# Does the digital divide hinder women's educational performance? Evidence from African Countries

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**Abstract**

This article analyses the influence of the digital divide on the educational performance of women in a panel of 54 African countries over the period 2000-2021. Using the GMM-SYS, our main results show that the digital divide weakens the educational performance of women in Africa. By adding institutional variables to the basic model, this negative effect of the digital divide is confirmed. Furthermore, we found that the digital divide between regions is also a severe handicap for the educational performance of women in regions with low digital coverage. Our results remain robust when using alternative measures of the digital divide and women's educational performance. Similarly, we found that using the Quantile-Regression (QR) method, the results reveal that in all quantiles (10th to 95th) the digital divide weakens women's educational performance. However, the main recommendation would be to implement policies to reduce the digital divide by providing IT tools to all and to all institutions in order to boost the educational performance of women in Africa.

***Key words****:* Digital divide, Educational Performance of Women, Africa, GMM-SYS, Quantile-Regression

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## 1. Introduction

Education is one of the components of human capital, the vector of economic growth and development (Lucas, 1988 and Romer, 1986; 1990). Its essential role is socialization and integration into society. It enables individuals to acquire skills that allow them to participate effectively in the socio-economic development of their society (Nomaye, 1998). In fact, it is one of the Sustainable Development Goals (SDGs) and ranks fourth (Delzangles, 2019). It should be noted that achieving SDG-4 depends on getting women into school, as women account for two-thirds of the 796 million illiterate people in the world (UN Women, 2012). The 2030 Education Agenda emphasis's that gender equality requires an approach that ensures that women and men have equal access to the various levels of education, right through to completion (UNESCO, 2015). In 2017, the overall school enrolment rate in the developed regions reached 91%, and the enrolment rate for girls also increased, reaching an average of 90% in 2020 compared with 71% in 2010. The results are quite impressive, as these countries have made significant progress (UNESCO, 2017). However, this success has not been fully effective in developing regions, for a number of reasons, including the persistence of armed conflict in some regions and the persistence of high levels of poverty, which pushes girls to drop out of school. However, since 2015, African countries have reached an average of 60% of girls in primary and secondary education, compared with 44.03% in 2005 (UNESCO, 2022).

However, the problem of school performance in these countries persists. The World Bank (2018) noted that some forty million African women obtain little knowledge at school and are not significantly different from those who have never been to school. Totouom (2018) and Bebey (2023) therefore look at the issue of education in general and show that Africa faces a number of problems that hamper the development of women's educational performance, including the problem of transport and energy infrastructure, and economic, financial, sociological and political problems. Similarly, Fertahi, Y. and Lhasnaoui, Z, M (2022) point out that the problem of access to ICTs is a handicap to school performance, and they also show that with the onset of the COVID-19 crisis, the situation has become more serious, as the education sector is faced with the imperative of ensuring pedagogical continuity online to enable thousands of learners to continue their studies in the normal way via ICTs. But these learners quickly found themselves confronted with the digital divide (DD) in terms of both access and use.

Indeed, the digital divide is a real threat to the educational performance of women in Africa, with evidence showing that around 89% of learners do not have access to home computers and 82% to the internet (GSMA, 2021). In addition, while mobile phones can enable learners to access information, around 56 million learners live in locations not served by mobile networks in Africa (ITU, 2021). These disparities are also observable at the gender level, where 45%, 53% and 34% of male learners versus 32%, 46% and 28% of females have a computer, a smartphone and internal access, respectively, in Africa (GSMA, 2021). These facts are correlated with women's low levels of educational performance (see Figure 3). Similarly, studies in the literature, such as those by Zhu and Li (2022) and Hu and Yu (2021) show that the gap in access to and use of ICTs is negatively associated with students' academic performance.

In this context, this article aims to explore the relationship between the digital divide and the educational performance of women in African countries. It makes three important contributions. First, we propose one of the first empirical assessments of the link between the digital divide (using both absolute and relative approaches) and female educational performance in Africa. This provides important evidence for policies aimed at reducing the digital divide and overcoming the challenge that prevents women from thriving scientifically in Africa. Second, this study takes endogeneity into account by using appropriate econometric

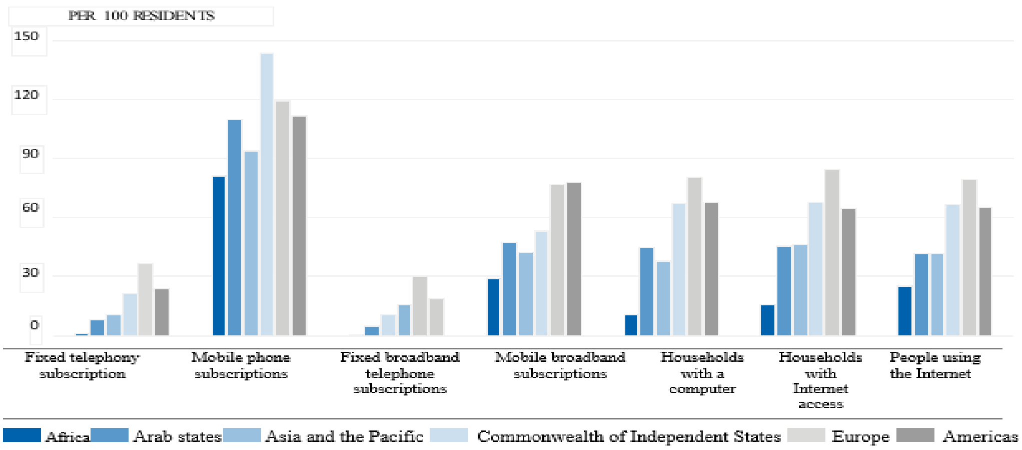
methods. To do so, this study uses two alternative empirical strategies, namely the two-stage generalized method of moments (GMM), which has the advantage of using internal instruments, and the two-stage least squares instrumental variable approach (2SLS-IV), which uses external instruments. To make the results more robust, the relationship is again tested empirically using the Quantile-Regression (QR) method proposed and developed by Koenker and Bassett (1978). The particularity of this method is that it takes into account the effect of one variable on another at different points in its distribution. To our knowledge, our study is the first to use this methodology on this subject.
Our empirical strategy is based on the GMM-SYS used to analyses the effect of the digital divide on the educational performance of women in Africa. Our results show that the digital divide weakens the educational performance of women in Africa. The rest of the paper is structured as follows: section 2 presents some stylized facts, theoretical foundations and complementary empirical literature. Section 3 shows the methodology used and describes the variables. Preliminary results, basic conclusions and robustness checks are presented and interpreted in Section 4. Section 5 concludes the paper and proposes some policy recommendations.

## *2.* **A few stylised facts**

### ***a. ICT developments worldwide***

In Figure (1), the major digital trends in the world show that the proportion of people using the Internet rose from 16.8% to 53.6% between 2000 and 2021. This represents around 4.1 billion people in 2021, with an average annual growth rate of 10% (ITU, 2022). However, mobile phone subscriptions are following the same dynamic, increasing from 7.9% to 103.8% in developing countries and from 47.1% to 128.9% in developed countries between 2000 and 2021. Only fixed-line telephony shows an overall downward trend, whether in developed countries (48.7% in 2005 and 35.6% in 2019) or in developing countries (9.0% in 2005 and 7.4% in 2019). Despite this trend, developing regions in general and Africa in particular remain very marginalized in terms of digital penetration (see Figure. 1). This confirms the idea of digital convergence clubs established by Park et al (2015) and the African technology gap documented by Das and Drine (2020). More people do not have access to the internet in Africa, where gender inequalities are strong. However, Africa remains the only region in the world not to have achieved a 100% penetration rate. This makes it the most digitally fractured region, in terms of both fixed and mobile telephony. As in other developing regions, the lack of skills and infrastructure are presented as the main obstacles to digital access (IUT, 2022).

**Figure 1:** ICT indicators per 100 inhabitants worldwide

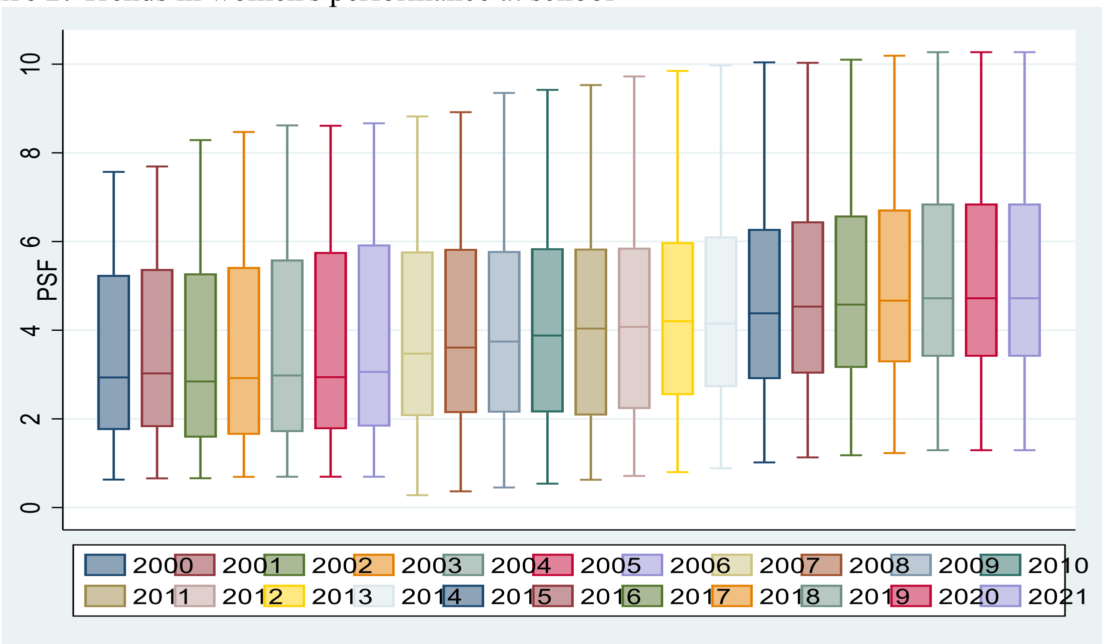



***Source**: Authors based on ITU data (2022)*

***b. Changes in school performance***

Women's performance at school has gone through different cycles in Africa, more specifically in primary and secondary education. Overall, the ends of each box represent the minimum values and the values of each distribution, i.e. the values of women's school performance for each year. Each box is made up of three horizontal lines: the bottom line gives the value of the first quartile, the line inside the box gives the value of the second quartile (or median value), and the top line gives the value of the third quartile. The dots represent the extreme values. Thus, focusing on the values on the top line, Figure (2) shows that girls school performance improved considerably in secondary education between 2000 and 2021, rising from 47% in 2015 to 60.3% in 2022. The data on WEP are taken from UNESCO.

**Figure 2:** Trends in women's performance at school

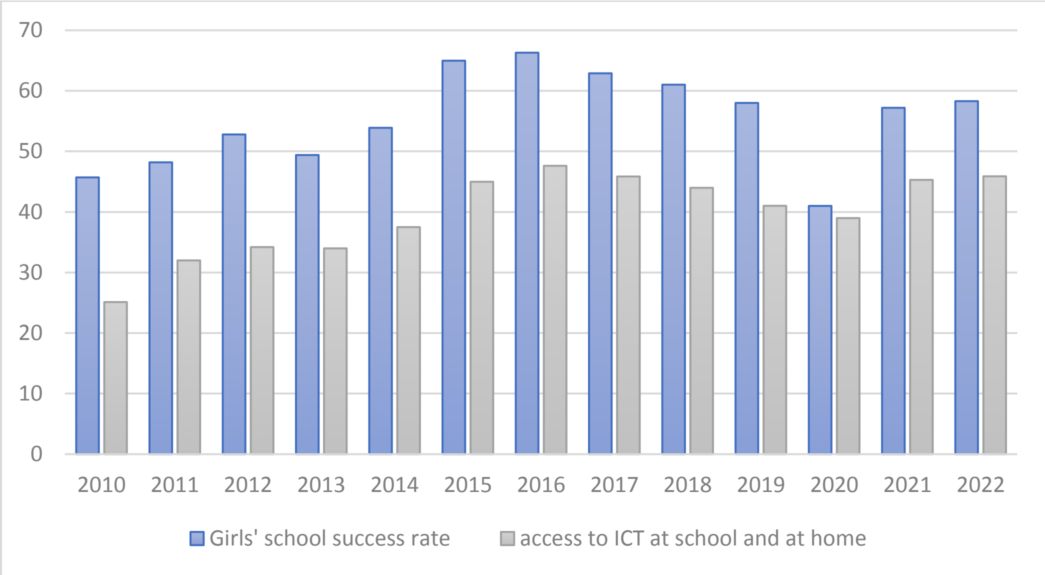



**<u>Source</u>**: *Authors by UNESCO data (2022)*

***C. Evaluation of the joint effect of the digital divide and women's performance at school***

Women's performance at school and their access to ICTs at school and at home have evolved differently in Africa over the periods analyzed.

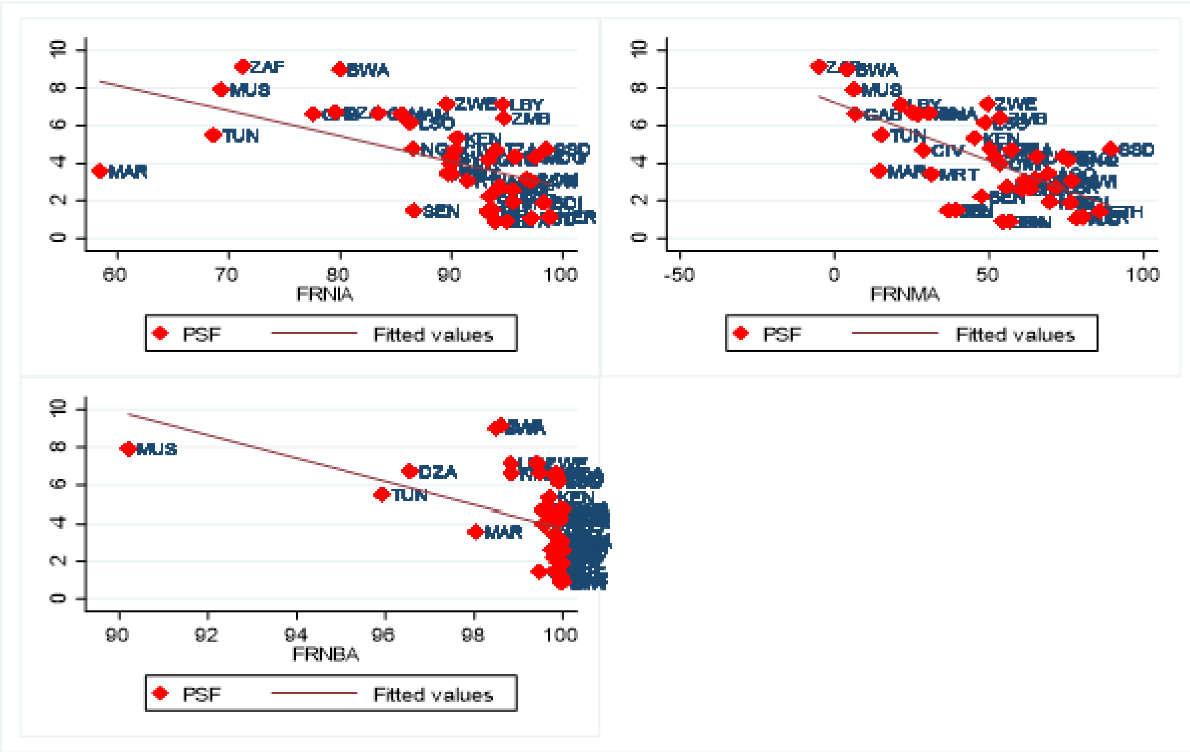
**Figure 3:** Comparative analysis of women's educational performance and access to ICT at school and at home in Africa



***Source***: *Authors based on WDI and UNESCO data (2022)*

Throughout the period under review, women in African countries have been performing strongly at school since 2015, following the launch of a digital support policy set up by UNESCO. We note that in 2020, a break in this growth is observed with the advent of COVID-19. The education sector was faced with the imperative of ensuring pedagogical continuity online to enable thousands of learners to pursue their studies in the normal way via ICTs, but these learners soon found themselves confronted with the digital divide (DD) in terms of both access and use. The main characteristic of Africa, which is the most fractured region in the world, has several consequences for its socio-economic conditions, particularly as regards the educational performance of women. To assess this effect, the correlation between women's performance at school and certain DD indicators is analyzed (100 minus the penetration level). Analysis of Figure 3 reveals an overall decreasing relationship between the DD indicators and the educational performance of women in Africa. This effect, while consistent, differs according to the DD indicators considered.

**Figure 4:** DD and women's performance at school




**Source**: *Authors based on WDI and UNESCO data (2022)*

## 3. Literature review

The literature on the relationship between the availability of ICT resources and women's academic performance is ambiguous. However, the work of Hu et al. (2018) finds that a one-point increase in the frequency of ICT use at school is positively associated with school performance in mathematics, science and reading across the 44 countries examined with PISA 2015 data. These results are consistent with previous studies by Zhang and Liu (2016) and Petko et al. (2017), who find a positive association between the pedagogical use of ICT in the classroom and girls' achievement using PISA 2000; 2012 data. In contrast, the study by Zhu and Li (2022) shows that the digital divide is negatively associated with student achievement. Similarly, Hu and Yu (2021) assess the impact of girls' use of ICT at school on student performance. The results indicate that adolescent girls' frequent use of ICT-based social media at school, including online chat at school, have negative effects on academic performance.

When it comes to the use of ICT at home and girls' academic performance, the results are also ambiguous. The work of Fuchs and Wößmann (2005); Lee and Wu (2012) and Petko et al. (2017) also found that the use of ICT at home for school work (browsing the internet for school work, using email to communicate with other students about school work and completing homework on a computer) was positively associated with girls' academic achievement. Furthermore, surprisingly, the study by Biagi and Loi (2013) and Hu et al. (2018) found evidence that students who use ICT resources more often for leisure activities (e.g. playing online games, chatting online, reading news on the internet and downloading new apps on a mobile device) tend to perform better in reading tests.  On the other hand, Papanastasiou et al (2005) suggested that the association between ICT use (in general) and academic performance might not be linear, but follow a form of inverted U, since excessive use might distract students from their schoolwork. Moreover, the study by Luu and Freeman (2011) and Petko et al. (2017)

showed that the use of productivity and entertainment software was negatively associated with academic performance. One of the reasons for these mixed results could lie in the level of ICT penetration and its use for school work. Based on these conclusions, the hypothesis can be formulated as follows: the digital divide weakens the educational performance of women in African countries.

On the basis of the above empirical literature, it generally emerges that the effects of the digital divide on educational performance in Africa have not yet been satisfactorily explained. Yet Africa is considered to be the most fractured region in the world, with a number of social and economic consequences. Previous studies have also not examined the effects of DD on gender, yet women are also more fractured than men. Thus, a study in this direction is needed to understand how the digital divide affects women's educational performance and to propose relevant recommendations and fill gaps in the contemporary literature on the relationship.

## 4. Methodology strategy

The main aim of this article is to examine the influence of the digital divide on the educational performance of women in African countries.

### *4.1. Construction of the Digital Divide Index*

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.

***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).

***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.

### 4.2. Model and empirical data

Based on existing literature, the empirical model is specified as follows:

$$\boldsymbol{IWEP_{it} = \alpha + digital\ divide_{it} + \lambda X_{it} + v_i + \mu_t + \varepsilon_{it}} \quad (1)$$

Where $IWEP$ is the indicator of women's educational performance measured by the rate of women's educational success per year, provided by UNESCO. $digital\ divide_{it}$ represents the gap in access to and use of ICTs. $X$ is a set of control variables that explain the school performance of . The choice of these variables is based on the literature. They are growth, entrepreneurship, population, fertility, remittances, FDI and access to electricity. Measured by the growth rate of GDP per capita, growth is the first control variable. The literature generally supports the existence of a positive correlation between an economy's level of growth and women's level of educational performance. Papanastasiou et al (2005) suggest that an increase in household income boosts girls' performance at school. Access to electricity is measured by the rate of access to electricity. The literature identifies it as a major determinant of school performance. Inequalities in access to electricity reduce girls' ability to perform at school. As for foreign direct investment (FDI), various studies agree on its beneficial short- and long-term effects on school performance. Ibarra-Olivo (2021) finds that FDI increases girls' performance at school when a wage increase is more pronounced in the manufacturing sector. Fertility is measured by the number of children that could be born to a woman who lives to the end of her childbearing years and bears children in accordance with the age-specific fertility rate for the year specified. This variable will allow us to see whether the number of births to women influences the educational performance of women. The expected sign for this variable is negative. Work by Prata et al (2017) ; Upadhyay et al, (2014) shows that women's educational performance is associated with lower fertility. With regard to entrepreneurship (self_emp) this variable makes it possible to see whether women's economic empowerment enhances their educational performance, remittances (REM), this variable makes it possible to see whether migrant remittances influence WEP. Relative to the size of the female population, it measures all resident women, regardless of their legal status or citizenship. n the same way, $v_i$ is the time effect of the country, $\mu_t$ is the country-specific effect and $\varepsilon_{it}$ the error term. And so, $v_i$ , $\mu_t$ et $\varepsilon_{it}$ are the time fixed effects, the country fixed effects and the disturbance, respectively.

The basic model can be augmented by adding the lagged value of women's educational performance to account for memory effects, as well as cultural, institutional and religious variables. The assumption of strict exogeneity of the estimator is violated in a dynamic fixed-effects model because OLS 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 women's educational performance. We use systemic GMM rather than differential GMM because the former has better asymptotic and finite sample properties (Bond, Hoeffler, & Temple, 2001). The augmented and dynamic equation for women's educational performance is therefore expressed as follows:

$$IWEP_{it} = \alpha + PSF_{it-1} + digital\ divide_{it} + \lambda X_{it} + \gamma Z_{it} + v_i + \mu_t + \varepsilon_{it} \qquad (2)$$

Where $Z$. denotes the vector of institutional variables (government effectiveness; political stability; regulation and laws; corruption, Voice (level of voice and accountability); quality of regulation). The chosen control variables are not the only ones likely to influence the WEP in relation to the digital divide.

### 4.3. Estimation technique

Based on a cross-sectional perspective, preliminary results for the coefficient of interest $\gamma$ are obtained using the ordinary least squares (OLS) estimator. Although this estimator is interesting, it has the limitation of not correcting for endogeneity. Theoretically, an endogeneity problem can arise in this model due to simultaneity, omitted variable bias, measurement errors or selection bias. An inverse causality may exist between the digital divide and the educational performance of women. In addition, simultaneity bias could arise because many of the variables in the model are determined at the same time. To resolve simultaneity and endogeneity bias, an appropriate identification strategy is therefore required, in particular the generalized moments technique (GMM) suggested by Arellano and Bond (1991). The consistency of the GMM estimator is determined by two factors: the validity of the assumption that the error term is not serially correlated (AR (2)) and the validity of the instruments (Hansen test). Too many instruments can seriously weaken and bias Hansen's test of identification restrictions, so the general rule is that the number of instruments should be less than the number of countries (Roodman, 2009). For the purposes of comparison and, above all, robustness, we also used the IV-2SLS method to analyze the effect of the digital divide on women's educational performance. We then assess our results by opting for a limited dependent approach and a non-parametric econometric method based on quantile regressions (QR).

### 4.4. Statistical analysis

In this section, we first present the descriptive statistics and the correlation table for the variables in the model. As mentioned above, the aim of this article is to verify the influence of the digital divide on the educational performance of women in Africa. The descriptive statistics presented in Table (1) show that, in general, school performance is relatively concentrated according to their means and standard deviations. This is also observed in the DD indicators. Mean DD values are high with small standard deviations for most variables, which is confirmed by generally small ranges. This indicates that African countries are among the most fractured in the world, which could have a negative impact on the level of women's educational performance. The overall averages of our variables are respectively 4.183 for women's educational performance, and 99.123, 88.938 and 50.425 for the digital divide (from bandwidth, internet, and mobile telephony to absolute value). With a standard deviation of 2.371 for the first variable and 2.930; 15.956 and 44.180 respectively for the second variables.

Table 1. Descriptive statistics

| Variable[4] | Obs | Mean | Standard deviation | Min | Max | Sources |
|---|---|---|---|---|---|---|
| women's academic performance | 874 | 4.183848 | 2.371107 | .278 | 10.27 | UNESCO |
| Broadband Divide (A) | 1,188 | 99.12353 | 2.930517 | 61.22852 | 100 | WDI |
| Internet Divide (a) | 1,188 | 88.93893 | 15.95609 | 11.86968 | 100 | WDI |
| Mobile Divide (A) | 1,188 | 50.42522 | 44.18049 | -85.55935 | 100 | WDI |
| Internet Divide (R) | 1,188 | 77.06924 | 15.95609 | 3.00e-08 | 88.13032 | WDI |
| Mobile Divide (R) | 1,188 | 135.9846 | 44.18049 | 0 | 185.5593 | WDI |
| Broadband Divide (R) | 1,188 | 37.89502 | 2.930517 | 0 | 38.77148 | WDI |
| Fertility | 1,134 | 4.682029 | 1.401442 | 1.36 | 7.732 | WDI |
| FDI | 1,145 | 4.287982 | 7.76822 | -18.91777 | 103.3374 | WDI |
| GDP_perc | 1,125 | 2382.335 | 2908.495 | 255.1003 | 16747.34 | WDI |
| Remittances | 1,089 | 3.437102 | 5.677562 | 0 | 53.8264 | WDI |
| Electricity access | 1,172 | 44.21324 | 29.47534 | .796383 | 100 | WDI |
| Pop_female | 1,188 | 50.31913 | .8794991 | 47.07884 | 53.08219 | WDI |
| Entrepreneurship | 1,166 | 75.06133 | 24.33915 | 11.8113 | 98.91045 | WDI |

[4]The Absolute Broadband Divide (A), the Absolute Mobile Divide (A) and the Absolute Internet Divide (A) and the Relative Broadband Divide (R), the Relative Mobile Divide (R) and the Relative Internet Divide (R). And women's academic performance (WEP)

**<u>Source</u>**: *Authors based on WDI and UNESCO data (2022)*

The correlation matrix revealed a strong negative relationship between the digital divide indicators and women's educational performance in Table 2. As a result, there is a negative correlation at the 1% level between the digital divide and women's educational performance. Similarly, there is a negative correlation between the FDI, entrepreneurship and fertility variables and the explained female educational performance variable at the 1% threshold. On the other hand, the GDP_precapita, female population and remittances variables are positively correlated with female educational performance at the 1% level.

**Table 2: Correlation**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) IWEP | 1.00 | | | | | | | | | | | | | |
| (2) Broadband Divide (A) | -0.43* | 1.00 | | | | | | | | | | | | |
| (3) Internet Divide (A) | -0.47* | 0.52* | 1.00 | | | | | | | | | | | |
| (4) Mobile Divide (A) | -0.55* | 0.48* | 0.70* | 1.00 | | | | | | | | | | |
| (5) Internet Divide (R) | -0.47* | 0.52* | 1.00* | 0.70* | 1.00 | | | | | | | | | |
| (6) Mobile Divide (R) | -0.55* | 0.48* | 0.70* | 1.00* | 0.70* | 1.00 | | | | | | | | |
| (7) Broadband Divide (R) | -0.43* | 1.00* | 0.52* | 0.48* | 0.52* | 0.48* | 1.00 | | | | | | | |
| (8) Fertility | -0.75* | 0.45* | 0.58* | 0.53* | 0.58* | 0.53* | 0.45* | 1.00 | | | | | | |
| (9) FDI | -0.10* | -0.03 | 0.02 | -0.01 | 0.02 | -0.01 | -0.03 | 0.02 | 1.00 | | | | | |
| (10) GDP per | 0.67* | -0.54* | -0.40* | -0.42* | -0.40* | -0.42* | -0.54* | -0.59* | 0.06 | 1.00 | | | | |
| (11) Remittances | 0.03 | 0.03 | -0.06 | -0.03 | -0.06 | -0.03 | 0.03 | -0.13* | 0.09* | -0.19* | 1.00 | | | |
| (12) Access electricity | 0.60* | -0.45* | -0.59* | -0.57* | -0.59* | -0.57* | -0.45* | -0.76* | -0.03 | 0.66* | 0.00 | 1.00 | | |
| (13) Female population | 0.16* | 0.22* | 0.14* | 0.13* | 0.14* | 0.13* | 0.22* | 0.01 | -0.06 | -0.41* | 0.10* | -0.36* | 1.00 | |
| (14) Entrepreneurship | -0.71* | 0.51* | 0.48* | 0.47* | 0.48* | 0.47* | 0.51* | 0.81* | 0.12* | -0.69* | 0.02 | -0.73* | -0.04 | 1.00 |

**** p<0.01, ** p<0.05, * p<0.1*

**Source:** *Authors based on WDI and UNESCO data (2022)*

## 5. Empirical results

### 5.1. Base line

We estimate the effect of the digital divide (DD) on women's educational performance, initially using ordinary least squares (OLS) methods. Generally speaking, in Table (3), column (1) presents the results of the bivariate relationship between the absolute value of the internet digital divide and women's school performance, i.e. without control variables or fixed effects. As shown in Figure (4), we find that the digital divide significantly worsens women's educational performance at the 1% level. However, in columns 2 to 7, we include the control variables and our variable of interest remains practically significant at the 1% level.

**Table 3**. Digital divide and educational performance of women, baseline results estimated by OLS

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | OLS | | | | | | |
| VARIABLES | Women's performance at school | | | | | | |
| Internet Divide | -0.118*** | -0.118*** | -0.117*** | -0.115*** | -0.0892*** | -0.0914*** | -0.0910*** |
| | (0.0223) | (0.0226) | (0.0230) | (0.0230) | (0.0246) | (0.0261) | (0.0269) |
| Fertility | -0.257*** | -0.261*** | -0.262*** | -0.261*** | -0.285*** | -0.221*** | -0.222*** |
| | (0.0582) | (0.0593) | (0.0587) | (0.0586) | (0.0613) | (0.0617) | (0.0662) |
| Remittances | | 0.283*** | 0.285*** | 0.303*** | 0.295*** | 0.272*** | 0.273*** |
| | | (0.0441) | (0.0445) | (0.0442) | (0.0438) | (0.0408) | (0.0410) |
| Entrepreneurship | | | -0.0111 | -0.0149 | -0.0262 | -0.0472 | -0.0468 |
| | | | (0.0563) | (0.0563) | (0.0555) | (0.0556) | (0.0556) |
| FDI | | | | -0.000356*** | -0.000377*** | -0.000440*** | -0.000441*** |
| | | | | (0.000119) | (0.000121) | (0.000130) | (0.000132) |
| GDP_per | | | | | 0.970* | 1.161** | 1.165** |
| | | | | | (0.498) | (0.461) | (0.472) |
| Electricity access | | | | | | -0.0970*** | -0.0985*** |
| | | | | | | (0.0277) | (0.0235) |
| Female population | | | | | | | -0.116 |
| | | | | | | | (1.125) |
| Effet fixes pays | Oui | Oui | Oui | Oui | Oui | Oui | Oui |
| Effets fixes Times | Oui | Oui | Oui | Oui | Oui | Oui | Oui |
| Constant | 0.135** | 0.131** | 0.139* | 0.139* | 0.0833 | 0.161** | 0.219 |
| | (0.0567) | (0.0583) | (0.0718) | (0.0717) | (0.0788) | (0.0819) | (0.547) |
| Observations | 832 | 802 | 802 | 798 | 798 | 795 | 795 |
| R-squared | 0.981 | 0.981 | 0.981 | 0.982 | 0.982 | 0.982 | 0.982 |

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

**Source**: *Authors based on WDI and UNESCO data (2022)*

Given the limitations of the estimation methods discussed above, including their weakness in overcoming endogeneity problems, we resort to a more robust estimator. We repeat the regressions of equation (1) using the GMM-System, which is more appropriate for this method and provides better results. We follow the same steps as in Table (3). The results are presented in Table (4) and are similar to those obtained previously. In addition, the results of the various diagnostic tests show that the model is well specified. The Hansen test confirms the validity of the instruments. In addition, the hypothesis of no second-order autocorrelation (AR 2) was not rejected. Finally, too many instruments in the model can distort the results, which is why the rule is that the number of instruments in the model should not exceed the number of countries (Roodman, 2009). As Table (4) shows, in all specifications, the number of countries is greater than the number of instruments.

**Table 4:** Digital divide and educational performance of women, estimated by OLS with fixed and random effects and SYS-GMM

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | OLS | | OLS-FE | | OLS-RE | | SYS-GMM | |
| VARIABLES | Women's secondary performance (WEP) | | | | | | | |
| L. WEP | | | | | | | 0.951*** | 0.918*** |
| | | | | | | | (0.00824) | (0.00549) |
| Internet Divide | -0.125*** | -0.0910*** | -0.362*** | -0.307*** | -0.363*** | -0.299*** | -0.0464*** | -0.00987*** |
| | (0.0184) | (0.0269) | (0.0287) | (0.0591) | (0.0288) | (0.0540) | (0.00627) | (0.00209) |
| Fertility | | -0.222*** | | -0.527*** | | -0.538*** | | -0.0566*** |
| | | (0.0662) | | (0.184) | | (0.177) | | (0.00784) |
| Remittances | | 0.273*** | | 0.288*** | | 0.284*** | | 0.00985** |
| | | (0.0410) | | (0.0608) | | (0.0621) | | (0.00448) |
| Entrepreneurship | | -0.0468 | | -0.119 | | -0.154 | | -0.00699** |
| | | (0.0556) | | (0.173) | | (0.137) | | (0.00281) |
| FDI | | -0.000441*** | | -3.85e-05 | | -6.31e-05 | | |
| | | (0.000132) | | (0.000261) | | (0.000248) | | |
| GDP_percapital | | 1.165** | | 0.677 | | 0.849 | | 0.381*** |
| | | (0.472) | | (1.891) | | (1.763) | | (0.0265) |
| Electricity access | | -0.0985*** | | 0.0307 | | 0.0289 | | 0.00165 |
| | | (0.0235) | | (0.0776) | | (0.0775) | | (0.00286) |
| Female population | | -0.116 | | 2.112 | | 2.283 | | 0.532*** |
| | | (1.125) | | (4.030) | | (3.548) | | (0.0605) |
| FDI | | | | | | | | 0.0172 |
| | | | | | | | | (0.0223) |
| Constant | 0.314*** | 0.219 | 0.740*** | -0.0855 | 0.742*** | -0.145 | 0.0696*** | -0.196*** |
| | (0.0274) | (0.547) | (0.0255) | (1.884) | (0.0397) | (1.645) | (0.00867) | (0.0300) |
| Observations | 874 | 795 | 874 | 795 | 874 | 795 | 832 | 760 |
| R-squared | 0.979 | 0.982 | 0.427 | 0.671 | | | | |
| Nombre groupes | | | 42 | 42 | 42 | 42 | 42 | 42 |
| Instruments | | | | | | | 13 | 40 |
| AR (1) | | | | | | | 0.0213 | 0.0777 |
| AR (2) | | | | | | | 0.418 | 0.244 |
| Hansen P-value | | | | | | | 0.501 | 0.319 |
| r2_w | | | 0.427 | 0.671 | 0.427 | 0.670 | | |
| r2_o | | | 0.218 | 0.607 | 0.218 | 0.617 | | |
| r2_b | | | 0.288 | 0.584 | 0.288 | 0.592 | | |

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

**Source:** *Authors based on WDI and UNESCO data (2022)*

Overall, for each specification of the model provided in Table 4, the DD weakens the educational performance of women in Africa. More specifically, it should be noted that a **1** percentage point increase in the Internet digital divide is correlated with a **0.0464** decrease in the level of women's educational performance. In other words, these results show that the low use of ICT deteriorates women's access to information and their ability to carry out research, which further hampers their performance at school. This can be explained by economic, financial, sociological, political and transport infrastructure problems (Totouom, 2018 and Bebey, 2023). In addition, the lack of quality electricity coverage in African countries and the high fertility rate among girls, which reduces their time to concentrate on research rather than looking after children and the household, also explain women's under-performance at school. Similarly, as demonstrated in the study by Papanastasiou et al (2005), the low level of income required to use a computer may explain the negative effect of DD on women's performance at school.

Broadly speaking, these results are in line with the study by Zhu and Li (2022), which shows that low levels of access to ICT are negatively associated with student performance in a linear fashion, including girls in particular. Similarly, Hu and Yu (2021) assess the relationship between ICT use at school and student performance. The results indicate that low levels of frequent use of ICT at school have negative effects on school performance. Thus, a good reduction in the digital divide leads to high school performance. However, we find that, with the exception of the variables "GDP per capita, female population and remittances", all the coefficients of the control variables have a negative sign and are significant in at least one of the model specifications.

### 5.2. Sensitivity analysis

To check whether the results are stable, we include additional variables, as shown in Table 5. In particular, the literature has identified several factors that can affect women's school performance. Our baseline results may be biased if we do not properly control for these factors. We therefore include two additional controls: (i) institutional variables and (ii) regional effects.

#### 5.2.1. Sensitivity analysis with institutional variables

The purpose of this sensitivity analysis is to assess whether the effects of the digital divide are stable when institutional variables are added. The results of the sensitivity analysis with the institutional variables provided in Table (5) reveal more clearly that the digital divide weakens the educational performance of women. The results are consistent with those obtained in the basic model and the empirical literature. The variables of political stability, regulatory quality, and regulation and laws significantly improve the educational performance of women in Africa. Efforts to improve the quality of institutions in Africa by guaranteeing individual freedom and gender equality have contributed to educational inclusion and the expansion of women's scientific discovery and development. More importantly, it can also contribute to increasing women's leadership. This result is in line with research by Preconcillo et al (2020). Nevertheless, corruption significantly weakens the educational performance of women in Africa. Corruption makes women who depend on these mechanisms less compliant at school. This is consistent with research by Memon et al (2023), who found that corruption is disproportionately biased against women's educational performance in Pakistan as elsewhere.

**Table 5.** Sensitivity test with institutional variables

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Sensitivity of institutional variables | | | | | |
| VARIABLES | Women's performance at school | | | | | |
| L.WEP | 0.919*** | 0.921*** | 0.923*** | 0.937*** | 0.949*** | 0.946*** |
| | (0.00404) | (0.00467) | (0.00785) | (0.0117) | (0.00996) | (0.0102) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Internet Divide | **-0.00515*** ** | **-0.00686*** ** | **0.000638** | **0.00432** | **0.0166*** ** | **0.0168*** ** |
| | (0.00104) | (0.00231) | (0.00276) | (0.00406) | (0.00451) | (0.00445) |
| Fertility | **-0.0544*** ** | **-0.0667*** ** | **-0.0595** ** | **-0.0692*** ** | **-0.0221** | **-0.0115** |
| | (0.00745) | (0.00838) | (0.0228) | (0.0230) | (0.0317) | (0.0314) |
| FDI | -0.00580 | -0.0122 | 0.0136 | -0.00300 | 0.708*** | 0.570*** |
| | (0.0147) | (0.0230) | (0.0249) | (0.0187) | (0.123) | (0.123) |
| GDP_percapital | **0.477*** ** | **0.322*** ** | **0.170** ** | **-0.00150** | **0.827*** ** | **0.847*** ** |
| | (0.0255) | (0.0193) | (0.0724) | (0.0405) | (0.0677) | (0.0725) |
| Remittances | **0.0158** ** | **0.0252*** ** | **0.0441*** ** | **0.0495*** ** | **0.210*** ** | **0.176*** ** |
| | (0.00597) | (0.00624) | (0.00531) | (0.00835) | (0.0238) | (0.0237) |
| Electricity access | **-0.00699** ** | **-0.00463* ** | **-0.00743** | **-0.00126** | **-0.0165** ** | **-0.0193** ** |
| | (0.00286) | (0.00263) | (0.00571) | (0.00558) | (0.00761) | (0.00944) |
| Female population | 0.486*** | 0.311*** | 0.331*** | 0.0730 | 0.473* | 0.477* |
| | (0.0618) | (0.112) | (0.110) | (0.152) | (0.256) | (0.264) |
| Entrepreneurship | -0.0125*** | 0.00216 | -0.00557 | -0.0105 | -0.0471*** | -0.0429*** |
| | (0.00356) | (0.00279) | (0.00739) | (0.00648) | (0.0102) | (0.0108) |
| Corruption | **-0.0102*** ** | **-0.000278** | **-0.0289*** ** | **-0.0313*** ** | **-0.0167*** ** | **-0.0161*** ** |
| | (0.00101) | (0.00170) | (0.00648) | (0.00714) | (0.00388) | (0.00472) |
| Political stability | | **0.00513*** ** | **0.00407*** ** | **0.00510*** ** | **-0.0115*** ** | **-0.0127*** ** |
| | | (0.00123) | (0.00111) | (0.00152) | (0.00194) | (0.00221) |
| Regulations-Laws | | | **0.0352*** ** | **0.0259*** ** | **0.0230*** ** | **0.0243*** ** |
| | | | (0.00613) | (0.00743) | (0.00689) | (0.00681) |
| Government effectiveness | | | | 0.0132*** | -0.0137*** | -0.0209*** |
| | | | | (0.00453) | (0.00495) | (0.00508) |
| Voice | | | | | 0.00996** | 0.0112** |
| | | | | | (0.00417) | (0.00520) |
| Quality of regulations | | | | | | 0.00503 |
| | | | | | | (0.00600) |
| Constant | -0.189*** | -0.0854 | -0.0928 | 0.0455 | -0.254* | -0.261* |
| | (0.0293) | (0.0570) | (0.0554) | (0.0729) | (0.141) | (0.143) |
| Observations | 731 | 731 | 731 | 731 | 731 | 731 |
| Nombre groupes | 42 | 42 | 42 | 42 | 42 | 42 |
| Instruments | 47 | 47 | 47 | 47 | 40 | 40 |
| AR (1) | 0.0569 | 0.0542 | 0.0319 | 0.0339 | 0.00891 | 0.0109 |
| AR (2) | 0.308 | 0.328 | 0.314 | 0.380 | 0.477 | 0.479 |
| Hansen P-value | 0.501 | 0.626 | 0.560 | 0.580 | 0.501 | 0.362 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Source:** *Authors based on WDI and UNESCO data (2022)*

### 5.2.2. Sensitivity analysis of regional effects

The purpose of this sensitivity analysis is to assess whether the effects of the digital divide are felt in the same way in the different regions of Africa. To do this, the database is divided into sub-samples: North Africa, Southern Africa, East Africa, West Africa and Central Africa. The results show that the digital divide has a negative impact on all sub-regions of the African continent. However, this effect is more pronounced in Central Africa, East Africa and North Africa (Table 6). In these different regions, highly unequal access to ICT amplifies the harmful effect of the digital divide on women's performance at school. In such a context, women's school performance and the education system are affected, which could hinder the development of this sector. Less fractured regions such as West and Southern Africa seem to have made more efforts in terms of the latest IUT reports. The factors explaining these different results could be economic, political, institutional, demographic, technical, etc.

Table 6: Sub-regional effects of the digital divide on women's educational performance

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Eastern Africa | Middle Africa | Northern Africa | Southern Africa | Western Africa |
| VARIABLES | | | WEP | | |
| Internet Divide | -0.141*** | -0.393*** | -0.0497** | -0.205 | -0.0383 |
| | (0.0257) | (0.0424) | (0.0228) | (0.0971) | (0.128) |
| Fertility | -0.731*** | -0.259 | -0.868*** | -1.440*** | -0.740*** |
| | (0.228) | (0.360) | (0.247) | (0.115) | (0.132) |
| Remittances | 0.213 | -6.334*** | 0.373*** | -0.463** | 2.110*** |
| | (2.000) | (0.664) | (0.0724) | (0.190) | (0.429) |
| Female population | -0.427*** | -0.342*** | -0.00987 | -0.164 | 0.303*** |
| | (0.0555) | (0.0692) | (0.0816) | (0.104) | (0.111) |
| FDI | -0.000945 | 0.00237 | -0.00379** | 0.00151*** | -0.00449*** |
| | (0.00103) | (0.00286) | (0.00147) | (0.000458) | (0.00113) |
| GDP_perc | -2.266*** | -0.608** | 7.082*** | 15.50*** | 4.727*** |
| | (0.347) | (0.239) | (0.561) | (1.542) | (1.154) |
| Electricity access | 0.287*** | -0.530*** | 0.0861* | 0.0341 | 0.154* |
| | (0.102) | (0.0977) | (0.0488) | (0.0627) | (0.0922) |
| Female population | -2.764*** | 2.891 | -8.402*** | -13.20*** | 5.251*** |
| | (0.732) | (3.117) | (1.252) | (1.310) | (1.331) |
| Constant | 2.535*** | 0.320 | 5.043*** | 7.455*** | -2.312*** |
| | (0.529) | (1.690) | (0.589) | (0.720) | (0.803) |
| Observations | 72 | 84 | 84 | 236 | 215 |
| R-squared | 0.992 | 0.939 | 0.974 | 0.761 | 0.713 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

**Source:** *Authors based on WDI and UNESCO data (2022)*

### 5.3. Robustness checks

The previous section used the absolute internet divide as a measure of the digital divide. This measure may lead to a limited examination of the effect of the digital divide on women's educational performance, as the digital divide is composed of several indicators and approaches (absolute and relative). In addition, 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 reproduce the previous regressions by adding other indicators of the absolute digital divide, also the different indicators of the relative approach. Second, we perform the robustness test with the model instrumental variables technique and the quantile regression (QR) method to make our results more robust. Overall, in all robustness checks, we find results from specifications equivalent to those in Table 3.

#### *5.3.1. Alternative measures to bridge the digital divide*

The DD measure used so far is an absolute measure, which assesses the gap between countries and the full penetration rate. According to James (2009), the aim of this robustness test is to assess the relative DD effect on women's educational performance. To this end, the country with the best performance in numerical penetration is determined each year. This value is used as a reference for calculating the DD. The role of this indicator is to reinforce the relative DD result.

However, the selected country suffers from the relative digital divide. Overall, the results validate the existence of adverse effects of DD on the educational performance of women in Africa. The amplitude is higher with the broadband channel and lower with the mobile phone channel. Thus, while heterogeneity persists for the other digital channels, African countries seem to be converging towards the use of the mobile phone, which justifies the low magnitude of its DD. The small disparity in the use of mobile phones tends to cancel out the effect of DD on women's performance at school. On the one hand, if the mobile phone were the only channel for digitalization, African countries would tend to show converging educational performance.

**Table 7:** Robustness check using relative digital divide components

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measuring the digital divide in absolute terms | | | | | | Measuring the digital divide in relative terms | | | | | |
| | Women's performance at school | | | | | | | | | | | |
| L.WEP | 0.965*** | 0.907*** | 0.951*** | 0.918*** | 1.001*** | 0.914*** | 0.979*** | 0.907*** | 0.948*** | 0.918*** | 0.992*** | 0.914*** |
| | (0.0183) | (0.00531) | (0.00824) | (0.00549) | (0.00865) | (0.00449) | (0.00727) | (0.00529) | (0.00803) | (0.00549) | (0.00897) | (0.00449) |
| Mobile Divide (A) | -0.0106* | -0.00883*** | | | | | | | | | | |
| | (0.00629) | (0.00100) | | | | | | | | | | |
| Internet Divide (A) | | | -0.0464*** | -0.00987*** | | | | | | | | |
| | | | (0.00627) | (0.00209) | | | | | | | | |
| Broadband Divide (A) | | | | | -0.0342 | -0.0159* | | | | | | |
| | | | | | (0.0326) | (0.00908) | | | | | | |
| Mobile Divide (R) | | | | | | | -0.0564** | -0.0877*** | | | | |
| | | | | | | | (0.0232) | (0.0100) | | | | |
| Internet Divide (R) | | | | | | | | | -0.0471*** | -0.00987*** | | |
| | | | | | | | | | (0.00619) | (0.00209) | | |
| Broadband Divide (R) | | | | | | | | | | | -0.0883*** | -0.0159* |
| | | | | | | | | | | | (0.0337) | (0.00908) |
| Fertility | | -0.0388*** | | -0.0566*** | | -0.0657*** | | -0.0387*** | | -0.0566*** | | -0.0657*** |
| | | (0.0104) | | (0.00784) | | (0.00828) | | (0.0104) | | (0.00784) | | (0.00828) |
| FDI | | -0.0297 | | 0.0172 | | 0.0338 | | -0.0308* | | 0.0172 | | 0.0338 |
| | | (0.0180) | | (0.0223) | | (0.0283) | | (0.0181) | | (0.0223) | | (0.0283) |
| GDP_Percapital | | 0.392*** | | 0.381*** | | 0.385*** | | 0.392*** | | 0.381*** | | 0.385*** |
| | | (0.0242) | | (0.0265) | | (0.0204) | | (0.0242) | | (0.0265) | | (0.0204) |
| Remittances | | 0.0191*** | | 0.00985** | | 0.00725 | | 0.0192*** | | 0.00985** | | 0.00725 |
| | | (0.00346) | | (0.00448) | | (0.00438) | | (0.00347) | | (0.00448) | | (0.00438) |
| Electricity access | | 0.00908*** | | 0.00165 | | 0.00445* | | 0.00914*** | | 0.00165 | | 0.00445* |
| | | (0.00279) | | (0.00286) | | (0.00250) | | (0.00280) | | (0.00286) | | (0.00250) |
| Female population | | 0.664*** | | 0.532*** | | 0.591*** | | 0.661*** | | 0.532*** | | 0.591*** |
| | | (0.0511) | | (0.0605) | | (0.0580) | | (0.0504) | | (0.0605) | | (0.0580) |
| Entrepreneurship | | -0.0143*** | | -0.00699** | | -0.00681 | | -0.0143*** | | -0.00699** | | -0.00681 |
| | | (0.00381) | | (0.00281) | | (0.00423) | | (0.00383) | | (0.00281) | | (0.00423) |
| Constant | 0.0270** | -0.269*** | 0.0696*** | -0.196*** | 0.0415 | -0.214*** | 0.0228*** | -0.260*** | 0.0664*** | -0.197*** | 0.0444*** | -0.223*** |
| | (0.0107) | (0.0245) | (0.00867) | (0.0300) | (0.0360) | (0.0356) | (0.00584) | (0.0240) | (0.00765) | (0.0300) | (0.0166) | (0.0326) |
| Observations | 832 | 760 | 832 | 760 | 832 | 702 | 832 | 760 | 832 | 760 | 832 | 702 |
| Nombre groupes | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| Instruments | 7 | 40 | 13 | 40 | 7 | 40 | 12 | 40 | 12 | 40 | 13 | 40 |
| AR (1) | 0.0799 | 0.0869 | 0.0213 | 0.0777 | 0.0794 | 0.0795 | 0.0804 | 0.0868 | 0.0209 | 0.0777 | 0.0827 | 0.0795 |
| AR (2) | 0.296 | 0.156 | 0.418 | 0.244 | 0.432 | 0.245 | 0.348 | 0.156 | 0.415 | 0.244 | 0.397 | 0.245 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hansen P-value | 0.264 | 0.324 | 0.501 | 0.319 | 0.236 | 0.339 | 0.237 | 0.319 | 0.727 | 0.319 | 0.306 | 0.339 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Source**: *Authors based on WDI and UNESCO data (2022)*

*5.3.2. Alternative measures of school performance*

Several proxies have been used in the economic literature to measure women's educational performance. While recognizing the rigor of this measure, it would be relevant to verify the stability of the results using the female secondary school completion rate, which is another measure of the WEP. The school completion rate is the percentage of a cohort of children or young people aged 3 to 5 years above the expected age for the last year of each level of education who have completed that year. The choice of this variable is justified by its acceptable correlation with the indicator of women's school performance provided by UNESCO. These results confirm the negative effects of the digital divide. More specifically, the results show that each dimension of the digital divide weakens women's school completion in Africa.

**Table 8:** The digital divide and alternative measures of women's performance at school

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Relative | | | Absolue | | |
| VARIABLES | Secondary completion, female | | | | | |
| L.Second_female | 0.933*** | 0.845*** | 0.837*** | 0.933*** | 0.956*** | 0.949*** |
| | (0.0150) | (0.0102) | (0.0119) | (0.0151) | (0.0114) | (0.0133) |
| Mobile Divide (R) | -0.00492** | | | | | |
| | (0.00237) | | | | | |
| Internet Divide (R) | | -0.00130* | | | | |
| | | (0.000648) | | | | |
| Broadband Divide (R) | | | -0.0225*** | | | |
| | | | (0.00666) | | | |
| Mobile Divide (A) | | | | -0.000494** | | |
| | | | | (0.000237) | | |
| Internet Divide (A) | | | | | 0.000169 | |
| | | | | | (0.000416) | |
| Broadband Divide (A) | | | | | | -0.0164*** |
| | | | | | | (0.00427) |
| Fertility | 0.00944 | -0.00144 | -0.00626* | 0.00929 | 0.00540** | -0.000451 |
| | (0.00653) | (0.00289) | (0.00339) | (0.00659) | (0.00236) | (0.00331) |
| FDI | -0.0802* | 0.0402* | 0.0596** | -0.0796* | -0.0871*** | -0.103*** |
| | (0.0415) | (0.0220) | (0.0240) | (0.0415) | (0.0175) | (0.0147) |
| GDP_perc | -0.0269 | -0.0877*** | -0.148*** | -0.0280 | -0.00846 | -0.0455** |
| | (0.0237) | (0.0107) | (0.0147) | (0.0236) | (0.00930) | (0.0176) |
| Remittances | 0.0105** | -0.00541 | -0.00519 | 0.0102** | 0.0140*** | 0.0143*** |
| | (0.00465) | (0.00388) | (0.00354) | (0.00457) | (0.00424) | (0.00331) |
| Electricity access | 0.000958 | 0.00398*** | 0.00361*** | 0.000937 | 0.00144* | 2.14e-05 |
| | (0.00206) | (0.00131) | (0.00111) | (0.00205) | (0.000722) | (0.000857) |
| Pop_female | 0.0267 | 0.134*** | 0.111*** | 0.0266 | 0.0117 | 0.00202 |
| | (0.0338) | (0.0294) | (0.0267) | (0.0341) | (0.0164) | (0.0185) |
| Entrepreneurship | -0.00196 | -0.000939 | -0.00216 | -0.00199 | 0.000970 | 0.000876 |
| | (0.00262) | (0.00178) | (0.00182) | (0.00264) | (0.00105) | (0.00158) |
| Constant | 0.0176 | 0.0107 | 0.0377** | 0.0177 | 0.0125 | 0.0412*** |
| | (0.0191) | (0.0176) | (0.0169) | (0.0191) | (0.00817) | (0.0149) |
| Observations | 575 | 575 | 575 | 575 | 575 | 575 |
| Nombre de groupes | 49 | 49 | 49 | 49 | 49 | 49 |
| Instruments | 33 | 47 | 47 | 33 | 47 | 47 |

| | | | | | | |
|---|---|---|---|---|---|---|
| AR (1) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| AR (2) | 0.212 | 0.185 | 0.172 | 0.212 | 0.217 | 0.206 |
| Hansen p-value | 0.648 | 0.255 | 0.266 | 0.649 | 0.646 | 0.631 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Source**: *Authors based on WDI data (2022)*

### *5.3.3.* Instrumental variables approach

To overcome this endogeneity problem in the absence of a purely external instrument in our relationship we will refer to the internal instrumentation approach developed by Lewbel, (2012). We will use the two-stage least squares (2SLS) estimation method of Lewbel (2012). Indeed, we justify the use of Lewbel's 2SLS method by the fact that, unlike other techniques, in particular the instrumental variables technique, finding adequate instruments that can satisfy all the conditions is often very difficult and constitutes a real challenge or even a real problem for most applied research using this instrumental variable technique (Baum et al., 2012; Stock et al., 2002). Lewbel's 2SLS method is applied when the sources of identification, in particular having adequate internal and external instruments, are not available or are weak. In addition, this method is essential for identifying structural parameters in regression models with an endogenous or poorly measured regressor in the absence of traditional identification information. This Lewbel 2SLS approach has instruments that are built in-house based on heteroskedasticity. These internally constructed instruments are generated from the residuals of the auxiliary equation, which are multiplied by each of the included exogenous variables in mean-centred form. Furthermore, one of the advantages of this approach is that it does not depend on the satisfaction of standard exclusion restrictions (Ngounou et al, 2023).

The results of the 2SLS regression are presented in Table 9. The results concerning the quality of the instruments are satisfactory. With regard to the relevance of the instruments, the Kleibergen-Paap Wald rk F statistic was 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 (Saadi, 2020). The statistics presented in Table 9 are greater than 10, indicating that weak identification is not a problem. In addition, the Kleibergen-Paaprk LM statistic is used to test for under-identification.

Second, the Sanderson and Windmeijer (2016) F-test value for the excluded instrument is greater than the rule-of-thumb value of 10. While there is reason to suspect non-orthogonality between regressors and errors, the use of IV estimation to address this issue must be balanced against the inevitable loss of efficiency relative to OLS. It is therefore very useful to have a test to determine whether OLS is inconsistent and whether IV is necessary. Many studies indicate that the digital divide variable may be endogenous. These studies examine the endogeneity of the digital divide using the Durbin-Wu-Hausman (DWH) test (Burnside and Dollar 2000; Dalgaard and Hansen, 2001). In line with this literature, the DWH test presented in table 9 does not reject the null hypothesis of exogeneity of the digital divide with respect to educational performance, IV estimation is not required and OLS estimates are unbiased and reliable (Baum et al., 2007a). However, the coefficient associated with the digital divide remains negative and statistically significant, which is consistent with our hypothesis.

**Table 9.** Robustness check using the relative digital divide and the 2SLS model

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | IV-2SLS | | | | | |
| | Absolute indicator of the digital divide | | | Relative indicator of the digital divide | | |
| VARIABLES | WEP | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Internet Divide (A) | **-0.202*** ** | | | | | |
| | (0.0477) | | | | | |
| Mobile Divide (A) | | | **-0.136*** ** | | | |
| | | | (0.0257) | | | |
| Broadband Divide (A) | | **-1.989*** ** | | | | |
| | | (0.151) | | | | |
| Internet Divide (R) | | | | **-0.202*** ** | | |
| | | | | (0.0477) | | |
| Mobile Divide (R) | | | | | | **-1.362*** ** |
| | | | | | | (0.257) |
| Broadband Divide (R) | | | | | **-0.963*** ** | |
| | | | | | (0.104) | |
| Fertility | -0.639*** | -0.472*** | -0.608*** | -0.639*** | 0.177*** | -0.608*** |
| | (0.0792) | (0.0694) | (0.0844) | (0.0792) | (0.0504) | (0.0844) |
| Remittances | 0.182** | 0.314*** | 0.194** | 0.182** | 0.303*** | 0.194** |
| | (0.0880) | (0.0543) | (0.0950) | (0.0880) | (0.0461) | (0.0950) |
| Entrepreneurship | -0.0167 | -0.210*** | -0.0563 | -0.0167 | -0.0205 | -0.0563 |
| | (0.0530) | (0.0669) | (0.0544) | (0.0530) | (0.0563) | (0.0544) |
| | - | | | - | - | - |
| FDI | 0.000944*** | -0.000287* | -0.00126*** | 0.000944*** | 0.000420*** | 0.00126*** |
| | (0.000333) | (0.000148) | (0.000381) | (0.000333) | (0.000131) | (0.000381) |
| GDP_Percapital | 3.916*** | -0.867** | 3.378*** | 3.916*** | 0.0758 | 3.378*** |
| | (0.444) | (0.371) | (0.449) | (0.444) | (0.326) | (0.449) |
| Electricity access | 0.00386 | 0.196*** | -0.0367 | 0.00386 | 0.00421 | -0.0367 |
| | (0.0406) | (0.0280) | (0.0417) | (0.0406) | (0.0266) | (0.0417) |
| Female population | 5.228*** | -3.510** | 4.846*** | 5.228*** | -2.600** | 4.846*** |
| | (0.821) | (1.611) | (0.830) | (0.821) | (1.063) | (0.830) |
| Constant | -1.821*** | 4.474*** | -1.693*** | -1.845*** | 1.810*** | -1.577*** |
| | (0.465) | (0.824) | (0.470) | (0.464) | (0.560) | (0.476) |
| Observations | 737 | 737 | 737 | 737 | 737 | 737 |
| R-squared | 0.656 | 0.979 | 0.672 | 0.656 | 0.987 | 0.672 |
| Hansen J test p-value | 0.513 | 0.842 | 0.179 | 0.513 | 0.619 | 0.179 |
| Kleibergen paap test p-value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Kleibergen paap statistic | 154.0 | 26.73 | 177.4 | 154.0 | 27.68 | 177.4 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

**Source**: *Authors based on WDI and UNESCO data (2022)*

### 5.3.4. The digital divide and women's performance at school: a non-parametric approach

The non-parametric approach used is based on quantile regression. Indeed, given the constraints of the a priori estimation techniques (OLS) which focus only on the mean effect and do not take into account the effect that our measures of the digital divide could have on different level of educational performance of women and also the OLS method can be inefficient if the errors are strongly non-normal, thus, a panel quantile regression (QR) approach is needed to study the distributional and heterogeneous influence between quantiles and also it is more robust to non-normal errors and outliers. The fundamental work of Koenker and Bassett (1978) established the panel quantile regression technique. QR has the particularity of taking into account the effect of one variable on another at different points in its distribution. This approach is more robust than the OLS approach for several reasons. For example, it is appropriate when errors are not normally distributed and when outliers are involved. In addition, when the distribution of the dependent variable is wide, the mean can be highly variable in the presence of strong heterogeneity in the sample (Cade and Noon, 2003). QR therefore provides a more accurate description of the distribution of a variable of interest conditional on its determinants than simple linear regression, which focuses on the conditional mean. In line with the work of Binder and Coad, (2011), the quantile regression model can be written as follows:

$$y_{it} = x_{it}'\beta_\theta + u_{\theta it} \text{ avec } Quant_\theta(y_{it}|x_{it}) = x_{it}'\beta_\theta \qquad (3)$$

Where $y_i$ is the level of women's educational performance, 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 $x_{it}$ given. The quantile estimator is obtained by solving the following optimization problem for the θth quantile (0 < θ < 1):

$$\min_{\beta \in R^K} \left[ \sum_{i,t:y_{it} \geq x_{it}'\beta} \theta \left| y_{it} - x_{it}'\beta \right| + \sum_{i,t:y_{it} \geq x_{it}'\beta} (1-\theta) \left| y_{it} - x_{it}'\beta \right| \right] \qquad (4)$$

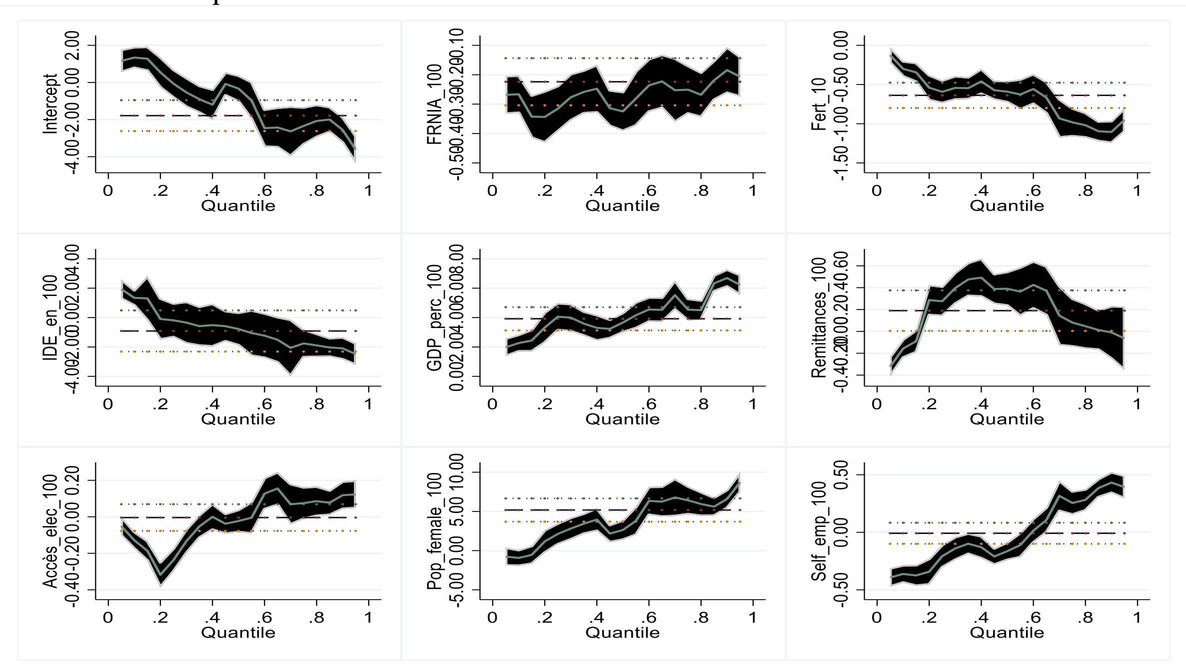
Table 10. Quantile regression.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Q10 | Q25 | Q50 | Q75 | Q95 |
| VARIABLES | | | WEP | | |
| Internet Divide (A) | **-0.266*** ** | **-0.316*** ** | **-0.268*** ** | **-0.251*** ** | **-0.207*** ** |
| | (0.0348) | (0.0580) | (0.0432) | (0.0540) | (0.0555) |
| **Fertility** | **-0.300*** ** | **-0.592*** ** | **-0.124** | **-0.982*** ** | **-0.951*** ** |
| | (0.0702) | (0.117) | (0.0871) | (0.109) | (0.112) |
| FDI | 1.344** | -0.185 | 1.935** | -1.756* | -2.480** |
| | (0.608) | (1.014) | (0.755) | (0.944) | (0.970) |
| GDP_Percapital | **2.267*** ** | **4.062*** ** | **1.976*** ** | **4.540*** ** | **6.223*** ** |
| | (0.343) | (0.572) | (0.426) | (0.533) | (0.548) |
| Remittances | **0.157*** | **0.276** ** | **-0.323*** ** | **0.0807** | **-0.0638** |
| | (0.0805) | (0.134) | (0.0999) | (0.125) | (0.128) |
| Electricity access | **-0.128*** ** | **-0.237*** ** | **-0.0508** | **0.0750** | **0.123** ** |
| | (0.0317) | (0.0529) | (0.0394) | (0.0493) | (0.0506) |
| Female population | -0.931 | 2.134** | -0.760 | 6.419*** | 8.725*** |
| | (0.644) | (1.075) | (0.800) | (1.000) | (1.028) |
| Entrepreneurship | **-0.362*** ** | **-0.207*** ** | **-0.392*** ** | **0.255*** ** | **0.393*** ** |
| | (0.0397) | (0.0662) | (0.0493) | (0.0616) | (0.0633) |
| Constant | 1.344*** | -0.0603 | 1.160*** | -2.340*** | -3.608*** |
| | (0.361) | (0.602) | (0.448) | (0.561) | (0.576) |
| Observations | 795 | 795 | 795 | 795 | 795 |
| Pseudo R2 | 0.3843 | 0.3982 | 0.3700 | 0.4595 | 0.5434 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Source**: *Authors based on WDI and UNESCO data (2022)*

Table 10 presents a summary of the quantile regression (QR) results. In addition, the quantile plot of the heterogeneous effect of GDP_Percapital, access to electricity, remittances, FDI, fertility, digital divide, entrepreneurship and female population on female educational performance is shown in (Figure 5). The analysis covers five quantiles (10-95). The results indicate that there is a negative effect between the internet digital divide and women's educational performance in all quantiles. More specifically, the effect is statistically significant at the 1% threshold on all quantile distributions. Similarly, the decline in women's educational performance in Africa is obviously caused by the DD. However, women's educational performance falls from 0.266 to 0.207 as the quantile decreases. The gap in access to and use of ICTs decreases slowly in the early phases of the expansion and accelerates in the later phase. Consequently, a delay in narrowing this gap has an undesirable effect on women's educational performance.
These results are confirmed by Figure 5, which illustrates how the negative effects of the digital divide on women's educational performance vary according to quantile, and how the magnitude of the effects at the different quantiles differs considerably from the OLS coefficient (presented as horizontal lines). In this way, the thesis of the curse of the African technological divide documented by Das and Drine (2020) is verified as a function of the level of women's educational performance.
Figure 5: Magnitude of the effects of the digital divide on women's educational performance as a function of quantiles




**Source**: *Authors' constructions based on WDI and UNESCO data. Horizontal lines represent OLS with 95% confidence intervals.*

## 6. Conclusion

Internet-based technologies such as search engines and cloud computing have brought about a paradigm shift in the education sector. More specifically, the digitization of the education system via the Internet and ICT tools has enabled a shift from traditional knowledge transmission to electronic or digital intermediation. The need for a strong and effective education sector in Africa has always been the subject of considerable research because of its impact on development. However, the issue of the role of technological change (particularly

ICT) on educational performance is relatively recent. According to the literature, the less susceptible an economy is to ICT, the greater the impact on the education sector.
It was therefore necessary to revisit empirically the influence of DD on the educational performance of women in a panel of 54 African countries over the period 2000-2021. Using the GMM-SYS estimation technique, the main result shows that women's performance at school is a significantly decreasing function of DD. Poor access to ICTs, particularly in the broadband, mobile phone and even Internet sectors, is a major handicap to women's educational performance in Africa. The result remains consistent when the absolute DD of bandwidth, internet and mobile telephony is replaced by the relative measure. This is also the case when the alternative female educational performance indicator is used. In particular, it is shown that even relative DD is a handicap to women's educational performance in Africa. This means that the regions with the lowest access to digital technologies in relative terms are those that have the highest level of women underperforming in educational matters. Similarly, using the Quantile-Regression (QR) method, the results reveal that in all quantiles (10th to 95th) the digital divide weakens women's educational performance.
The document therefore recommends making it easier to appropriate ICTs and developing an education sector that is more receptive to the dynamics of ICTs:
However, the main recommendation would be to reduce overall and relative DD in order to boost the educational performance of women in Africa. To guarantee access to education and knowledge for all, issues relating to access to ICTs, their use and the upgrading of people's skills need to be addressed: (i) In relation to conditions of access, factors such as cost are fundamental. Whether we are talking about telephones (fixed and mobile), broadband or IT, the importance of ex-ante costs (brokerage, purchase, etc.) and ex-post costs (connectivity, maintenance, etc.) is decisive. To achieve this, actions aimed at stabilizing these costs (taxation) or guaranteeing a certain standard of living for households are necessary; (ii) The use of ICTs is conditional on access. The challenge of usage is often quickly resolved when ex-post access costs are kept under control. Furthermore, the use of ICTs depends on the intrinsic functionality of the gadgets and the subscription to certain services, provided that the cost of the subscription is also reasonable; if not, it will be accessible but the use of ICTs will remain a luxury; (iii) the profitability of IT tools depends largely on the faculties or skills of its users. These relate not only to their level of education, but also to the quality of that education. Pragmatic measures therefore need to be taken to modernize educational structures in Africa. This modernization requires not only quantitative and qualitative investment in school infrastructure, but also the orientation of the majority of learners towards technical, scientific and technological fields.

Appendix

**Appendix 1. List of countries**

| |
|---|
| Algeria, Angola, Botswana, Burundi, Cameroon, Comoros, CAR, Djibouti, Gabon, Equatorial Guinea, DRC, Congo, Benin, Burkina-Faso, Cape Verde, Ivory Coast, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Morocco, Mauritius, Mozambique, Niger, Nigeria, Uganda, Sao Tome and Principe, Senegal, Sierra Leone, Sudan, Togo, Lesotho, Namibia, Eswatini, Africa South, Tanzania, Chad, Tunisia, Rwanda, Somalia, Zambia, Zimbabwe. |

Source: Authors.

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