity IV. Definitions and sources are provided in Appendix A4.

3.1.1. Measure of digital divide

According to Song et al (2020), three categories of indicators can be used to understand the digital divide. They relate to: (i) access (computer penetration, mobile penetration, Internet service providers per capita, Internet access prices), (ii) use (Internet users per capita, broadband subscribers per capita, time spent online, Internet bandwidth per capita) and (iii) outcome (economics of e-commerce, benefits of online shopping, e-learning outcomes, e-government). Due to the lack of data in some African countries, three main measures of the digital divide are used: the mobile divide (MD), the Internet divide (ID) and the bandwidth divide (BD). The economic literature uses two approaches to measure the digital divide: absolute and relative.

3.1.1.1.1. The Absolute Approach

The absolute approach evaluates the gap for each selected indicator, the gap being calculated as the difference between 100% (the total penetration rate) and the percentage level of the indicator (Rice & Katz, 2003).

3.1.1.2. The Relative Approach

In this approach, the digital divide indicator is calculated as the difference in digital penetration between the country assumed to be at the technological frontier and those of other countries over the course of a year. To this end, the country with the best performance in digital penetration is determined each year. For our sample case, this is South Africa because of its above-average digital penetration compared to the other African countries in our sample. In addition, for this article we use the absolute approach as the base variable and we verify our robustness using the relative approach.

3.1.2. The dependent variable: Measuring women's economic participation

The dependent variable in this study is women's economic participation, captured by the women's economic participation index, according to the new ILO (2018) measure, this variable is calculated by women's individual employment and labour market participation (on a scale of 0-100). that women's economic empowerment implies According to the MDGs (2015), labour market participation is likely to promote women's economic independence. The choice of this variable is consistent with the contemporary literature on gender-sensitive development (Achuo et al. 2022).

3.1.3. Control variables

Based on the findings of the literature, we have selected the following control variables: control of corruption, GDP per capita growth, secondary education of women, natural resource rents, female population and inflation. For the control of corruption (cont-cor), the use of public funds for personal enrichment, including petty and grand corruption, and the "capture" of the state by elites and private interests. Values range from -2.5 (low) to +2.5 (high).

GDP per capita: this variable is captured by the GDP growth rate. Economic growth is an important source of income for women (Duflo, 2012). Jonson (2015) finds that an increase in GDP is associated with higher female labour force participation. This finding is consistent with Anyanwu (2016) who demonstrates that growth in GDP per capita increases gender equality in women's employment. In line with the work of Duflo (2012) we expect a positive sign from this indicator on women's economic participation in Africa.

Women's secondary education (Edusec) captured by the rate of women enrolled in secondary education, and considered in the literature as a variable of women's empowerment (Duflo, 2012; Asongu et al. 2020). Education tends to broaden points of view, reduce ethnocentrism and therefore increase flexibility in accepting new customs and norms. The level of education attained by the general population thus plays an important role in the growing acceptance of the concept of gender equality and women's empowerment (Anyanwu, 2012). Indeed, women with a high level of education are more likely to enter the labour market in urban areas worldwide (Ogawa and Akter,2007).

Natural resource rents, the sum of oil rents, natural gas rents, coal rents (hard and soft), mining rents and forestry rents. This variable shows how the distribution of natural resource rents influences women's participation in the labour force. The expected sign for this variable is negative. The female population (Popfemm) as a % of the total population could be an indicator of women's empowerment if they represent the majority of the population. Political stability index indicates a politically stable country allows for women's economic inclusion (Asongu et al., 2020). Inflation (infl) reflecting the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that can be fixed or changed at specified intervals, for example annually. This variable will allow us to see whether the variation in prices enables women to have a job or not. The expected sign for this variable is (+/-)

3.2. Econometric specification and estimation strategy

To test the effect of the digital divide on women's economic participation we follow the earlier work of Samargandi et al. (2019), used multiple linear regression models to highlight the effects of ICT on women's participation in the labour market in developed and developing countries. We specify the following equation:

$$WEP_{i,t} = \alpha + \beta_1 digital\ divide_{\ i,t} + \beta_2 X_{i,t} + \mu_i + v_t + \varepsilon_{i,t} \quad (1)$$

$WEP_{i,t}$ Represents the index of women's economic participation, $\boldsymbol{digital\ divide_{i,t}}$ represents the ICT access and use gap. According to Song et al. (2020), three groups of indicators can be used to analyze the digital divide. These indicators concern the following aspects: (i) access (penetration rate of computers, cell phones, number of Internet service providers per inhabitant, cost of Internet access), (ii) use (number of Internet users per inhabitant, broadband subscribers per inhabitant, duration of Internet use, bandwidth per inhabitant), and (iii) results (economics of e-commerce, benefits of e-shopping, results of e-education, e-government services). Due to insufficient data in some African countries, two main measures of the digital divide are used: the mobile divide (MTD), the internet divide (ID) and the bandwidth divide.

For each indicator chosen, the gap is determined by subtracting the percentage of the indicator from the total penetration rate of 100% (Rice & Katz, 2003). $X_{i,t}$ is the set of economic control variables that explain the dynamics of the IEF, such as: (i) female education; (ii) inflation; (iii) female population; (iv) GDP per capita; (v) control of corruption; (vi) natural resource rents. The choice of these variables is based on the literature. In addition, $\mu_i + v_t + \boldsymbol{\varepsilon}_{i,t}$ are time fixed effects, country fixed effects and disturbance k.

3.2.1. Technical estimation

To estimate equation (1), we employ a sequential econometric approach, taking into account the difficulties associated with each estimation method. We begin by estimating using ordinary least squares (OLS). This method makes full use of the information available at both individual and temporal levels. It also increases the probability of obtaining unbiased and consistent estimators, provided that the exogeneity assumption for the explanatory variables is respected. We also introduce control variables into the regression in order to limit the omitted variable bias. This method has been used by authors such as Mignamissi and Malah (2021) in the study of the relationship between natural resources and happiness.

Subsequently, we assess the robustness of our results by opting for several approaches. (i) given that the dependent variable is bounded in the interval [0-100], our results could be biased with OLS. To remedy this bias, in this work we run the TOBIT, censored Poisson and truncated negative Binomial estimators[1]. (ii) The relevance of our analyses could be questioned by the fact that the OLS estimator focuses only on the average effect, and does not take into account the effect that our different measures of the digital divide could have on different rate intervals of women's economic participation. To compensate for this, a competing approach among others is quantile regressions (QR). (iii) although OLS allow us to improve our model, they do not take into account the unobserved heterogeneity of certain variables, suggesting the existence of heteroskedasticity and possible endogeneity in our model. Thus, to correct for these two problems, we will use the two-stage least squares (2SLS) estimation method of Lewbel (2012) and (iv) to account for potential dynamic effects and endogeneity (Arellano & Bover, 1995; Blundell & Bond, 1998), we will use the generalised method of moments developed by Arellano and Bond (1991).

[1] TOBIT estimates represent a model in which the censored values of the dependent variable are fixed. Censoring can occur on the left, right or both sides. The censored Poisson model is recommended when a dependent variable has some observations censored on the left, right or both sides. The truncated negative binomial regression model is used when the dependent variable is a positive count variable, all values of which exceed a certain truncation threshold.

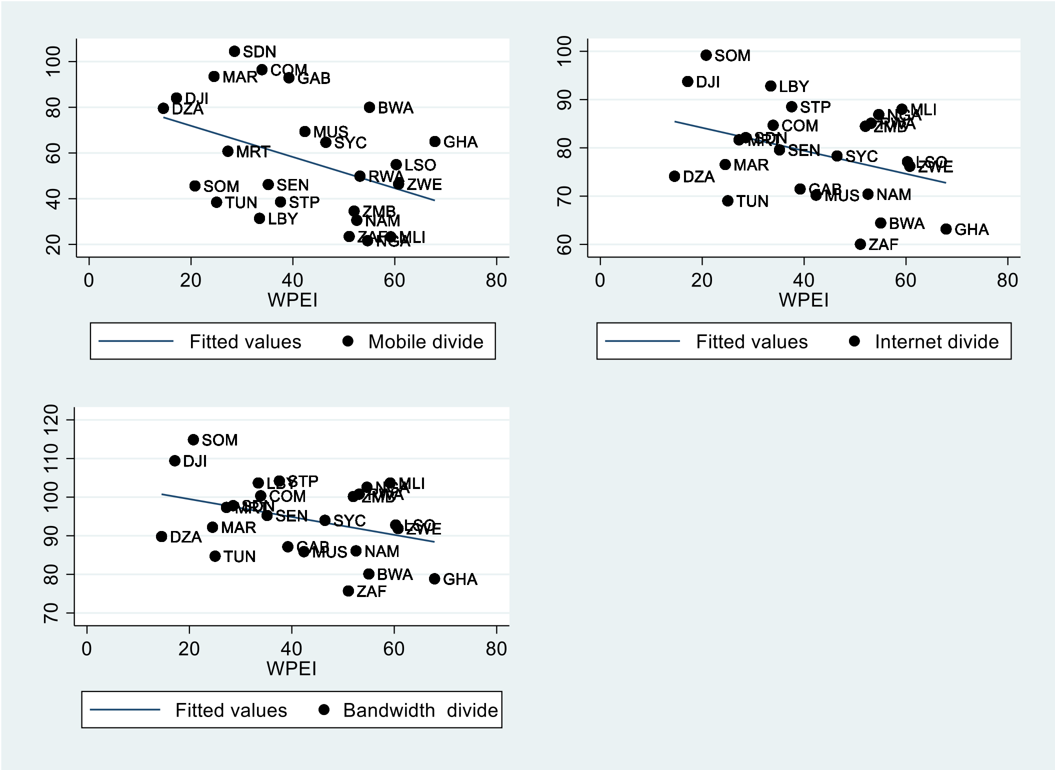
4. Empirical analysis

4.1. Preliminary result

The descriptive statistics presented in table (A2) show that, in general, women's economic participation is relatively concentrated according to their means and standard deviations. This is also observed in the digital divide (DD) indicators. The mean values of the DD are high with small standard deviations for most of the variables, which is confirmed by the generally small ranges. This situation indicates that African countries are among the most fractured in the world, which could have a negative impact on the level of women's economic participation. The overall averages of our variables are respectively 53.302 for women's economic participation, and 134.556, 76.567 and 101.215 for the digital divide (from bandwidth, internet, and mobile telephony to absolute value). With a standard deviation of 18,698 for the first variable and 44,486, 16,249 and 23,635 respectively for the second variables.

The correlation between our digital divide indicators and women's economic participation is negative, as shown in Figure 1 and Table A3 in the Appendix. Over the period 2000-2021, the digital divide increased, while women's participation in the labour market deteriorated. This is because women have difficulty accessing ICTs for a number of reasons, including income and digital literacy issues, which limit women's access to ICTs.

Figure 1: Evolution of the digital divide and women's economic participation in Africa



Source: Author, based on Stata with the WDI and OLT database

4.2. Basic results

Table (1) presents the relationship between the absolute digital divide (mobile telephony, Internet and bandwidth) and women's participation in economic activity. Columns 1, 3 and 5 present the bivariate relationship between the digital divide and women's participation in economic activity. The coefficient of the digital divide is negative and statistically significant in all specifications. This indicates that an increase in the digital divide reduces women's participation in economic activity. Specifically, a 1% increase in the various digital divide indicators results in a 0.077, 0.298 and 0.094 percentage point decrease in women's economic participation in Africa. This finding may be explained by the fact that women without access to the internet or cell phones may be excluded from accessing information on economic opportunities, job offers, vocational training and other resources useful for improving their skills and economic prospects. A similar finding was made by Fallon and Boutilier (2021) in the case of Ghana, who point out that women living in the northern and southern regions are not only numerically underserved, but also excluded from employment opportunities and economic remuneration. Similarly, Omotoso et al (2020) and Amber and Chichaibelu (2023) have repeatedly examined the gender digital access gap in South Africa and Pakistan and its impact on women's labour market outcomes. Key findings show that inequalities in women's ownership of digital technologies are negatively associated with women's labour market participation.

What's more, the digital divide can make it harder for women to manage work-life balance. Indeed, digital technologies often enable women to participate in flexible jobs, such as remote working or online self-employment. Without adequate access to the internet, phones and bandwidth, these opportunities can be limited for women, depriving them of potential sources of income and household management. In addition, women with limited access to the internet or cell phone services may be at a disadvantage in terms of access to training and continuing education, which can affect their employability and economic opportunities (Asongu et al., 2020 and Galpein and Arcidiacano, 2021).

However, the negative relationship between the Internet divide and women's economic participation is stronger than that of the cell phone and bandwidth divides. This can be explained by the fact that few women do not have access to the internet and do not know how to exploit it (Galpein and Arcidiacano, 2021), they use the interest for other facts in particular, for social networks and for entertainment (Van Deursen and Van Dijk, 2015) and that the cost of internet access is extremely high in most developing countries. This in turn increases the obstacles preventing women from undertaking economic activities.

As far as the control variables are concerned, they are introduced gradually into the model. The analysis of control variables focuses essentially on the results contained in columns (2, 4 and 6). Growth in GDP per capita increases women's economic participation by around 1%. This corroborates the findings of Jonson (2015) and Anyanwu (2016), who demonstrate that per capita GDP growth increases gender equality in women's employment. The same is true for corruption control, where a 1% increase is associated with a 0.14 percentage point increase in female labour force participation, suggesting that reducing corruption to an optimal level can generate broader economic activity and employment opportunities for women.

There's also a positive link between female population density and female economic participation of at least 1%. In an African context, it is possible that a higher proportion of women in the population will increase the visibility of women in the workforce. Indeed, in many African countries, the population is dominated by women, which explains why there are more policies to include them in the development process. This corroborates the work of Klasen and Pieters (2012) and Anyanwu (2016), who support the idea that the size of a country's female population is an element conducive to improving the size of the economic participation basket. More specifically, it influences women's level of participation in the labour market or entrepreneurship. Relative to women's level of education, an increase in their human capital manifests itself as an improvement in women's economic participation. This implies that the stock of human capital determines women's inclusion in the labour market (Ince, 2010).

In terms of inflation, it could lead to an expansion of the sector of economic activity, i.e. an increase in price (from P1 to P2) leads to an increase in the quantity of production and an increase in the producer's surplus, which in turn requires a new demand for labour and capital. These explanations taken from Gregory Mankiw's curve (1998) therefore clearly show that an inflation control generates new employment and economic activity opportunities for women.

On the other hand, variables such as natural resource rents reduce women's economic participation in Africa. A 1% increase in total natural resource rents reduces women's economic participation in the selected sample by at least 0.146%. These results corroborate those of Awoa et al (2022), who show that natural resource rents reduce women's empowerment. More specifically, through the Corden and Neary (1982) Dutch disease mechanism, the natural resource boom reduces women's economic participation, which affects their economic representativeness. Some studies have also shown that natural resource abundance can influence women's economic empowerment (Simmons, 2019).

Table 1: Effect of the digital divide on women's economic participation

	Women's economic participation index					
	OLS					
	(1)	(2)	(3)	(4)	(5)	(6)
Mobile phone divide	**-0.077***** (0.012)	**-0.104***** (0.018)				
Internet divide			**-0.298***** (0.032)	**-0.373***** (0.047)		
Bandwidth divide					**-0.094***** (0.025)	**-0.159***** (0.041)
GDP_per capital		0.030*** (0.008)		0.034*** (0.008)		0.036*** (0.009)
Women's education		0.131*** (0.087)		0.223*** (0.090)		0.174*** (0.093)
Corruption Control		0.203*** (0.987)		0.082** (0.994)		0.148*** (1.101)
Total female population		0.103*** (0.028)		0.078*** (0.025)		0.062** (0.030)
Total income from natural resources		-0.148*** (0.015)		-0.116*** (0.017)		-0.174*** (0.015)
Inflation		0.639*** (0.147)		0.546*** (0.143)		0.657*** (0.167)
Constant	42.824*** (1.601)	41.824*** (4.603)	30.707*** (2.425)	28.161*** (5.261)	43.624*** (2.544)	45.144*** (5.918)
Observations	975	596	958	585	863	525
R-squared	0.033	0.200	0.068	0.243	0.014	0.183

*Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$*

Source: Author based on WDI and OTI data (2022)

4.3. Sensitivity and robustness analysis

4.3.1. Sensitivity analysis of cultural variables

Sensitivity analysis with cultural variables (such as values, beliefs, social norms) is crucial to understanding how these factors influence different economic outcomes. Adding cultural variables to the model allows us to check whether our results remain stable and to correct the problem of omitted variables. Our results in Table (2) reveal that, by adding cultural variables to the model, the digital divide reduces women's economic participation. More specifically, in this table, we find that cultural variables such as linguistic fragmentation and Catholic religion significantly increase women's economic participation. This can be explained by the fact that colonial policies and practices attempted to take into account beliefs, customs, language and culture. For example, a French legal system systematizes the use of traditional values and reinforces social norms. This conclusion is consistent with Antonio and Tuffley (2014) and Cummings and O'Neil (2015).

However, the results also show that in Africa, social identity in the form of ethnic fragmentation and Muslim and Protestant religious fragmentation reduces women's ability to access economic opportunities. Indeed, Islam has been accused of reducing African women's sphere of activity to the home and the family. Especially as articulated by Islamic sages, it propagates an ideology of female domesticity. This contributes in no small measure to the "menagization" of women in Muslim households across the continent. This negative finding is consistent with that of Sudarkasa (1986) and Ongo et al. (2022), who found that the Muslim religion hinders women's empowerment.

In addition, Protestantism, like many religions, has historically promoted traditional gender roles, where women were often seen as responsible for the home and children, while men were the main economic providers. This can limit women’s opportunities to engage in economic activities outside the home (Weber, 1905, Norris & Inglehart, 2011). Conservative interpretations of Protestant religious texts may promote the idea that women should submit to male authority, including in the economic context. This perspective can limit women's opportunities for leadership and economic autonomy (Woodhead, 2012).

Table 2: cultural variables

Women's economic participation index			
	OLS		
	(1)	(2)	(3)
Mobile phone divide	**-0.071***** (0.012)		
Internet divide		**-0.213***** (0.028)	
Bandwidth divide			**-0.106***** (0.022)
GDP_per capital	0.017* (0.010)	0.011 (0.008)	0.012 (0.009)
Women's education	0.064*** (0.042)	0.118*** (0.045)	0.065*** (0.046)
Corruption Control	1.013* (0.967)	-1.464 (0.961)	-1.179 (1.101)
Total female population	0.114*** (0.032)	0.134*** (0.030)	0.143*** (0.032)
Total income from natural resources	-0.128*** (0.013)	-0.116*** (0.015)	-0.136*** (0.016)
Inflation	0.540*** (0.117)	0.506*** (0.118)	0.504*** (0.128)
Catholic	0.489*** (0.665)	0.605*** (0.656)	0.809*** (0.825)
Muslim	-0.036*** (0.083)	-0.071*** (0.818)	-0.070*** (0.098)
Protestant	-0.037*** (0.063)	-0.498*** (0.385)	-0.628*** (0.568)
Ethnic fragmentation	-0.162 (0.569)	-0.513* (0.629)	-0.278* (0.900)
Linguistic fragmentation	0.098*** (0.025)	0.068*** (0.048)	0.051*** (2.974)
Constant	61.847*** (5.115)	55.507*** (4.905)	0.247*** (0.180)
Observations	572	561	504
R-squared	0.640	0.653	0.638

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Author based on WDI and OTI data (2022)

4.3.2. Sensitivity analysis based on country political systems

The aim of this analysis is to assess whether the relationship between the digital divide and women's economic participation is perceived in the same way in different countries, depending on the political system. To this end, the analysis is conducted at two levels. On the one hand, we analyzed the relationship between the digital divide and women's economic participation in a democratic country and, on the other, in an autocratic country. In these different groups of countries, the results show that in democratic countries, the cell phone digital divide and bandwidth have no significant consequence on women's economic participation, whereas the Internet digital divide hampers women's economic participation.

These results also show that efforts to improve freedom for all in Africa since the 2000s have contributed to the inclusion of gender in the economic sphere, that democracy is an essential element in advancing gender equality, and that women's access to ICT increases their participation in the workforce, as highlighted by (Stroup, 2008). On the other hand, in autocratic countries, all measures of the digital divide significantly hinder women's economic participation. In such a context, women-led sectors of economic activity are handicapped, potentially hindering inclusive development (Stroup, 2008).

Table 3: The effect of the digital divide on women's economic participation: by political system

	Women's economic participation index					
	OLS					
	Democratic system			**Autocratic regime**		
Mobile phone divide	**-0.064** (0.051)			**-0.322***** (0.044)		
Internet divide		**-0.273*** (0.063)			**-0.976***** (0.087)	
Bandwidth divide			0.287 (0.069)			**-0.462***** (0.058)
GDP_per capital	0.268** (0.113)	0.143** (0.067)	0.148** (0.074)	0.005 (0.005)	0.018* (0.006)	0.026* (0.007)
Women's education	0.303*** (0.269)	0.137*** (0.280)	0.190*** (0.310)	0.158 (0.179)	0.318** (0.219)	0.596*** (0.243)
Corruption Control	0.013*** (3.690)	0.303*** (3.365)	0.888*** (2.929)	-0.805*** (4.035)	-0.612*** (3.746)	-0.040*** (4.410)
Total female population	-0.067 (0.155)	-0.071 (0.131)	-0.050 (0.130)	-0.020 (0.074)	0.068 (0.080)	0.034 (0.101)
Total income from natural resources	-0.230*** (0.063)	-0.219*** (0.065)	-0.225*** (0.061)	-0.002*** (0.053)	-0.063*** (0.058)	-0.075*** (0.060)
Inflation	-0.050 (0.203)	-0.065 (0.196)	-0.007 (0.198)	0.094*** (0.086)	0.013*** (0.061)	0.086*** (0.355)
Constant	76.249*** (23.069)	63.438*** (17.776)	52.975*** (18.005)	16.344** (7.551)	-14.721* (8.600)	19.602** (8.761)
Observations	113	110	103	95	94	89
R-squared	0.450	0.490	0.456	0.699	0.713	0.660

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Author based on WDI and OTI data (2022)

4.4. Analysis of the robustness of the results

There are several aspects to the robustness analysis of this study. First, we introduce additional digital divide variables to account for the influence of the digital divide on women's economic participation. Second, the results may be influenced by the measure of women's economic participation than the overall index, so we check the robustness by sectoral measures of women's economic participation. Third, the results may also be influenced by the estimation technique. Therefore, to test the robustness of our main results, we perform two significant robustness tests in this subsection. First, we check the boundedness of the dependent variable with the TOBIT, censored Poisson and truncated negative binomial estimators and second, we perform the robustness test with the quantile regression (QR) method to make our results more robust. Overall, in all robustness tests, we find specification results equivalent to those in the base table.

4.4.1. Alternative measures to bridge the digital divide

The previous section used the absolute digital divide. This measure may give rise to a limited examination of the link between the digital divide and women's economic participation. This section therefore considers the relative digital divide. The role of this indicator is to reinforce the result of the digital divide on women's economic participation. Overall, the results validate that the digital divide systematically hinders women's economic participation in Africa. The amplitude is higher with the broadband channel and lower with the cell phone channel. So, while heterogeneity persists for other digital channels, African countries seem to be converging towards cell phone use, which justifies the low magnitude of its digital divide. The low disparity in cell phone use tends to increase women's economic participation. On the one hand, if cell phones were the only digitization channel, African countries would tend to have high female economic participation rates.

Table 4: Robustness check using relative digital divide components[2]

Women's economic participation index			
	OLS		
	(1)	**(2)**	**(3)**
Mobile phone divide (R)	**-0.040**** (0.018)		
Internet divide (R)		**-0.161***** (0.041)	
Bandwidth divide (R)			**-0.513**** (0.071)
GDP_per capital	0.024** (0.010)	0.036*** (0.009)	0.021** (0.010)
Women's education	0.063*** (0.086)	0.174*** (0.093)	0.012*** (0.090)
Corruption Control	0.792*** (1.046)	0.138*** (1.094)	0.672*** (0.988)
Total female population	0.047* (0.027)	0.062** (0.030)	0.048* (0.028)
Total income from natural resources	-0.173*** (0.014)	-0.173*** (0.015)	-0.165*** (0.017)
Inflation	0.564*** (0.145)	0.626*** (0.158)	0.620*** (0.140)
Constant	60.232*** (3.206)	47.567*** (5.385)	-14.541 (36.179)
Observations	589	531	597
R-squared	0.160	0.184	0.158

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Author based on WDI and OTI data (2022)

4.4.2. According to women's economic activity sectors

This robustness analysis is important because it allows us to check whether the relationships observed between the digital divide and women's economic participation are solid and consistent, even when different sectors of women's economic activity are

[2] (R) Represents the different measures of the relative digital divide

taken into account. In other words, examining the robustness of the results ensures that the relationships between the digital divide and women's sectoral activity variables are not simply the result of coincidence or statistical bias. This strengthens the validity of the conclusions drawn from the analysis and provides a more solid basis for political or economic decision-making. Thus, in this section, we test the effects of the digital divide on sectoral economic participation using the three sub-indices of women's economic participation (agriculture, industry and services) as dependent variables in the dynamic model, again with OLS estimation.

Indeed, the negative relationship between the digital divide and women's participation in the industrial sector may reflect the fact that Africa has experienced an access and usage gap in new products and processes, a low rate of innovation in various countries have a knock-on effect on industries. Furthermore, the fact that the digital divide is less likely to have an impact on women's economic participation in the agricultural sector may be justified by the high visibility of women in this sector. These results are close to those of Ndubuisi et al (2021). Finally, economic variables such as GDP growth, female population, corruption control and inflation are almost all positively and significantly associated with women's participation in the three economic sectors, while women's education and natural resource rents are negatively associated with women's economic activity.

Table 5: The effect of the digital divide on women's sectoral economic participation

VARIABLES	OLS								
	Agriculture (1)	Industry (2)	Services (3)	Agriculture (5)	Industry (6)	Services (7)	Agriculture (8)	Industry (9)	Services (10)
Mobile phone divide	**0.024***** (0.093)	**-0.116***** (0.574)	**-10.665***** (2.333)						
Internet divide				**-0.500** (0.212)	**-0.764***** (0.529)	**-28.586***** (7.191)			
Bandwidth divide							**0.036***** (0.053)	**-0.350** (0.985)	**-5.477** (4.046)
GDP_per capital	0.555** (0.726)	0.022 (0.545)	1.034 (2.154)	0.350* (0.740)	0.020 (0.560)	1.011 (2.211)	0.087** (0.776)	-0.007 (0.473)	0.748 (1.835)
Women's education	0.758 (0.399)	0.286*** (0.861)	0.282*** (7.051)	0.869* (0.834)	3.500*** (2.086)	8.997*** (7.867)	0.959* (6.592)	6.528** (2.115)	23.990*** (6.993)
Corruption Control	0.840** (0.168)	0.730*** (0.899)	0.084*** (0.984)	0.061*** (0.066)	0.049*** (0.082)	0.055*** (0.079)	0.629** (0.859)	0.612*** (0.775)	0.176*** (0.054)
Total female population	0.292 (0.508)	-1.096 (0.877)	-6.853** (3.401)	-1.228 (2.497)	-0.958 (0.867)	-5.713* (3.340)	1.535 (2.615)	0.567 (0.857)	-0.510 (3.180)
Total income from natural resources	-0.051*** (0.015)	-0.957*** (0.646)	-0.287*** (0.602)	-0.224*** (0.461)	-4.615*** (0.724)	-0.402*** (0.037)	-0.578*** (0.072)	-3.276*** (0.571)	-0.822*** (0.274)
Inflation	0.034*** (0.014)	2.838 (2.671)	0.592* (0.772)	0.095*** (0.409)	0.384 (0.735)	0.207** (0.014)	0.048*** (0.907)	3.845 (2.976)	0.585** (0.515)
Constant	1,735.686*** (432.570)	983.980*** (179.413)	4,115.365*** (752.273)	2,668.751*** (574.676)	1,160.252*** (214.375)	4,911.830*** (971.104)	1,429.218*** (450.597)	526.878*** (167.363)	2,385.525*** (711.308)
Observations	596	596	596	585	585	585	525	525	525
R-squared	0.106	0.095	0.101	0.104	0.104	0.110	0.106	0.085	0.083

4.4.3. Checking the limited nature of the dependent variable

Since the dependent variable is limited to the interval [0-100], the use of OLS or similar methods could lead to biased results. This is because OLS is not suitable for limited dependent variables with a high degree of diversity. A dependent variable may be continuous over one or more intervals, but may also take on specific values with a defined probability. Models for limited dependent variables are designed to handle samples that are either truncated or censored. To correct for this bias, specific estimators can be used. In this study, we use TOBIT, censored Poisson and truncated negative binomial models.

These models are called "counting models" because they count the occurrences of an event. More precisely, they take into account the problems of censoring and truncation. A sample is considered truncated if certain observations that should have been included have been systematically omitted. Conversely, a sample is said to be censored when no observations have been excluded, but part of the information has been masked. These situations can occur with the extreme values (0 and 100) for women's economic participation. The results presented in Table 6, whether or not regional fixed effects are involved, confirm the previous observations: the digital divide in Africa is a reality.

Table 6: The effect of the digital divide on women's economic participation: controlling for boundedness

	Women's economic participation index								
	TOBIT			Censored fish			Negative binomial		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mobile phone divide	**-0.004** (0.024)			**-0.002***** (0.000)			**-0.002***** (0.000)		
Internet divide		**-0.122**** (0.053)			**-0.008***** (0.001)			**-0.008***** (0.001)	
Bandwidth divide			**-0.060** (0.039)			**-0.003***** (0.001)			**-0.003***** (0.001)
GDP_per capital	0.472*** (0.156)	0.416*** (0.148)	0.427*** (0.144)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Women's education	0.375*** (0.093)	0.398*** (0.092)	0.401*** (0.092)	0.002 (0.002)	0.004** (0.002)	0.003* (0.002)	0.002 (0.002)	0.004** (0.002)	0.003** (0.002)
Corruption Control	-0.876 (1.727)	-0.892 (1.572)	-0.627 (1.636)	0.063*** (0.018)	0.043** (0.019)	0.064*** (0.020)	0.068*** (0.020)	0.044** (0.020)	0.067*** (0.022)
Total female population	-0.092 (0.056)	-0.074 (0.054)	-0.083 (0.054)	0.002*** (0.000)	0.002*** (0.000)	0.001** (0.001)	0.002*** (0.000)	0.001*** (0.000)	0.001** (0.001)
Total income from natural resources	-0.113*** (0.025)	-0.091*** (0.024)	-0.109*** (0.023)	-0.003*** (0.000)	-0.003*** (0.000)	-0.004*** (0.000)	-0.003*** (0.000)	-0.002*** (0.000)	-0.004*** (0.000)
Inflation	1.441*** (0.437)	1.309*** (0.408)	1.300*** (0.403)	0.012*** (0.002)	0.010*** (0.002)	0.013*** (0.003)	0.012*** (0.003)	0.011*** (0.003)	0.013*** (0.003)
Constant	55.441*** (9.311)	43.517*** (8.670)	47.946*** (8.698)	3.789*** (0.087)	3.448*** (0.113)	3.825*** (0.118)	3.803*** (0.086)	3.450*** (0.114)	3.832*** (0.120)
Pseudo R2	0.1237	0.1323	0.1305	0.1041	0.1316	0.1006	0.0223	0.0299	0.0212
Observations	596	585	525	596	585	525	596	585	525

4.4.4. The non-parametric approach

Whether or not the relationship between a digital divide and women's economic participation is negative may depend on the econometric approach used. We used a parametric econometric approach based on OLS regressions. However, the relevance of our analyses may be called into question by the fact that the OLS estimator focuses solely on the mean and does not take into account the different distributions that our digital divide measures could have on women's economic participation.

A competing approach to this problem is quantile regression (QR). First introduced in the seminal contribution by Koenker and Bassett (1978), QR is a non-parametric approach widely used in the literature to take into account the effect of one variable on another at different points in its distribution. Thus, unlike previous work that focuses on modeling the average effect of the digital divide, this study goes beyond these lines and examines the relationship between the digital divide and different intervals of the distribution of women's economic participation. This approach may be superior to OLS in a number of ways. For example, OLS may be ineffective if errors are highly non-normal, the QR method is more robust to non-normal errors and outliers.

Similarly, when the dependent variable has a wide distribution, as is the case for the "scale of life" variable, the mean can fluctuate significantly in the presence of high diversity within the sample. Estimation of the mean can also be distorted if data are censored, i.e. when the variable is only observed above or below a certain threshold. In such a situation, estimating the mean or conditional mean of a censored variable may be irrelevant, unless parametric assumptions are made about the distribution of this variable beyond the threshold. QR overcomes these obstacles and offers a more detailed description of the distribution of a variable of interest as a function of its determinants than simple linear regression, which focuses solely on the conditional mean. Quantile estimation is obtained by solving the following optimization problem, which can be formulated as follows:

$$y_{it} = x'_{it}\beta_\theta + u_{\theta it} \text{ with } 〚Quant_\theta(y_{it}|x_{it}) = x'_{it}\beta_\theta \quad (2)$$

Where $y_i$is the index of women's economic participation, β is the vector of parameters to be estimated, x_i is a vector of regressors and u is the vector of residuals. $Quant_\theta(y_{it}|x_{it})$ represents the θth conditional quantile of y_{it} for a given x_{it}. The quantile estimator is obtained by solving the following optimization problem for the θth quantile (0 < θ < 1):

$$\min_{\beta \in R^K} \left[\sum_{i,t:y_{it} \geq x_{it}'\beta} \theta \left| y_{it} - x_{it}'\beta \right| + \sum_{i,t:y_{it} \geq x_{it}'\beta} (1-\theta) \left| y_{it} - x_{it}'\beta \right| \right] \quad (3)$$

In line with the methodology used previously, we assess the relationship between the digital divide and women's economic participation. Columns (1)-(5) show estimates for the 10th, 25th, 50th, 75th and 95th quantiles. We observe that the internet, cell phone and broadband digital divide varies throughout the distribution of women's economic participation. Specifically, from the 10th to the 25th quantile distribution, the cell phone divide severely handicaps women's economic participation. However, from the 50th quantile distribution onwards, the negative sign loses its significance, and from the 75th to the 95th becomes positive and significant at the 1% threshold. These results may be explained by the fact that, over time, the level of cell phone penetration improves and women's phone ownership increases, as does their access to labour market information and economic opportunities. As a result, their level of economic participation increases over time.

With regard to the internet divide, we find that at the 10 th, 75 th and 95 th quantile, women's economic participation is negative, while at the 25 th and 50 th quantile distribution, women's economic participation becomes positive. These results can be explained by the fact that access to the Internet in African countries remains relatively low, and most women have no knowledge of how to use the Internet, which has a negative effect on their economic participation. With regard to the bandwidth divide, the results show that from the 10 th quantile is positive but not significant, and from the 25 th quantile distribution becomes negative and significant. These results can be explained by women's limited access to bandwidth, which deprives them of potential sources of income.

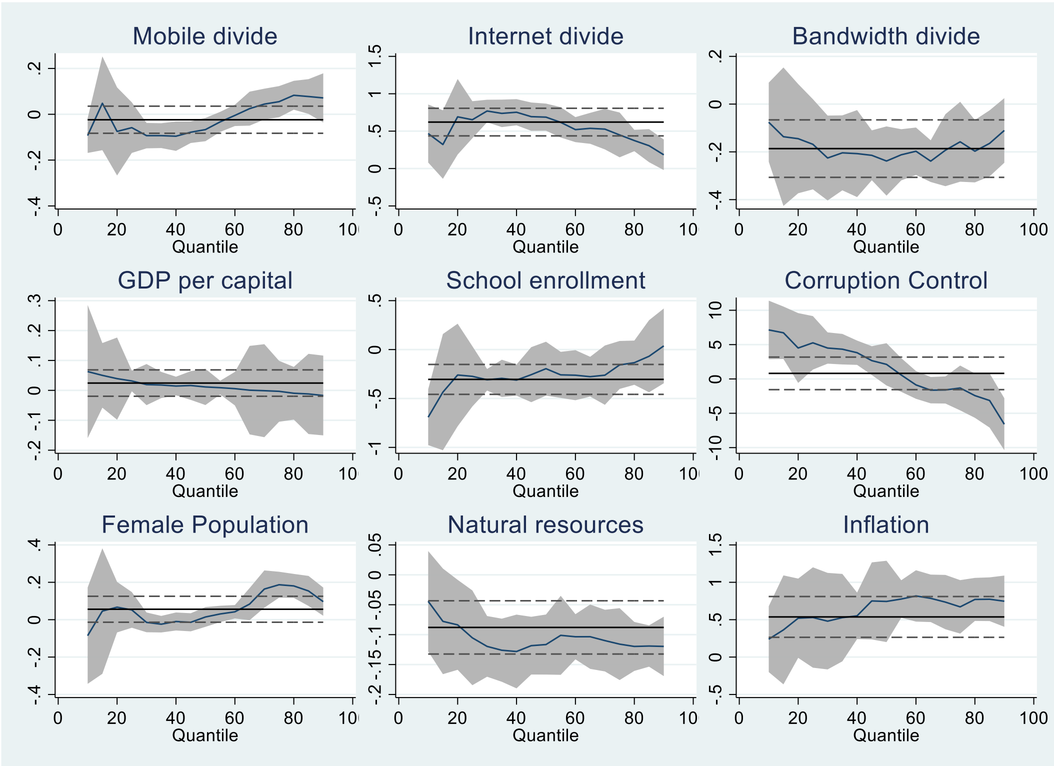
Table 7: Quantile Regression

Women's economic participation index					
	Quantile regression				
	Q10	Q25	Q50	Q75	Q95
Mobile phone divide	**-0.026** (0.046)	**-0.144***** (0.020)	**-0.022** (0.031)	**0.088***** (0.022)	**0.064***** (0.012)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	45.495*** (14.364)	28.687*** (8.242)	62.150*** (6.578)	43.599*** (4.561)	61.685*** (4.251)
Observations	596	596	596	596	596
Pseudo R2	0.1000	0.1485	0.1089	0.1786	0.1868
Internet divide	**-0.295***** (0.092)	**0.391*** (0.064)	**0.316**** (0.069)	**-0.348***** (0.055)	**-0.163**** (0.079)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	14.670 (15.449)	25.704*** (7.290)	37.690*** (6.921)	29.464*** (4.917)	56.846*** (7.249)
Observations	596	596	596	596	596
Pseudo R2	0.1156	0.1730	0.1352	0.1853	0.1883
Bandwidth divide	**0.083** (0.052)	**-0.260***** (0.060)	**-0.049**** (0.067)	**-0.112*** (0.061)	**0.085**** (0.033)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	40.583*** (7.364)	30.536*** (8.587)	61.762*** (8.677)	48.354*** (9.138)	62.483*** (6.671)
Observations	596	596	596	596	596
Pseudo R2	0.1070	0.1238	0.1151	0.1562	0.1704

Source: Authors based on WDI and OTI data (2022)

These results are confirmed by figure (2), which illustrates how the digital divide handicaps women's economic participation in the different quantile distributions, and how the magnitude of these effects at the different quantiles differs significantly from the OLS coefficient (presented as horizontal lines). In this way, the thesis of the curse of the African technology divide documented by Das and Drine (2020) is verified as a function of women's level of economic participation.

Figure 2: Magnitude of the effects of the digital divide on women's economic participation as a function of quantiles.



Source: Authors based on WDI and OTI data (2022)

4.4.5. Alternative approaches to controlling for endogeneity

By taking into account the unobserved heterogeneity of certain variables, thus suggesting a presumption of the existence of heteroskedasticity and possible endogeneity in our model. Thus, to correct these two problems we apply the approach of Lewbel (2012), (LIML) IV-2SLS and IV-GMM2S.

4.4.5.1. IV-2SLS, Lewbel, (2012)

Firstly, to ensure that our results do not suffer from instrumentation-related problems, we use the instrumental variables method. However, the difficulty with this method lies in finding an instrument that is perfectly exogenous and adequate. According to Baum et al. (2012), an instrument is considered adequate if it is highly correlated with the endogenous variable, if it respects the orthogonality condition, and if it is correctly excluded from the model, so that its effect on the explained variable is only indirect (Baum et al., 2012). Indeed, the complexity of these requirements makes it difficult to find an exogenous instrument, but Lewbel's (2012) instrumental variable estimation method offers a better solution when obtaining a purely exogenous instrument is complicated, as in our case. This method is crucial for identifying structural parameters in regression models with endogenous or poorly measured regressors, without the need for traditional instruments. Instruments based on heteroskedasticity are integrated into Lewbel's 2SLS. The residuals of the auxiliary equation are multiplied by each external variable in a form centered around the mean to construct the internal instruments. This approach circumvents the usual exclusion constraints, as the estimates of the Lewbel 2SLS without external instruments are quite close to those obtained with external instruments (Lewbel, 2012). Numerous studies in the literature have adopted this estimation technique (Domguia et al., 2022; Ngounou et al, 2023; Fang et al, 2023). Indeed, the basic results remain stable after the endogeneity check with the Lewbel (2012) technique.

Table 8: IV-LEWBEL, (2012)

	(1)	(2)	(3)
VARIABLES		**WEP**	
Mobile phone digital divide	-0.00928*** (0.00139)		
Internet digital divide		-0.0250*** (0.00428)	
Bandwidth digital divide			-0.0139*** (0.00284)
GDP_per capital	0.431*** (0.101)	0.448*** (0.0994)	0.516*** (0.109)
Women's education	-0.00127 (0.0333)	0.0468 (0.0323)	0.0647* (0.0348)
Corruption Control	0.000100 (0.00158)	0.000256 (0.00159)	-0.000529 (0.00181)
Total female population	2.624*** (0.226)	2.426*** (0.228)	2.476*** (0.261)
Total income from natural resources	-0.0200** (0.00777)	-0.00851 (0.00714)	-0.0153* (0.00894)
Inflation	-8.11e-05 (0.00505)	-0.00290 (0.00407)	-0.00236 (0.00449)
Constant	-0.861*** (0.120)	-0.746*** (0.122)	-0.786*** (0.139)
Observations	637	633	561
R-squared	0.993	0.993	0.993
Kleibergen-Paap rk Wald F statistic	144.3***	156.4***	127.3***
Sanderson-Windmeijer	144.3	156.4	127.3

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Authors based on WDI and OTI data (2022)

4.4.5.2. IV-2SLS LIML and GMM2S approach

Second, in contrast to the simple IV-2SLS approach, we apply the IV-2SLS and IV-GMM2S Limited Information Maximum Likelihood (LIML), respectively. The IV-GMM2S approach yields more efficient estimation coefficients with standardised errors based on the two-stage generalised method of moments. In IV-GMM2S, the efficient or optimal weighting matrix is the inverse of an estimate of the covariance matrix of the orthogonality conditions. The efficiency gains of this estimator compared with the traditional IV-2SLS estimator come from the use of the optimal weighting matrix, the restrictions on over-identification of the model and the relaxation of the orthogonality conditions. For an exactly identified model, the GMM2S and traditional IV-2SLS estimators coincide, and under the assumptions of conditional homoscedasticity and independence, the GMM2S estimator also coincides with the traditional IV-2SLS estimator (Davidson and MacKinnon, 1993; Baum, 2006; Hayashi, 2011). In contrast, the IV-2SLS-LIML approach controls for the problem of weak instruments.

Parameter inference is based on the consistent estimation of a maximum of four terms of the asymptotic variance, while the specification test is based on the asymptotically normal (or asymptotically equivalent, optionally adjusted chi2) distribution of the overidentifying test of the parameter statistic (Fuller, 1977; Davidson and MacKinnon, 1993; Baum, 2006; Anatolyev, 2019). The results of this analysis are shown in Table 9 below. Analysis of this table allows us to see that the coefficients estimated by the IV-LIML and GMM2S methods are relatively different from those of the traditional IV-2SLS which may reflect the intuition that the baseline results following the IV-2SLS approach have been corrected for the low instrumentation problem while providing more efficient coefficients. Our results confirm the baseline results in the sense that the digital divide reduces women's economic participation. The results concerning the quality of the instruments are satisfactory. Regarding the relevance of the instruments, the Kleibergen -Paap Wald rk F-statistic is used to test the weakness of the instruments (Kleibergen and Paap, 2006). The Kleibergen -Paap Wald rk F-statistic must be at least 10 for weak identification not to be considered a problem (Tadadjeu et al., 2023b; Nguena and Piva, 2023; Mignamissi et al., 2024).

Table 9: IV-LEWBEL, (2012) LIML and GMM2S

	(1)	(2)	(3)	(4)	(5)	(6)
	LIML			GMM2S		
VARIABLES			**WEP**			
Mobile phone digital divide	-0.0136*** (0.00216)			-0.00898*** (0.000509)		
Internet digital divide		-0.0285*** (0.00523)			-0.0259*** (0.00202)	
Bandwidth digital divide			-0.0144*** (0.00325)			-0.0140*** (0.00113)
GDP_per capital	0.303*** (0.106)	0.412*** (0.101)	0.510*** (0.111)	0.375*** (0.0497)	0.346*** (0.0538)	0.462*** (0.0487)
Women's education	-0.0475 (0.0369)	0.0397 (0.0327)	0.0634* (0.0351)	0.0182 (0.0145)	0.0327** (0.0146)	0.0611*** (0.0190)
Corruption Control	-0.000148 (0.00153)	0.000197 (0.00157)	-0.000544 (0.00180)	0.000154 (0.000686)	0.00126 (0.000841)	0.00112 (0.000808)
Total female population	2.691*** (0.226)	2.419*** (0.225)	2.473*** (0.261)	2.333*** (0.113)	2.144*** (0.117)	2.440*** (0.117)
Total income from natural resources	-0.0199*** (0.00745)	-0.00688 (0.00704)	-0.0150* (0.00892)	-0.0233*** (0.00591)	-0.00963* (0.00532)	-0.0158** (0.00632)
Inflation	-0.00111 (0.00637)	-0.00357 (0.00426)	-0.00252 (0.00458)	0.00251 (0.00386)	-0.00462* (0.00274)	-0.00228 (0.00312)
Constant	-0.888*** (0.120)	-0.738*** (0.121)	-0.784*** (0.139)	-0.712*** (0.0593)	-0.595*** (0.0625)	-0.767*** (0.0619)
Observations	637	633	561	637	633	561
R-squared	0.993	0.993	0.993	0.993	0.993	0.993
Kleibergen-Paap rk Wald F statistic	144.3	156.4	127.3	144.3	156.4	127.3
Sanderson-Windmeijer	144.3	156.4	127.3	144.3	156.4	127.3

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Authors based on WDI and OTI data (2022)

5. Conclusion

This article aims to investigate the relationship between the digital divide and women's economic participation. Based on data covering 45 African countries and using parametric and non-parametric approaches, we found evidence of the digital divide curse on women's economic participation. Specifically, we found that the digital divide tends to reduce women's economic participation, but that this effect differs according to political system, types of economic activity and different digital divide indices. Indeed, by studying the heterogeneity of results between countries, we found that the digital divide reduces economic participation more in more fractured regions and countries with weak democracies.

These results remain broadly robust when we use other measures of the digital divide. To put the relationship between the digital divide and women's economic participation into perspective, we employed a non-parametric approach using the quantile regression technique. The results show that the influence of the digital divide varies at different intervals of women's economic participation.

On the basis of our analysis, two main recommendations, among others, can be identified: (i) the main recommendation would be to reduce the global digital divide by improving digital inclusion for all, alongside financial inclusion, in order to popularise the digital technologies and services needed for business development and women's entrepreneurship; (ii) improve gender equality in the workforce, by making labour markets more inclusive and improving access to ICTs in order to reduce information asymmetries and eliminate the gender gap in decision-making.

Limitation: this study may be limited by a lack of reliable data. In addition, the available data may not reflect all dimensions of the digital divide, such as connection quality and digital skills. Furthermore, the method used does not take into account a causal relationship between the digital divide and women's economic participation.

Future work: Carry out longitudinal studies tracking changes in the digital divide and their impact on women's economic participation over a long period. Comparing these dynamics between different countries or regions could also provide valuable insights into the factors that promote or hinder this relationship. For example, comparing the impact of the digital divide on women's economic participation in countries with advanced digital policies and developing countries.

Appendices

Table A1: list of countries

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

Table A2: Descriptive statistics

Variable	Obs.	Mean	Standard deviation	Min	Max
WEP	989	53.302	18.698	12.335	87.123
Mobile phone divide	976	134.556	44.486	0	185.559
Internet divide	959	76.567	16.249	0	88.13
Heavy Band divide	864	101.215	23.635	0	115.675
GDP_per capita	949	10.399	31.195	-24.847	558.56
Women's education	919	11.316	11.505	.001	67.89
Corruption Control	935	-.771	.633	-2.45	1.161
Female Population	729	97.66	24.237	16.626	151.314
Total natural resources	850	70.916	40.059	.785	347.997
Inflation	921	4.424	8.138	-11.199	103.337

Table A3 : Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) WEP	1.000												
(2) Mobile divide (A)	-0.182 (0.000)	1.000											
(3) Mobile divide (R)	-0.048 (0.140)	-0.305 (0.000)	1.000										
(4) Intern divide (A)	-0.261 (0.000)	0.727 (0.000)	-0.248 (0.000)	1.000									
(5) Intern divide (R)	-0.114 (0.001)	0.722 (0.000)	-0.167 (0.000)	0.669 (0.000)	1.000								
(6) Bandep divide (A)	-0.117 (0.001)	0.749 (0.000)	-0.175 (0.000)	0.669 (0.000)	1.000 (0.000)	1.000							
(7) Bandep divide (R)	-0.235 (0.000)	0.025 (0.445)	-0.137 (0.000)	0.109 (0.001)	-0.050 (0.137)	-0.047 (0.165)	1.000						
(8) GDP_per capita	0.014 (0.660)	0.069 (0.034)	0.009 (0.776)	0.058 (0.079)	-0.024 (0.479)	-0.023 (0.503)	0.078 (0.016)	1.000					
(9) Women's education	-0.024 (0.468)	0.083 (0.012)	0.056 (0.092)	0.242 (0.000)	0.215 (0.000)	0.210 (0.000)	-0.307 (0.000)	0.115 (0.001)	1.000				
(10) Corruption control	0.112 (0.001)	-0.038 (0.244)	0.034 (0.299)	-0.029 (0.387)	-0.046 (0.181)	-0.055 (0.115)	0.135 (0.000)	-0.052 (0.122)	-0.231 (0.000)	1.000			
(11) Female population	0.145 (0.000)	-0.265 (0.000)	0.036 (0.328)	-0.174 (0.000)	-0.167 (0.000)	-0.170 (0.000)	0.182 (0.000)	0.000 (0.996)	-0.096 (0.010)	0.103 (0.007)	1.000		
(12) Natural resources	-0.253 (0.000)	-0.246 (0.000)	0.016 (0.645)	-0.333 (0.000)	-0.070 (0.055)	-0.073 (0.048)	-0.266 (0.000)	0.004 (0.904)	0.037 (0.289)	0.164 (0.000)	0.090 (0.023)	1.000	
(13) Inflation	0.035 (0.285)	-0.001 (0.973)	0.123 (0.000)	0.026 (0.443)	0.065 (0.061)	0.063 (0.071)	-0.111 (0.001)	0.011 (0.732)	0.059 (0.074)	0.077 (0.023)	0.020 (0.601)	0.376 (0.000)	1.000

Table A 4: Variable definitions

Variables	Description	Sources
Women's participation in the labour market	Employment/population ratio, 15–64-year-olds, women (%) (ILO modelled estimate).	OIT (2022)
Internet digital divide	Internet access and usage per capita gap indicator (calculated from WDI data)	WDI (2022)
Mobile telephone divide	Per capita telephone access and use indicator (calculated from WDI data)	WDI (2022
GDP_per capital	Gross domestic product divided by population at mid-year	WDI (2022)
Women's education	Number of girls enrolled in secondary school.	WDI (2022)
Financial development	Volume of financial resources provided to the private sector by financial institutions.	WDI (2022)
Female population	Proportion of women in the total population.	WDI (2022)
Human capital	Mean years of schooling	UNDP
Control of corruption	captures perceptions of the extent to which public power is exercised for forms of corruption	GTI (2022)
Natural Rescue annuity	Sum of oil rents, natural gas rents, coal rents (hard and soft), mining rents and forestry rents.	WDI (2022)
Inflation	reflecting the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or modified at specified intervals, for example each year	WDI (2022)
Digital divide in the panhandle	Per capita telephone access and use indicator (calculated from WDI data)	WDI (2022)

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