Regional initiatives
Africa

ITU Publications

Economic contribution of broadband, digitization and ICT regulation

Econometric modelling for Africa

Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for Africa

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This report has been prepared by the International Telecommunication Union (ITU) with the collaboration of the ITU Telecommunication Development Bureau (BDT) Regulatory and Market Environment Division (RME). It is based on regional findings from research prepared for the ITU report on the economic contribution of broadband, digitization and ICT regulation published in 2018. The research study is based on desk research and on data from the ITU ICT Regulatory Tracker as well as the Digital Ecosystem Development Index, which was developed with funding from the CAF (Corporación Andina de Fomento) Development Bank for Latin America.

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Foreword

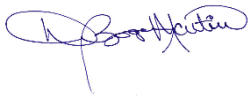
The transformative power of digital technologies and connectivity is empowering people, creating an environment that nurtures innovation, and is triggering positive change in business processes and in the global economy.

The recent ITU study on the economic contribution of broadband, digitization and ICT regulation provided a global econometric analysis of robust and reliable data resources to measure the impact of fixed and mobile broadband and digital transformation on the economy as a whole. It also analysed the impact of institutional and regulatory variables to the development of the digital ecosystem.

Based on the data and analysis to measure the impact of digitization as a whole, a further need was identified to conduct studies that delved deeper into these effects, focusing on specific regions of the world. By applying the same methodologies and econometric models used for assessing global effects, this report focuses on the impact of broadband, digital transformation and policy and regulatory frameworks on the growth of markets for digital services in Africa. It also provides evidence of the importance of regulatory and institutional variables in driving digital growth, illustrating that broadband technologies and effective ICT regulation can have positive impacts on the development of national economies and prosperity.

This landmark regional study of the majority of countries in the Africa region confirms that an increase of 10 per cent in mobile broadband penetration in Africa would yield an increase in 2.5 per cent in GDP per capita. In addition, it suggests that a 10 per cent drop in mobile broadband prices will boost adoption of mobile broadband technology by more than 3.1 per cent.

I am delighted that this ever-growing body of research will guide and assist membership in the Africa region to design sustainable policies and strategies, and to benefit from the dynamic and exciting broadband ecosystem.



Doreen Bogdan-Martin
Director, ITU Telecommunication Development Bureau

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1 Introduction

ITU published the findings of a global study on the economic contribution of broadband, digitization and ICT regulation in September 2018[1]. Following this report, The *Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for Africa* presents a set of econometric analyses that estimate the economic contribution of broadband and digitization, as well as the impact of ICT policy on the development of the digital economy in the Africa region. It provides substantial evidence regarding the impact of broadband and digital transformation on the economy as well as the impact of institutional and regulatory variables on the growth of the digital ecosystem.

The ITU report in 2018 was based on a large set of advanced and emerging economies, and showed effects for countries based on their level of development:

- Fixed broadband economic impact is guided by a return-to-scale effect[2], according to which its economic impact is higher in more advanced economies than in emerging economies.
- The economic impact of mobile broadband depicts a saturation effect, according to which its contribution is higher in less developed countries than in more developed ones.
- The impact of the digital ecosystem on more advanced economies is higher than in developing countries.
- The regulatory and policy framework has a consistent impact on the development of the digital ecosystem, regardless of the country's level of development.

This evidence was considered significant for policy makers and regulators in particular with regards to two key issues:

- Which technologies should become a policy priority in terms of adoption?
- How to ensure that, beyond broadband adoption, policies are deployed to stimulate the development of the digital ecosystem?

The conclusions generated by this research has prompted calls to conduct studies that delve deeper into these effects, focusing on specific regions of the world.

This report focuses on the Africa region by applying the same methodologies and models used for assessing global effects. Section 2 summarizes the results of the global study before section 3 presents the results of the analyses for the Africa region.

2 The effects identified on a global scale

The global ITU study cited above was focused on testing three effects:

1. the economic contribution of fixed and mobile broadband;
2. the economic contribution of digitization (a variable that subsumes broadband technology within a larger set of digital ecosystem components); and

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1 Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation.* Geneva, International Telecommunication Union (https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf).

2 Generally, *returns to scale effect* describes what happens as the scale of production increases over time, when inputs such as physical capital usage are variable. The *ITU report on the impact of broadband on the economy, 2012 (https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf)* states that according to the returns to scale theory, the economic impact of broadband increases exponentially with the penetration of the technology.

3. the impact of policy and regulatory frameworks on the growth of markets for digital services and applications.

The findings for each analysis are presented in order to provide the context within which the regional models are specified.

Economic impact of fixed broadband

The structural econometric model, composed of four equations[3], developed for the ITU global study generated further evidence of the economic impact of fixed broadband between 2010 and 2017. Based on a model run for 139 countries (general fixed broadband model), an increase of 10 per cent in fixed broadband penetration yielded an increase in 0.8 per cent in gross domestic product (GDP) per capita. The sample was split between high, medium, and low income countries to test whether fixed broadband contribution still existed and whether the impact increased or decreased by level of economic development for:

- countries with GDP per capita higher than USD 22 000 (50 countries);
- countries with GDP per capita between USD 12 000 and USD 22 000 (26 countries);
- countries with GDP per capita lower than USD 12 000 (63 countries).

The results supported the hypothesis that the economic contribution of fixed broadband increases with economic development:

- Higher income countries: 10 per cent increase in broadband penetration yields 1.4 per cent increase in GDP growth.
- Middle income countries: 10 per cent increase in broadband penetration yields 0.5 per cent increase in GDP growth.
- Low income countries: while the coefficient of fixed broadband impact was similar to the middle impact countries, it was not statistically significant.

Economic impact of mobile broadband

The impact of mobile broadband on the world economy is higher than the impact of fixed broadband.

Relying on a similar structural model run for a 139 country sample (the general mobile broadband model) from the ITU global study, an increase of 10 per cent in mobile broadband penetration yielded an average increase in 1.5 per cent in GDP.

However, for mobile broadband, the level of economic contribution was the opposite, with little or no impact in countries with higher than USD 22 000 GDP per capita. For other countries, an increase of 10 per cent in mobile broadband penetration yielded an increase in 1.8 per cent to 2.0 per cent in GDP.

- High income countries: no economic impact was detected.
- Middle income countries: An increase of 10 per cent in mobile broadband penetration yields an increase in 1.8 per cent in GDP.
- Low income countries: An increase of 10 per cent in mobile broadband penetration yields an increase in 2.0 per cent in GDP.

The difference in impact between high income and low income economies depends on the number of consumers who have access to fixed broadband. In many emerging economies, mobile broadband is the only technology that enables Internet access, while mobile broadband contribution to high income economies is only marginal while the impact in low income countries is extremely important.

[3] Detailed models and methodologies can be found in the ITU global study cited in footnote 1.

Economic impact of digitization

The economic impact of digitization was tested by relying on an endogenous growth model[4] that linked GDP to the fixed stock of capital, labour force, and the CAF Digital Ecosystem Development Index. The approach followed in this case was similar in terms of first testing the economic contribution for a sample of 73 countries worldwide (the general digitization model) and then splitting it for countries from the Organization for Economic Co-operation and Development (OECD) and non-OECD countries. According to the general digitization model, an increase of 10 per cent in the CAF Digital Ecosystem Development Index resulted in a 1.3 per cent growth in GDP per capita. When the sample was split between advanced and emerging economies, economic impact increased with development:

- OECD countries: An increase of 10 per cent in the CAF Digital Ecosystem Development Index resulted in a 1.4 per cent growth in GDP per capita.
- Non-OECD countries: An increase of 10 per cent in the CAF Digital Ecosystem Development Index yielded a 1.0 per cent growth in GDP per capita.

Furthermore, a single variable model with country and period fixed effects indicated that digitization also has an impact on labour and total factor productivity. An increase in the digitization index of 10 per cent yielded an increase in labour productivity of 2.6 per cent and in total factor productivity of 2.3 per cent.

Impact of policy and regulatory framework on digitization development

In this case, the contribution to digitization development was tested through a multivariate regression model with fixed effects based on two independent variables: the ITU ICT Regulatory Tracker[5] and a year lag of the same variable for control purposes. The model provided further evidence of the importance of the regulatory and institutional variable in driving digital ecosystem growth. An increase of 10 per cent in the ITU ICT Regulatory Tracker yielded a positive increase in the CAF Digital Ecosystem Development Index of 0.348 per cent in the subsequent time period.

Having presented the types of analyses, methodologies, and results relied upon for the ITU global study, the study of the econometric modelling of the Africa region will focus on validating the results with the regional studies. The presentation of the econometric model results is preceded by a review of the research literature on the economic contribution of broadband in Africa.

3 The economic contribution of broadband and digitization and the impact of policy on digitization in Africa

This section analyses the economic contribution of broadband and digitization for the majority of countries (34) in the ITU Africa region: Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Cote d´Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo, Rwanda, Senegal, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

3.1 Review of the research literature in Africa

The research literature on the economic impact of broadband is clustered around the assessment of micro-effects and econometric studies of mobile broadband.

[4] Assumes that investment in human capital, innovation, and knowledge contribute to economic growth.

[5] ITU ICT Regulatory Tracker is available at https://www.itu.int/net4/itu-d/irt/#/tracker-by-country/regulatory-tracker/2017

Multiple micro-economic studies from countries in the Africa region show that enhanced communication results in more efficient markets, which ultimately improve consumer welfare. For instance, in Niger, prices in the grain market fell, resulting in increased producer profits and, ultimately, consumer welfare improvements (Aker, 2008). In rural Uganda, banana farmers producing perishable crops benefitted as the costs of crop marketing decreased as a result of mobile coverage (Muto, 2008). Mobile networks can also address a lack of access to traditional services. In Kenya and Tanzania, the launch of financial services and micropayments via mobile phones reduced both the cost of banking services and the transactional burdens, leading to a reduction of the "unbanked" population in each country. Similarly, the introduction of mHealth mobile applications in such countries as Ghana and Cape Verde resulted in more accessible, affordable, and higher quality healthcare services in developing countries (Kelly and Minges, 2012).

In some instances, the introduction of mobile networks can lead to the development of new markets and services. When a region received wireless network coverage in South Africa, for example, employment significantly increased (Klonner and Nolen, 2010); likewise, in Malawi, female labour participation increased (Batziillis et al., 2010). On a related note, mobile applications that assist with the job search and application process are particularly beneficial in instances of low digital literacy or where the employment process is largely informal (Donner, Gitau, and Marsden, 2011). In many cases, the higher-quality jobs are listed online, where only those citizens with digital literacy skills and Internet access can apply for them.

Beyond the micro-economic impact studies of mobile broadband, other studies tested the economic impact of fixed broadband (Côte d´Ivoire, Guinea, Niger, Senegal) but did not find any positive effects apart from the most recent study of Senegal (Katz and Callorda, 2018c). This is consistent with the results on the global study that do not identify positive contribution of fixed broadband for low-income countries.

On the other hand, the economic contribution of mobile broadband in specific countries in the Africa region was consistently confirmed through mobile broadband economic impact studies on Senegal, the Democratic Republic of Congo, and Guinea, yielding the estimates in Table 1.

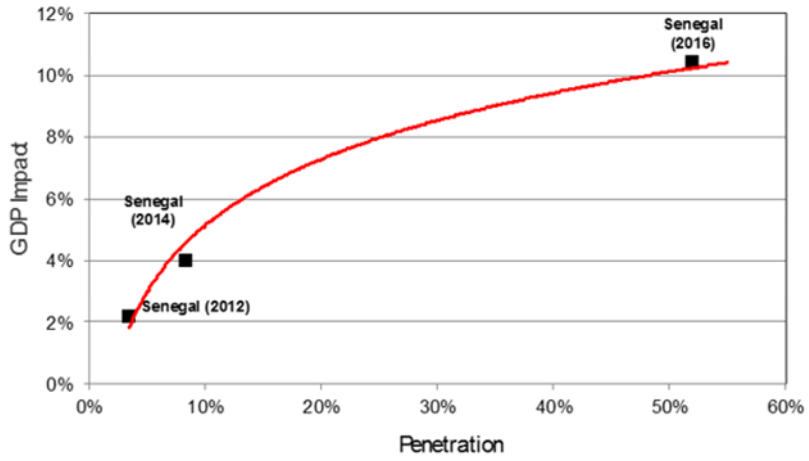
Table 1: Coefficient of economic contribution to GDP growth for every increase in 10 per cent mobile broadband penetration

Country	Year range	Coefficient of GDP growth
Senegal	2009-10	No impact
Senegal	2009-12	0.22
Senegal	2009-14	0.40
Guinea	2010-16	4.74 (*)
Democratic Republic of Congo	2013-16	1.16

(*) This coefficient might be subsuming any increases in fixed capital formation or human capital. Consequently, it is not feasible to draw conclusions of economic impact from mobile Internet in this study.

In a longitudinal study, Katz and Callorda (2018c) ran a similar structural model for mobile broadband in Senegal attempting to ascertain whether the economic contribution was increasing with penetration. The results indicated a growing contribution (see Figure 1).

Figure 1: Senegal: Mobile broadband economic impact



Source: Katz and Callorda (2018c)

The econometric model, run for the period between 2010 and 2016, estimates that each 10 per cent increase in mobile broadband penetration yields 1.04 per cent of GDP growth. The significant increase in economic impact of mobile broadband between 2014 and 2016 is the result not only of an increase in penetration but also because this technology is assuming the preeminent role in providing Internet connectivity in the context of fixed broadband underdevelopment both in terms of the number of subscribers, pricing and coverage.

3.2 Hypotheses

Considering the evidence generated in the research literature and the ITU global study that preceded this analysis, one could stipulate the following effects in the Africa region:

- Impact of fixed broadband: As low as the impact estimated for low income countries in the global sample.
- Impact of mobile broadband: As high as the impact estimated for low income countries in the global sample.
- Impact of digitization: Lower than that calculated for the global sample

3.3 Economic impact of fixed broadband in Africa

The estimation of the economic contribution of fixed broadband in the Africa region relied on the same structural model used in the ITU global study and in the estimation of effects in the other regions. The model consists of four equations: an aggregate production function modelling the economy and, subsequently, three functions: demand, supply and output.

3.3.1 Data

To test the hypothesis of fixed broadband economic impact presented above, a database of the countries in the Africa region[6] was built, containing time series for all the required variables between

[6] In this study: Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d´Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo, Rwanda, Senegal, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

2010 and 2017. The data sources are the International Telecommunication Union, the World Bank, and Ovum (see Annexes A and B for sources of data).

3.3.2 Model results and discussion

The model results for 34 countries in the Africa region are presented in Table 2.

Table 2: Economic impact of fixed broadband (Africa region)

GDP per capita (PPP)[7]	
Fixed broadband subscriber penetration	0.03031
Capital	0.11728 ***
Education	0.26642 ***
Fixed broadband subscriber penetration	
Fixed telephone subscribers	0.37878 ***
Rural population	-0.55948 ***
GDP per capita	0.50957 ***
Fixed broadband price	-0.22882 ***
HHI fixed broadband	-0.39252 ***
Revenue fixed broadband	
GDP per capita	0.54882 ***
Fixed broadband price	0.34617 ***
HHI fixed broadband	-0.87728 ***
Fixed broadband adoption growth	
Revenue fixed broadband	-0.55864 ***
Observations	956
Number of countries	34
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2010-2017
R-Squared first model	0.9826

***, **, * significant at 1%, 5% and 10% critical value respectively.

As expected, according to the fixed broadband model, this technology has a small economic contribution in Africa during the last seven years (2010-2017). An increase of 10 per cent in fixed broadband penetration yields an increase in 0.3 per cent in GDP per capita. More fundamentally, while holding a

[7] GDP per capita (PPP) refers to the gross domestic product at purchasing power parity per capita: PPP value goods and services produced within a country, divided by the average population for the same year.

positive sign, the results are not statistically significant. On the other hand, as expected, fixed capital formation and education remain positive contributors to GDP growth.

The Africa region results are consistent with the coefficients and signs derived for low income countries in the global study as presented in Table 3.

Table 3: Economic impact of fixed broadband (Africa region compared with global model countries)

	Global study-low income countries	Africa
GDP per capita (PPP)		
Fixed broadband subscriber penetration	0.05461	0.03031
Capital	0.21024 ***	0.11728 ***
Education	0.15569 ***	0.26642 ***
Fixed broadband subscriber penetration		
Fixed telephone subscribers	0.49262 ***	0.37878 ***
Rural population	-0.81927 ***	-0.55948 ***
GDP per capita	0.53821 ***	0.50957 ***
Fixed broadband price	-0.30159 ***	-0.22882 ***
HHI fixed broadband	-0.38882 ***	-0.39252 ***
Fixed broadband revenue		
GDP per capita	1.24272***	0.54882 ***
Fixed broadband price	0.14314 ***	0.34617 ***
HHI fixed broadband	-0.71760 ***	-0.87728 ***
Fixed broadband adoption growth		
Fixed broadband revenue	-0.74656 ***	-0.55864 ***
Observations	1,724	956
Number of countries	63	34
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2017	2010-2017
R-Squared first model	0.9831	0.9826

***, **, * significant at 1%, 5% and 10% critical value respectively

Note: The global model was built starting in 2010 given that by then most countries had exceeded the 5% adoption threshold.

As indicated in Table 3, neither model depicts a statistically significant contribution of fixed broadband. This could suggest that most of the economic contribution of broadband in the Africa region should rely on mobile broadband.

3.4 Economic impact of mobile broadband in Africa

Similarly, to the fixed broadband model, the structural model used to test the economic contribution of mobile broadband comprises four equations: an aggregate production function modelling the economy and, subsequently, three functions: demand, supply and output.

3.4.1 Data

To test the hypothesis of the economic impact of mobile broadband presented above, a database was built for the following countries: Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Republic of the Congo, Côte d´Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe. The database contains time series for all the required variables between 2010 and 2017. The data sources are the International Telecommunication Union, the World Bank, and GSMA (see Annexes A and B for sources of data).

3.4.2 Model results and discussion

The model, run with 34 countries, yields statistically significant results, confirming the effects identified in the global model (Table 4).

Table 4: Economic impact of mobile broadband (Africa region)

GDP per capita (PPP)	
Mobile broadband unique subscriber penetration	0.24613 ***
Capital	-0.00708
Education	0.22785 ***
Mobile broadband unique subscriber penetration	
Mobile unique subscriber penetration	1.58580 ***
Rural population	0.18895 ***
GDP per capita	0.20936 ***
Mobile broadband price	-0.31082 ***
HHI mobile broadband	-0.16634 ***
Revenue mobile broadband	
GDP per capita	0.71111 ***
Mobile broadband price	-0.46106 ***
HHI mobile broadband	-1.10363 ***
Mobile broadband adoption growth	
Revenue mobile broadband	-1.25511 ***
Observations	899
Number of countries	34

Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2010-2017
R-Squared first model	0.9784

***, **, * significant at 1%, 5% and 10% critical value respectively

According to the mobile broadband model in Table 4, an increase of 10 per cent in mobile broadband penetration yields an increase in 2.5 per cent in GDP per capita, which means that this technology has had a significant economic impact in the Africa region during the last seven years (2010-2017).

Moreover, the structural model provides estimates for other important parameters of the economy, although further analysis would be required in these variables since they are part of the structural model second equation. For example, pricing remains a key enabler for adoption of the technology. Strikingly, a 10 per cent drop in prices will boost adoption by more than 3.1 per cent[8]. Income variation across the sample period seems to have a similar impact on this process. Hence increasing the average disposable income (proxied by GDP per capita) by 10 per cent yields 2.1 per cent more fixed broadband adoption. Supply dynamics suggest that, as expected, income levels affect the revenues and investments of operators. The consumption propensity for broadband services seems to have a significant impact on increasing the supply of digital offerings. Increasing the disposable income (proxied by GDP per capita) attracts 0.71 per cent more supply (based on the coefficient of GDP in the supply equation in Table 4). Finally, revenues are found to have a significant impact on the performance of the industry, implying a reinvestment of the output to the productive basis of the economy in Africa[9]. This is an additional angle supporting the increasing returns to scale of ICT infrastructure.

This coefficient of economic impact of mobile broadband in Africa is higher than the one estimated for low income countries in the global study (Table 5).

Table 5: Economic impact of fixed broadband (Africa region compared with global model countries)

	Global study-low income countries	Africa
GDP per Capita (PPP)		
Mobile broadband unique subscriber penetration	0.19752 ***	0.24613 ***
Capital	0.23190 ***	-0.00708
Education	0.12406 ***	0.22785 ***
Mobile broadband unique subscriber penetration		
Mobile unique subscriber penetration	1.63963 ***	1.58580 ***
Rural population	-0.08433 ***	0.18895 ***
GDP per capita	0.04384 **	0.20936 ***
Mobile broadband price	-0.13139 ***	-0.31082 ***
HHI mobile broadband	-0.27510 ***	-0.16634 ***

[8] A word of caution: considering that this is a structural model based on a system of equations, the results of intermediate equations are inputs for the final result. In that sense, the coefficients of

[9] This is particularly relevant for markets undergoing high growth, while it not be the case with saturated markets.

	Global study-low income countries	Africa
Revenue Mobile Broadband		
GDP per capita	0.97739 ***	0.71111 ***
Mobile broadband price	-0.47023 ***	-0.46106 ***
HHI mobile broadband	-1.65927 ***	-1.10363 ***
Mobile broadband adoption growth		
Revenue mobile broadband	-1.11108 ***	-1.25511 ***
Observations	1,689	899
Number of countries	63	34
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2017	2010-2017
R-Squared first model	0.9799	0.9784

***, **, * significant at 1%, 5% and 10% critical value respectively.

The higher coefficient of economic impact of mobile broadband for the Africa region is capturing the late entry of these countries in the broadband era, with which mobile broadband equates to Internet diffusion. That being said, it is expected that, over time, as shown in the review of recent research presented above, this coefficient will decrease.

3.5 Economic impact of digitization in the Africa region

The economic contribution of digitization in the Africa region was tested relying on the CAF Digital Ecosystem Development Index[10]. The returns to scale hypothesis tests whether the economic contribution of digitization is lower in countries in the Africa region than in advanced economies.

3.5.1 Data

The CAF Digital Ecosystem Development Index was calculated for Botswana, Equatorial Guinea, Gabon, Mauritius, Seychelles, and South Africa. Countries with current GDP per capita lower than USD 7 500 were excluded. In addition, several Africa region countries had to be excluded from the sample because of their high variance year on year in GDP due to volatility in commodity pricing.

In addition, the model included independent variables for fixed capital formation (source: World Bank), GDP per capita (source: IMF) and tertiary school enrolment, as a proxy for labour quality (source: World Bank). The consideration of these variables had also an impact on the number of countries due to missing data.

3.5.2 Model results and discussion

The model was first run for six countries[11] for the period 2008-2017, which results in 43 observations, and includes fixed effects by year (Table 6).

[10] See https://www.sciencedirect.com/science/article/pii/S0308596117302914 (Katz, Callorba)
[11] Botswana, Equatorial Guinea, Gabon, Mauritius, Seychelles, and South Africa.

Table 6: Economic impact of digitization 2008-2017 (Africa region)

Variable	Coefficients
Previous GDP	0.4707 ** (0.1783)
Digitization	0.1871 (0.3189)
Capital	0.3272 ** (0.1213)
Labour	0.2415 (1.0771)
Constant	3.3805 (2.4301)
Observations	43
Year fixed effects	Yes

***, **, * significant at 1%, 5% and 10% critical value respectively.

According to the model, an increase of 10 per cent in the CAF Digital Ecosystem Development Index results in a 1.9 per cent growth in GDP per capita, but the coefficient is not statistically significant because of the reduced number of observations. With that caveat, an increase in the Digital Ecosystem Development Index from 50 to 51 will yield an increase of per capita GDP of 0.38 per cent (accounting both for direct and indirect effects on output).

Despite the lack of statistical significance, the results from the Africa model holds some similarity with the non-OECD model developed in the ITU global study (Table 7).

Table 7: Economic impact of digitization, 2017 (Africa region compared to non-OECD countries)

Variable	Africa	Non-OECD
Previous GDP	0.4707 ** (0.1783)	0.7279 *** (0.0294)
Digitization	0.1871 (0.3189)	0.1044 * (0.0592)
Capital	0.3272 ** (0.1213)	0.0471 * (0.0279)
Labour	0.2415 (1.0771)	0.0581 (0.0544)
Constant	3.3805 (2.4301)	1.6827 *** (0.2821)
Observations	43	429
Year fixed effects	Yes	Yes

***, **, * significant at 1%, 5% and 10% critical value respectively.

3.6 Impact of policy and regulatory framework on digitization in Africa

The following analysis is based on the similar model used in the ITU global study to test the impact of the ITU ICT Regulatory Tracker on the CAF Digital Ecosystem Development Index.

3.6.1 Data

The models rely on the ITU ICT Regulatory Tracker and the CAF Digital Ecosystem Development Index for the period between 2008 and 2017 for Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Democratic Republic of the Congo, Cote d´Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

As indicated in the section above, the CAF Digital Ecosystem Development Index includes an institutional and regulatory pillar, which had to be excluded in order to avoid co-linearity. Once that was done and the index was recalculated, it was possible to test the impact of the ITU ICT Regulatory Tracker on digitization.

3.6.2 Model results and discussion

As in the prior section, a correlational analysis between both indices was initially run, and results are presented in Table 8.

Table 8: ITU ICT Regulatory Tracker and CAF Digital Ecosystem Development Index correlation (Africa region)

CAF Digital Ecosystem Development Index (without the regulatory sub-index)	Coefficient (standard deviation) Africa
ITU ICT Regulatory Tracker	0.1662 (0.0111)***
Constant	2.5572 (0.6345) ***
R-square	0.3419
Fixed effects for year and country	Yes
Countries	43
Observations	473
Years	2007-2017

***, **, * significant at 1%, 5% and 10% critical value respectively.

In order to test for the causal link, a control of a one-year lag of the ITU ICT Regulatory Tracker was added (Table 9).

Table 9: Impact of lagged ITU ICT Regulatory Tracker on CAF Digital Ecosystem Development Index (Africa region)

CAF Digital Ecosystem Development Index (without the regulatory sub-index)	Coefficient (Standard deviation) Africa
CAF Digital Ecosystem Development Index (w/o regulation pillar)	0.0965 (0.0254)***
ITU ICT Regulatory Tracker (t-1)	0.0927 (0.0215)***
Constant	1.5486 (0.7612) **
R-squared	0.3783
Fixed effects for year and country	Yes
Groups	43
Observations	430
Years	2008-2017

***, **, * significant at 1%, 5% and 10% critical value respectively.

In this model, it was found that an additional point in the ITU ICT Regulatory Tracker yields 0.0965 points higher in the CAF Digital Ecosystem Development Index (without the regulatory sub-index) in the same period and 0.0927 higher in the subsequent period, which, by adding both effects yields a total coefficient of 0.1892.

Considering that the two previous models tested the correlation between both indices, the model was specified through logarithms of all variables to assess change, and also a recalculated CAF Digital Ecosystem Development Index, without the regulatory and the competition pillars (since the potential with co-linearity with the ITU ICT Regulatory Tracker is high) (Table 10).

Table 10: Impact of lagged ITU ICT Regulatory Tracker on CAF Digital Ecosystem Development Index (Africa region)

Log CAF Digital Ecosystem Development Index (without the regulatory and competition pillars)	Coefficient (standard deviation) Africa
Log CAF Digital Ecosystem Development Index (without regulation and competition pillars) (t-1)	1.8825 (0.0656)***
Log ITU ICT Regulatory Tracker (t-1)	0.0682 (0.0185)***
Constant	0.4605 (0.0716) ***
R-Squared	0.7410
Fixed effects for year and country	Yes
Groups	43
Observations	430

Log CAF Digital Ecosystem Development Index (without the regulatory and competition pillars)	Coefficient (standard deviation) Africa
Years	2008-2017

***, **, * significant at 1%, 5% and 10% critical value respectively.

Under this case, it is possible to prove the hypothesis: an increase of 10 per cent in the ITU ICT Regulatory Tracker yields a positive increase in the CAF Digital Ecosystem Development Index of 0.682 per cent in the subsequent time period.

In order to further test the relationship between the regulatory and the digital ecosystem indices, a set of alternative correlations between pillars was run (Table 11).

Table 11: Correlations between ITU ICT Regulatory Tracker and CAF Digital Ecosystem Development Index pillars (Africa region)

Pillars	ITU ICT Regulatory Tracker	ITU ICT Regulatory Tracker (without Competition)	Regulatory authority component	Regulatory mandate component	Regulatory regime component	Competition framework component
CAF Digital Ecosystem Development Index	0.2626 (0.0285) ***	0.2514 (0.0295) ***	0.3996 (0.0606) ***	0.3014 (0.0333) ***	0.4067 (0.0266) ***	0.2793 (0.0298) ***
Infrastructure of Digital Services	0.2917 (0.0333) ***	0.2820 (0.0344) ***	0.4475 (0.0705) ***	0.3337 (0.0389) ***	0.4522 (0.0316) ***	0.3013 (0.0354) ***
Connectivity of Digital Services	0.4873 (0.0534) ***	0.4682 (0.0554) ***	**0.7325 (0.1135) *****	0.5224 (0.0632) ***	**0.7669 (0.0504) *****	0.5138 (0.0574) ***
Household digitization	0.3224 (0.0369) ***	0.3080 (0.0382) ***	0.4953 (0.0781) ***	0.3540 (0.0434) ***	0.5401 (0.0340) ***	0.3498 (0.0389) ***
Digitization of production	**0.6156 (0.0552) *****	0.5843 (0.0576) ***	**0.8814 (0.1197) *****	**0.6513 (0.0658) *****	**0.9513 (0.0479) *****	**0.6766 (0.0574) *****
Digital Competitive Intensity	0.2412 (0.0316) ***	0.2311 (0.0327) ***	0.3544 (0.0666) ***	0.2824 (0.0368) ***	0.3643 (0.0313) ***	0.2444 (0.0337) ***
Development of Digital Industries	-0.0282 (0.0220)	-0.0279 (0.0225)	-0.0019 (0.0447)	-0.0050 (0.0257)	0.0150 (0.0238)	-0.0249 (0.0235)
Digital factors of production	0.3430 (0.0321) ***	0.3252 (0.0334) ***	0.4690 (0.0695) ***	0.3904 (0.0376) ***	0.4489 (0.0309) ***	0.3616 (0.0333) ***

***, **, * significant at 1%, 5% and 10% critical value respectively.

Note: The values in bold have correlations higher than 0.60.

A second set of regressions shows that the regulatory regime component of the ITU ICT Regulatory Tracker appears to be the main path of impact of the CAF Digital Ecosystem Development Index (Table 12).

Table 12: Impact of the ITU ICT Regulatory Tracker components on the CAF Digital Ecosystem Development Index pillars (Africa region)

	CAF Digital Ecosystem Development Index	Infrastructure of Digital Services	Connectivity of Digital Services	Household digitization	Digitization of production	Digital Competitive Intensity	Development of Digital Industries	Digital factors of production
Regulatory authority component	-0.1421 (0.0712) **	-0.1322 (0.0850)	-0.0937 (0.1355)	-0.1330 (0.0914)	-0.1276 (0.1289)	-0.1660 (0.0838) **	-0.1681 (0.0633) ***	-0.1563 (0.0826) *
Regulatory mandate component	0.1086 (0.0733)	0.1041 (0.0875)	-0.0506 (0.1395)	0.0340 (0.0941)	-0.0420 (0.1326)	0.0982 (0.0863)	0.1103 (0.0652) *	0.1380 (0.0850)
Regulatory regime component	0.3998 (0.0368) ***	0.4453 (0.0439) ***	0.8041 (0.0700) ***	0.5576 (0.0472) ***	0.9898 (0.0666) ***	0.3653 (0.0433) ***	0.0162 (0.0327)	0.4306 (0.0427) ***
Constant	1.1568 (0.3011) ***	0.7248 (0.3596) **	0.1951 (0.5733)	0.5423 (0.3866)	-1.4876 (0.5451) ***	2.1015 (0.3546) ***	2.3231 (0.2681) ***	0.3390 (0.3495)
R-squared	0.3682	0.3344	0.3581	0.3810	0.4856	0.2538	0.0211	0.3412

***, **, * significant at 1%, 5% and 10% critical value respectively.

Table 12 indicates that the regulatory regime component always[12] has a positive and significant impact on every single pillar of the digital ecosystem development index[13]. This could indicate that the regulatory regime could be the component that has a higher impact on digital development[14] in the Africa region.

4 Conclusion

The purpose of this study was to test the findings of the ITU global study on the economic contribution of broadband and digitization as well as the impact of regulation and policy on the digital economy development to the Africa region.

An assessment of the research literature on broadband economic contribution in the Africa region provided some validation of the findings on the ITU global study. For example, a compilation of econometric studies on the economic contribution of fixed broadband did not find any positive effects (with only one exception in the last five years, Senegal), while mobile broadband appears to be consistently

12 The only exception is the Digital Industries Pillar, where both this regression and the correlations in Table 26 indicate that there is no relationship between regulation and this component.

13 The regulatory regime component includes indicators such as type of licences provided to offer telecommunication services, obligations to publish interconnection offers by operators, monitoring of quality of service, infrastructure sharing for mobile operators permitted and/or mandated, unbundled access in local loop, spectrum secondary trading allowed, and number portability.

14 While the first two components of the ITU ICT Regulatory Tracker sometimes give a negative sign, the coefficient of regulatory regime and regulatory mandate is always bigger and positive.

yielding growing benefits. Considering the evidence generated in the research literature and the global study that preceded this analysis, one could stipulate different types of effects for Africa:

- Impact of fixed broadband in the Africa region is as low as the impact estimated for low income countries in the global sample.
- Impact of mobile broadband in the Africa region is as high as the impact estimated for low income countries in the global sample.
- Impact of digitization in the Africa region is similar to low income countries, in the global sample.

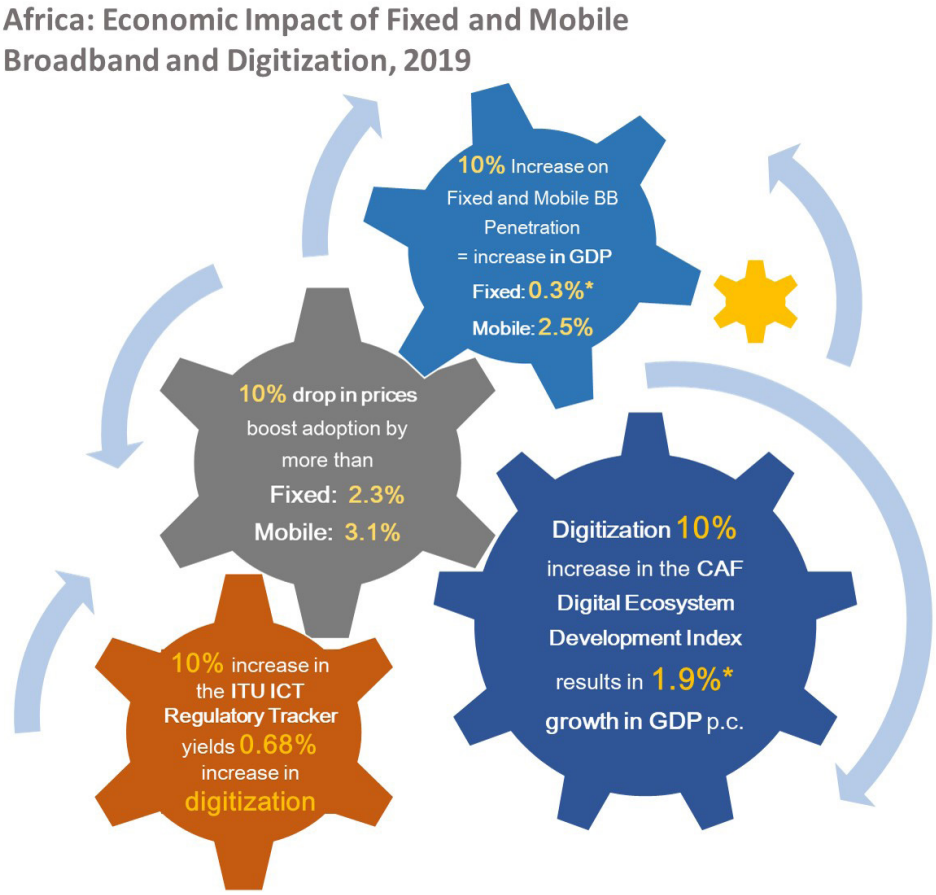
The evidence yielded by the econometric analysis confirms the hypotheses, however, the lack of statistical significance in the third hypothesis prevents a rigorous validation (Table 13).

Table 13: Summary of econometric model results (Africa region compared to other low income countries)

Hypothesis	10% increase impact on GDP per capita growth	
	Africa	Global study – low income countries
Economic impact of fixed broadband in Africa is as low as the impact estimated for low income countries in the global sample (Returns to Scale effect)	0.3 (not significant)	0.5 (not significant)
Economic Impact of mobile broadband in Africa is as high as the impact estimated for low income countries in the global sample (Saturation effect)	2.5	2.0
Economic Impact of digitization in Africa is lower than that calculated for the global sample (Returns to scale effect)	1.9 (not significant)	1.0 (non-OECD countries)

The main conclusions of the Africa region analyses are depicted in Figure 2.

Figure 2: Economic impact of fixed and mobile broadband and digitization 2019 (Africa)



Source: ITU

* While the coefficients in these models carry the correct positive signs, they are not statistically significant.

The impact of policy and regulatory frameworks on the development of digitization was also tested. In the case of the Africa region, the results also validated the positive impact of the policy and regulatory variable in the countries in the region. It was noted that an increase of 10 per cent in the ITU ICT Regulatory Tracker yields a positive increase in the CAF Digital Ecosystem Development Index of 0.682 per cent in the region.

A second set of regressions shows, again, that of all the components of the ITU ICT Regulatory Tracker, the regulatory regime component appears to be the main path of impact of the CAF Ecosystem Development Index. This analysis provided further evidence of the importance of the regulatory and institutional variable in driving the digital ecosystem growth.

Annex A: List of data sources for models testing the economic impact of fixed and mobile broadband

Indicator	Source
GDP per capita (PPP)	IMF
Fixed broadband subscriber penetration	ITU – OVUM
Capital – Gross capital formation (percentage of GDP)	World Bank
Education – School enrolment, tertiary (per cent gross)	World Bank
Fixed telephone subscribers	ITU
Rural population (per cent of total population)	World Bank
Fixed broadband price	ITU
HHI fixed broadband	OVUM
Fixed broadband revenue	ITU – OVUM
Mobile broadband unique subscribers penetration	GSMA
Mobile unique subscribers penetration	GSMA
Mobile Broadband Price/ARPU	ITU – GSMA
HHI mobile broadband	GSMA
Mobile broadband revenue	GSMA

Annex B: Indicators included in Digital Ecosystem Development Index and data sources

Pillar	Sub-pillar	Indicator	Source
Infrastructure	Investment	Telecommunications investment per capita in current prices – five year average (USD PPP)	World Bank; ITU
Infrastructure	Quality of service	Average fixed broadband download speed (Mbit/s)	Akamai
Infrastructure	Quality of service	Average mobile broadband download speed (Average Mbit/s)	Akamai
Infrastructure	Quality of service	Fixed broadband connections with download speed higher than 4 Mbit/s (percentage)	Akamai
Infrastructure	Quality of service	Fixed broadband connections with download speed higher than 10 Mbit/s (percentage)	Akamai
Infrastructure	Quality of service	Fixed broadband connections with download speed higher than 15 Mbit/s (percentage)	Akamai
Infrastructure	Quality of service	Fibre optic broadband connections as a percentage of total fixed broadband connections	ITU; FTTH; OECD
Infrastructure	Quality of service	International broadband bandwidth per Internet user (bit/s)	ITU
Infrastructure	Coverage	Fixed broadband coverage (% of households)	Eurostat, CAF Ideal; OECD
Infrastructure	Coverage	2G coverage	ITU
Infrastructure	Coverage	3G coverage	ITU
Infrastructure	Coverage	4G coverage	ITU
Infrastructure	Service infrastructure	IXPs per 1 000 000 population	Packet Clearing House; UNCTAD
Infrastructure	Service infrastructure	Number of secure servers (per 1,000,000 population)	World Bank
Infrastructure	Service infrastructure	Number of satellites (per 1 000 000 population)	N2yo.com
Connectivity	Affordability	Monthly fixed broadband subscription as percentage of GDP per capita	ITU
Connectivity	Affordability	Monthly mobile broadband Smartphone subscription (500 MB cap, prepaid) as percentage of GDP per capita	ITU
Connectivity	Affordability	Monthly mobile broadband PC subscription (1 GB cap, postpaid) as percentage of GDP per capita	ITU
Connectivity	Affordability	Monthly pay TV subscription as percentage of GDP per capita	Business Bureau; CAF; PwC; TAS

Pillar	Sub-pillar	Indicator	Source
Connectivity	Penetration	Fixed broadband penetration (connections per 100 households)	ITU
Connectivity	Penetration	Mobile broadband penetration (connections per 100 population)	ITU
Connectivity	Penetration	Unique mobile broadband users (per 100 population)	GSMA
Connectivity	Penetration	Pay TV penetration (connections per 100 households)	Business Bureau; CAF; PwC; TAS; ITU; Convergencia
Connectivity	Ownership	Penetration of computers (% of households)	ITU
Connectivity	Ownership	Smartphone users (per 100 population)	GSMA
Connectivity	Ownership	Percentage of population with access to electric energy	World Bank
Household digitization	Internet use	Percentage of population using the Internet	ITU
Household digitization	Internet use	Penetration of dominant social network (users per 100 population)	OWLOO
Household digitization	Internet use	Mobile data ARPU as percentage of total ARPU	GSMA
Household digitization	E-government	E-government index	ONU
Household digitization	E-commerce	Internet commerce as percentage of total retail commerce	Euromonitor
Household digitization	Telemedicine	National health policy (binary variables)	WHO
Household digitization	OTTs	Video on demand penetration (per cent households)	PWC
Digitization of production	Digital infrastructure	Per cent enterprises with Internet access	UNCTADstat; TAS; Eurostats
Digitization of production	Digital supply chain	Per cent enterprises using Internet for electronic banking	UNCTADstat; TAS; Eurostats
Digitization of production	Digital supply chain	Per cent enterprises using Internet for purchasing inputs	UNCTADstat; TAS; Eurostats
Digitization of production	Digital distribution	Per cent enterprises that sell products over the Internet	UNCTADstat; TAS; Eurostats
Digitization of production	Digital processing	Per cent workforce using the Internet	UNCTADstat; TAS; Eurostats
Digitization of production	Digital processing	Per cent workforce using computers	UNCTADstat; TAS; Eurostats

Pillar	Sub-pillar	Indicator	Source
Competitive intensity	Competition level	HHI fixed broadband	Convergencia; Regulators; TAS
Competitive intensity	Competition level	HHI mobile broadband	GSMA; Regulators
Competitive intensity	Competition level	HHI pay TV	Convergencia; Dataxis; Ofcom; TAS; Reguladores
Competitive intensity	Competition level	HHI mobile telephony	GSMA; Regulators
Digital industries	Exports	High technology exports (USD per capita in current prices)	World Bank
Digital industries	Exports	ICT services exports (USD per capita in current prices)	World Bank
Digital industries	Weight of digital industries	Digital ecosystem sales as a percentage of GDP	PWC; TAS; ITU
Digital industries	Weight of digital industries	Telecommunications operators revenues per capita (USD in current prices)	ITU
Digital industries	Weight of digital industries	Computer software spending (per cent of GDP)	INSEAD
Digital industries	Internet of Things	M2M connections (per 100 population)	ITU; OECD
Digital industries	Content production	Wikipedia pages edited per month (per million population between 15 and 69 years old)	INSEAD
Factors of digital production	Human capital	Education years expectancy (years)	World Bank; UNESCO
Factors of digital production	Human capital	Tertiary school enrollment (per cent population)	World Bank; UNESCO
Factors of digital production	Schools	Per cent educational establishments with Internet access	UNESCO; CEPAL
Factors of digital production	Schools	Computers per students ratio	UNESCO; CEPAL
Factors of digital production	Innovation	USPTO patents per country (per 1 000 000 population)	USPTO
Factors of digital production	Innovation	Intellectual property revenues (USD per capita PPA in current prices)	World Bank
Factors of digital production	Investment in innovation	R&D spending (per cent of GDP)	World Bank; UNESCO
Factors of digital production	Economic development	GDP per capita (USD current prices)	IMF
Factors of digital production	Economic development	Electric energy consumption (kWh per capita)	World Bank

Pillar	Sub-pillar	Indicator	Source
Institutional and regulatory	Cyber-security and piracy	Per cent of non-licensed installed software	BSA, The software alliance
Institutional and regulatory	Cyber-security and piracy	Commercial value of non-licensed software (as per cent of GDP)	BSA, The software alliance
Institutional and regulatory	Government role	Per cent of regulatory agency attributions based on ITU regulatory tracker	ITU; TAS
Institutional and regulatory	Government role	Per cent of regulatory agency functions based on ITU regulatory tracker	ITU; TAS
–	–	Population	World Bank
–	–	Exchange rate PPP	IMF
–	–	Number of households	ITU
–	–	GDP per capita for first quintile (USD in current prices)	IMF; World Mundial

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