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Economic contribution of broadband, digitization and ICT regulation

Econometric modelling for the ITU Commonwealth of Independent States region

Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the ITU Commonwealth of Independent States region

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This report has been prepared by International Telecommunication Union (ITU) experts Raul Katz, and Fernando Callorda under the direction of the ITU Telecommunication Development Bureau (BDT) Regulatory and Market Environment Division (RME).

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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 global study on the economic contribution of broadband, digitization and information and communication technology (ICT) regulation provided a global econometric analysis of robust and reliable data resources to measure the economic impact of fixed and mobile broadband as well as digitization. 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 economic impact of these technologies on a worldwide scale, 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 the ITU Commonwealth of Independent States (CIS) region. It also provides evidence of the importance of regulatory and institutional variables in driving digital growth. It illustrates that broadband technologies and effective ICT regulation can have a positive impact on the growth of national economies and prosperity.

As an example, this ITU report suggests that an increase of 10 per cent in mobile broadband penetration in the Commonwealth of Independent States would yield an increase in 1.25 per cent in GDP per capita; furthermore, an increase of 10 per cent in fixed broadband penetration would yield an increase in 0.63 per cent in GDP per capita. Importantly, the impact of policy and regulatory frameworks on the development of digitization was also tested for CIS region countries. The report validates the positive impact of the policy and regulatory component in the countries in the CIS region as well, suggesting 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 1.58 per cent.

I am delighted to present this ever-growing research for the Commonwealth of Independent States region to assist membership in designing smart and sustainable policies and strategies to reap the benefits of the dynamic and exciting broadband and digital transformation ecosystem.

Doreen Bogdan-Martin
Director, ITU Telecommunication Development Bureau

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1 Introduction

The *Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the ITU Commonwealth of Independent States region* 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 following countries: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Turkmenistan, Uzbekistan, Tajikistan. A summary of the econometric methodology applied is presented in annex C.

This report 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 of the CIS region.

This report also reflects the findings of the ITU 2018 global study[1] on the economic contribution of broadband, digitization, and ICT regulation, which was based on a large set of sample of countries, and showed four effects for countries based on the level of development:

1. Fixed broadband economic impact is guided by a *return to scale* effect[2], according to which the economic impact of fixed broadband is greater in high-income countries than in low-income country nations.
2. The economic impact of mobile broadband reflects a *saturation* effect, according to which the mobile broadband contribution to the economy is higher in low-income country economies than in mid- and high-income country economies, where mobile has reached almost complete adoption.
3. The impact of digitization is higher in advanced economies than in developing countries.
4. The regulatory and policy framework has a consistent impact on the development of the digital ecosystem, regardless of the level of development or income of a given country.

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

1. Which technologies should become a policy priority in terms of adoption?
2. How to ensure that, beyond broadband adoption, policies further develop the digital ecosystem?

The conclusions generated by the global study prompted calls to conduct studies that delve deeper into these effects, focusing on specific regions of the world[3]. By applying the same methodologies and models used for assessing global effects, this report focuses on the CIS countries. It is complemented by studies assessing these effects in other regions of the world[4].

Section 2 summarizes the results of the ITU 2018 global study while section 3 presents the results of the analyses for the CIS region countries.

[1] *The economic contribution of broadband, digitization and ICT regulation*. https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf

[2] Generally, the returns to scale effect refers to a reduction in unit cost 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, states that according to the returns to scale theory, the economic impact of broadband increases exponentially with the penetration of the technology. https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf

[3] Regional Studies on the Economic contribution of broadband, digitization and ICT: Econometric modelling for Africa, the Americas, Arab States, Asia-Pacific and Europe. See https://www.itu.int/pub/D-PREF-EF/en.

[4] See https://www.itu.int/pub/D-PREF-EF.

2 The effects identified in the ITU 2018 global study

This section presents the types of analyses and methodologies, and the results presented in the ITU 2018 global study.

The ITU 2018 global study tested three effects:

- The economic contribution of fixed and mobile broadband.
- The economic contribution of digitization (a variable that subsumes broadband technology within a larger set of digital ecosystem components)[5].
- The impact of the policy and regulatory frameworks on the growth of markets for digital services and applications.

The findings for each of the analyses is presented in order to provide the context within which the models for the CIS region countries are specified.

2.1 Economic impact of fixed broadband

A structural econometric model composed of four equations[6] that was developed for the ITU global study cited above was able to generate evidence of the economic impact of fixed broadband between 2010 and 2017. First, 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. Second, the sample was split between high-, medium-, and low-income countries to test with the same model whether the impact of fixed broadband increased or decreased depending on the level of economic development. The results supported the hypothesis that the economic contribution of fixed broadband increases with economic development:

- <u>Higher income countries</u> (Countries with GDP per capita higher than USD 22 000): 10 per cent increase in broadband penetration yields 1.4 per cent increase in GDP growth.
- <u>Middle income countries</u> (Countries with GDP per capita between USD 12 000 and USD 22 000): 10 per cent increase in broadband penetration yields 0.5 per cent increase in GDP growth.
- <u>Low income countries</u> (Countries with GDP per capita lower than USD 12 000): while the coefficient of fixed broadband impact was similar to the middle impact countries, it was not statistically significant.

2.2 Economic impact of mobile broadband

The ITU 2018 global study also showed that mobile broadband has a higher impact than fixed broadband on the world economy. Relying on a structural model run for a 139 country sample (general mobile broadband model), it was estimated that on average an increase of 10 per cent in mobile broadband penetration yielded an increase of 1.5 per cent in GDP. However, using the same three data sets (high-, medium-, and low-income countries) to test the economic impact of mobile broadband showed that the level of economic contribution of mobile broadband is higher in low-income countries than in high-income countries, where it had no impact:

- <u>high-income countries</u>: no economic impact was detected;
- <u>middle-income countries</u>: an increase of 10 per cent in mobile broadband penetration yielded an increase in 1.8 per cent in GDP;

[5] Digitization development is measured by the CAF Index of Development of Digital Eco-system (see indicators that are part of this index in Appendix B) and calculation method in Katz and Callorda, 2018a

[6] Detailed description of models and methodologies can be found in the ITU 2018 global study cited in footnote 1.

- low-income countries: an increase of 10 per cent in mobile broadband penetration yielded an increase in 2 per cent in GDP.

This difference reflects the high levels of access to fixed broadband in high-income countries, while mobile network access to broadband is the only technology available to the majority of consumers in low-income countries. Consequently, the mobile broadband contribution to high-income economies is only marginal and the impact of mobile broadband in low-income countries is extremely important.

2.3 Economic impact of digitization

The ITU 2018 global study tested the economic impact of digitization using an endogenous growth model that linked GDP to the fixed stock of capital, labour force, and the CAF Digital Ecosystem Development Index[7] (see section 3.5). The approach followed in this case tested the economic contribution for a sample of 73 countries worldwide (the general digitization model) and then split the results into two sets of countries: those within the Organization for Economic Co-operation and Development (OECD)[8] 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 OECD and non-OECD countries, economic impact was higher in the OECD countries relative to non-OECD nations:

- 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.

2.4 Impact of policy and regulatory framework on digitization development

In the ITU 2018 global study, 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[9] and a year lag of the same variable for control purposes.[10] 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 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 2018 global study, section 3 below focuses on validating the results for the CIS region, starting with a brief review of the research literature on economic contribution of broadband in the region.

[7] Digital Ecosystem Development Index developed by the CAF (Corporación Andina de Fomento) Development Bank for Latin America

[8] Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Republic of Korea, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.

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

[10] The year lag is the same variable (the ICT Regulatory Tracker Index) but included for a year before (t-1); this is done to isolate the effect of regulation in past years.

3 The economic contribution of broadband, digitization, and the impact of policy on digitization in the Commonwealth of Independent States region

This section analyses broadband and digitization economic contribution for nine countries in the CIS region: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Tajikistan, Turkmenistan, Uzbekistan.

3.1 Review of the research literature

Research on the economic impact of broadband in the CIS region is generally descriptive and correlational in nature. For example, Rosotto et al. (2015) provided an in-depth assessment of the state of broadband development in the Russian Federation and, based on the correlation between fixed broadband penetration and competitiveness, developed a set of recommendations to accelerate the deployment of the technology in the country. This conclusion is also endorsed by Trunikov (2019), although his focus was more on the conditions under which economic impact can be maximised rather than providing an estimate of economic impact. Endorsing the importance of broadband development for promoting economic growth, Petukhova et al. (2012) emphasized the need to address regional telecommunications development disparities in the Russian Federation.

Along those lines, Katz (2017) conducted an assessment of the development of broadband in Kazakhstan. Yet, again this study did not provide an estimation of the economic impact of broadband in this country. On the other hand, the study validated, based on qualitative evidence, the importance of the regulatory variable (in particular, Kazakhstan telecommunications competition model) in increasing broadband affordability and improving infrastructure deployment. A technical paper developed by the UNESCAP (2016) also provided a correlation-based validation of the importance of quality of regulation in driving fixed broadband adoption in Asia, including the CIS region in its analysis. Similarly, in its study of Afghanistan, Armenia, Georgia, Kazakhstan, the Kyrgyz Republic, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan, Lovelock (2015) stipulated that public polices can play an influential role in stimulating broadband Internet demand and supply.

More recently, the GSMA (2019) published a paper that provides a view of the economic impact not only of wireless broadband, but the whole mobile industry in the Russian Federation and other CIS region countries. The authors structured the economic contribution of the industry to GDP in terms direct effects (that is to say, the revenues of mobile operators), ecosystem and indirect effects (which include the enterprises that either provide inputs to mobile operators or offer products that depend on mobile networks, such as apps), and productivity gains (which is strictly speaking the spill overs of the mobile industry on the rest of the economy). Unfortunately, the paper does not provide the methodology that led to estimate total contribution to GDP of USD 101 billion and the creation of 620 000 jobs.

3.2 Hypotheses

In formulating the study hypotheses, it is important to consider first and foremost that the group of countries under the CIS region country category includes nations in different geographies with different levels of economic development, socio-economic contexts and market dynamics:

- upper middle-income countries, such as Azerbaijan, Belarus, Kazakhstan, Russian Federation, and Turkmenistan;
- lower middle-income countries, such as Armenia, Kyrgyz Republic, Tajikistan, and Uzbekistan.

Based on this, and considering the evidence generated in the ITU 2018 global study that preceded this analysis, the following broadband and digitization effects for this group of nations are stipulated:

- The impact of fixed broadband in the CIS region is expected to fall between the contribution of low-income and high-income countries as measured in the global sample.
- The impact of mobile broadband in the same region should fall between the contribution of low-income and high-income countries as estimated in the global sample.
- A similar prorated effect would be expected in the case of the economic contribution of digitization.

3.3 Economic contribution of fixed broadband in the CIS region

The estimation of the economic contribution of fixed broadband in the CIS region relied on the same structural model used in the ITU 2018 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 of demand, supply and output.

Data

To test the hypothesis of fixed broadband economic impact presented above, a database of the countries mentioned above was built, containing time series for all the required variables between 2004 and 2018. The data sources are the International Telecommunications Union, the World Bank, IMF, and Ovum (see annex A for data sources).

Model results and discussion

The model used to test the effect of fixed broadband was similar to the one used for the global study, except that a variable representing the change in the price of oil was added for control purposes. The results, run for eight CIS region countries[11], are as follows (see Table 1).

Table 1: Economic impact of fixed broadband, 2004-2018 (CIS region)

GDP per capita	
Fixed broadband subscriber penetration	0.06281 ***
Capital	0.14401 ***
Education	-0.88024 ***
Oil	-0.03771
Fixed broadband subscriber penetration	
Fixed telephone subscribers	2.62383 ***
Rural population	2.44438 ***
GDP per capita	0.23633 **
Fixed broadband price	-1.42759 ***
HHI fixed broadband	-0.76650 ***

[11] Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Turkmenistan, Uzbekistan. Tajikistan was not included because of lack of information about the level of competitive intensity (required to calculate the HHI index) for fixed broadband.

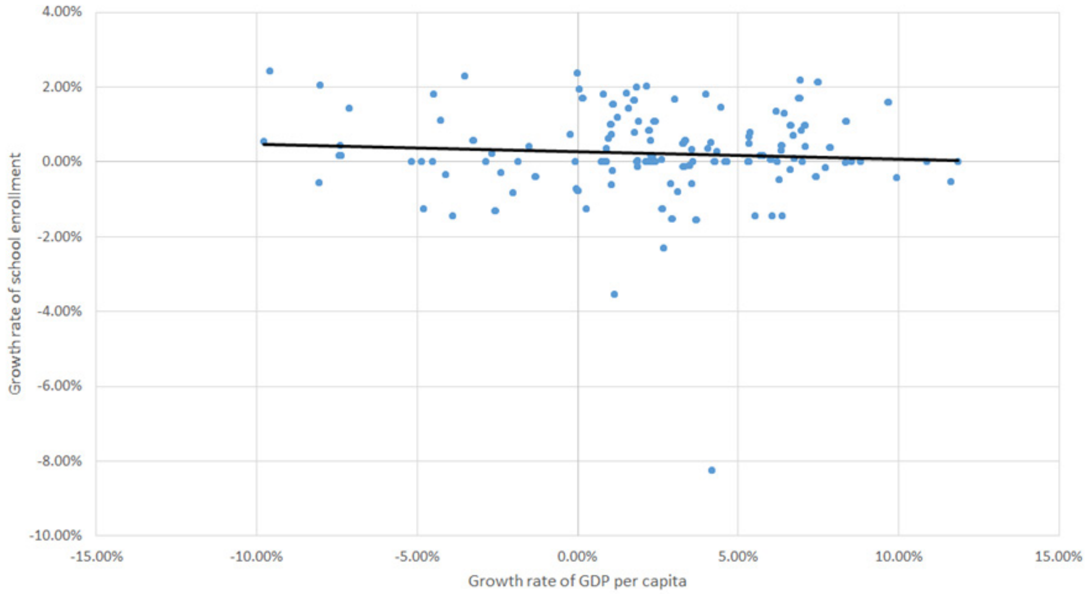
Revenue fixed broadband	
GDP per capita	1.08311 ***
Fixed broadband price	-0.76246 ***
HHI fixed broadband	-0.86594 ***
Fixed broadband adoption growth	
Revenue fixed broadband	-2.32242***
Observations	413
Number of countries	8
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2004-2018
R-Squared first model	0.9875

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

As detailed in the hypotheses above, fixed broadband has had a moderate economic contribution in the CIS region countries during the last fourteen years (2004-2018). An increase of 10 per cent in fixed broadband penetration yields an increase in 0.63 per cent in GDP per capita. Additionally, as indicated in the first equation, capital formation has a positive and statistically significant impact on GDP growth.

The negative and statistically significant coefficient for the education variable, implying that education is negative related to GDP, warrants further analysis. This issue appears to be specific to the CIS region. Figure 1 depicts the correlation between the growth rate of GDP per capita and the growth rate of school enrolment.

Figure 1: Correlation between GDP growth and school enrolment growth (2004-2018)



Source: Telecom Advisory Services analysis

One explanation could be that, since the impact of education on GDP is valid over the long term, a model specified with data between 2004 and 2018 does not capture this effect. Additionally, it could be argued that, in periods of economic recession, characterized by slow or negative GDP growth, the population emphasizes gaining access to additional education in order to be better prepared to find employment.

Consistent with the results of the global model, and reflecting the composition of CIS region countries, results for fixed broadband economic contribution are higher than the impact for low Income countries in the global sample (0.63 vs 0.54) (see Table 2).

Table 2: Economic impact of fixed broadband for low income countries (CIS region compared to global model results)

	Global study Low income countries	CIS region
GDP per capita		
Fixed broadband subscriber penetration	0.05461	0.06281 ***
Capital	0.21024 ***	0.14401 ***
Education	0.15569 ***	-0.88024 ***
Oil		-0.03771
Fixed broadband subscriber penetration		
Fixed telephone subscribers	0.49262 ***	2.62383 ***
Rural population	-0.81927 ***	2.44438 ***
GDP per capita	0.53821 ***	0.23633 **
Fixed broadband price	-0.30159 ***	-1.42759 ***
HHI Fixed broadband	-0.38882 ***	-0.76650 ***
Fixed broadband revenue		
GDP per capita	1.24272***	1.08311 ***
Fixed broadband price	0.14314 ***	-0.76246 ***
HHI Fixed broadband	-0.71760 ***	-0.86594 ***
Fixed broadband adoption growth		
Fixed broadband revenue	-0.74656 ***	-2.32242***
Observations	1,724	413
Number of countries	63	8
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2017	2004-2018
R-Squared first model	0.9831	0.9875

***, **, * 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.

3.4 Economic contribution of mobile broadband in the CIS region

The structural model that was 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.

Data

To test the hypothesis of mobile broadband economic impact presented above, a database was built for the following countries: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan. As indicated before, the database contains time series for all the required variables between 2010 and 2018. The data sources are the International Telecommunications Union, the International Monetary Fund (IMF), the World Bank, and the GSMA (see annex A for data sources).

Model results and discussion

The model relied upon was similar to the one used for the global study, except that, again, a variable representing the change in the price of oil was added for control purposes. The model was run for all nine countries, and yields statistically significant results, confirming the effects identified in the ITU 2019 global study (see Table 3).

Table 3: Economic impact of mobile broadband

GDP per capita	
Mobile broadband unique subscriber penetration	0.12504 **
Capital	0.08872
Education	-0.61427 ***
Oil	0.02888
Mobile broadband unique subscriber penetration	
Mobile unique subscriber penetration	1.76983 ***
Rural population	-0.31325 ***
GDP per capita	-0.16062 ***
Mobile broadband price	0.54283 ***
HHI Mobile broadband	-0.81111 ***
Revenue Mobile broadband	
GDP per capita	0.74983 ***
Mobile broadband price	1.10378 ***
HHI Mobile broadband	-3.98438 ***
Mobile broadband adoption growth	
Revenue mobile broadband	-0.24348

Observations	309
Number of countries	9
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2010-2018
R-Squared first model	0.9856

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

According to the mobile broadband model in Table 3, an increase of 10 per cent in mobile broadband penetration yields an increase in 1.25 per cent in GDP per capita, which means that this technology has had a significant economic impact in the CIS region during the last nine years (2010-2018). However, the coefficient is lower than the one estimated for low-income countries in the global study (see Table 4).

Table 4: Economic impact of mobile broadband (CIS region compared to global model)

	Global study Low-income countries	CIS region
GDP per capita		
Mobile broadband unique subscriber penetration	0.19752 ***	0.12504 **
Capital	0.23190 ***	0.08872
Education	0.12406 ***	-0.61427 ***
Oil		0.02888
Mobile broadband unique subscriber penetration		
Mobile unique subscriber penetration	1.63963 ***	1.76983 ***
Rural population	-0.08433 ***	-0.31325 ***
GDP per capita	0.04384 **	-0.16062 ***
Mobile broadband price	-0.13139 ***	0.54283 ***
HHI mobile broadband	-0.27510 ***	-0.81111 ***
Revenue mobile broadband		
GDP per capita	0.97739 ***	0.74983 ***
Mobile broadband price	-0.47023 ***	1.10378 ***
HHI mobile broadband	-1.65927 ***	-3.98438 ***
Mobile broadband adoption growth		
Revenue mobile broadband	-1.11108 ***	-0.24348
Observations	1,689	309
Number of countries	63	9

	Global study Low-income countries	CIS region
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2017	2010-2018
R-Squared first model	0.9799	0.9856

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

The fixed and mobile broadband model results indicate that the CIS region is, as anticipated in the hypotheses, in an intermediate position between high-income and low-income countries. This is the reason why both technologies have a positive, but moderate, contribution to GDP growth in the CIS countries.

3.5 Economic contribution of digitization in the CIS region

The economic contribution of digitization in the CIS region was tested relying on the CAF Digital Ecosystem Development Index. This Index can be applied to measure all countries around the world in terms of the development of their digital economy. Along the lines of what was discussed in section 3.3, the returns to scale hypothesis to be tested is whether the economic contribution of digitization is higher in the CIS region than that of less developed economies.

Data

The CAF Digital Ecosystem Development Index was calculated for Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan.

Model results and discussion

The model was first run for nine countries[12] for the period 2010-2018, which resulted in 81 observations, and included fixed effects by year. It is important to highlight that the model included independent variables for fixed capital formation, GDP per capita, the price of oil and the education index (source: United Nations Development Programme), as a proxy for labour quality (see Table 5).

Table 5: Economic impact of digitization, 2010-2018

Variable	Coefficients
Previous GDP	0.6132 *** (0.0571)
Digitization	0.2074 ** (0.0967)
Capital	-0.0925 (0.0943)
Labour	-1.2687 (0.8525)
Oil price	0.2795 *** (0.0437)

12 Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan.

Variable	Coefficients
Constant	1.2168 (0.7672)
Observations	81
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 2.07 per cent growth in GDP per capita. Therefore, an increase in the Digital Ecosystem Development Index from 50 to 51 will yield an increase of per capita GDP of 0.41 per cent (accounting both for direct and indirect effects on output).

The results from the CIS region model are higher than those of the impact of the non-OECD country model developed in the ITU 2018 global study (see Table 6).

Table 6: Economic impact of digitization, 2017 (CIS region compared to non-OECD countries)

Variable	CIS region	Non-OECD
Previous GDP	0.6132 *** (0.0571)	0.7279 *** (0.0294)
Digitization	0.2074 ** (0.0967)	0.1044 * (0.0592)
Capital	-0.0925 (0.0943)	0.0471 * (0.0279)
Labour	-1.2687 (0.8525)	0.0581 (0.0544)
Oil price	0.2795 *** (0.0437)	-
Constant	1.2168 (0.7672)	1.6827 *** (0.2821)
Observations	81	429
Year fixed effects	Yes	Yes

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

It should be pointed out that this result is not as robust as that developed for the ITU 2018 global study sample because of the reduced number of observations.

3.6 Impact of policy and regulatory framework on digitization in the CIS region

The following analysis was based on a model similar to the one used in the ITU 2018 global study to test the impact of the ITU ICT Regulatory Tracker on the CAF Digital Ecosystem Development Index.

Data

The models in this case relied on the ITU ICT Regulatory Tracker and the CAF Digital Ecosystem Development Index for the period between 2007 and 2018 for Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan. As indicated in the ITU 2018 global study, the CAF Digital Ecosystem Development Index includes an institutional and regulatory pillar, which had to be excluded in order to avoid co-linearity[13]. Once this was done and the index was recalculated, it was possible to test the impact of the ITU ICT Regulatory Tracker on digitization.

Model results and discussion

As in the prior section, a correlational analysis between both indices was initially run, with results presented in Table 7.

Table 7: Correlation between the ITU ICT Regulatory Tracker and the CAF Digital Ecosystem Development Index (CIS region)

CAF Digital Ecosystem Development Index (without the regulatory pillar)	Coefficient (standard deviation) CIS region
ITU ICT Regulatory Tracker	0.72845 (0.05002) ***
Constant	2.21834 (1.79873)
R-square	0.6839
Fixed effects for year and country	Yes
Countries	9
Observations	108
Years	2007-2018

***, **, * 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 also added (see table 8).

Table 8: Impact of the lagged ITU ICT Regulatory Tracker on the CAF Digital Ecosystem Development Index (CIS region)

CAF Digital Ecosystem Development Index (without the regulatory sub-index)	Coefficient (Standard deviation) CIS region
ICT Regulatory Tracker (t)	0.37315 (0.10664) ***
ICT Regulatory Tracker (t-1)	0.38166 (0.11059) ***

13 The CAF Digital Ecosystem Development Index comprises eight pillars, of which one measures the development of Institutional and Regulatory Framework in a given country (see Katz and Callorda, 2018a). If this last pillar were to be included in the measurement of the Index, it would be impossible to measure the effect of the ITU ICT Regulatory Tracker on digitization, because of the high level of correlation between two variables that measure approximately the same phenomenon (a condition known as collinearity).

CAF Digital Ecosystem Development Index (without the regulatory sub-index)	Coefficient (Standard deviation) CIS region
Constant	2.38742 (1.83932)
R-squared	0.7090
Fixed effects for year and country	Yes
Groups	9
Observations	99
Years	2008-2018

***, **, * 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 0.37315 points higher in the CAF Digital Ecosystem Development Index (without the regulatory sub-index) in the same period and 0.38166 higher in the subsequent period, which, by adding both effects yields a total coefficient of 0.75481.

Considering that the two previous models tested the correlation between both indices, the model was also run through logarithms of all variables to assess the rate of change. As before, the CAF Digital Ecosystem Development Index was also recalculated without the regulatory and the competition pillars (since, as indicated above, the potential co-linearity with the ITU ICT Regulatory Tracker is high) (see Table 9).

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

Log CAF Digital Ecosystem Development Index (without the regulatory and competition pillars)	Coefficient (Standard deviation) CIS region
Log CAF Digital Ecosystem Development Index (without regulation and competition pillars) (t-1)	2.33198 (0.07462) ***
Log ICT Regulatory Tracker (t-1)	0.15835 (0.03577) ***
Constant	0.10743 (0.08867)
R-Squared	0.9593
Fixed effects for year and country	Yes
Groups	9
Observations	99
Years	2008-2018

***, **, * 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 1.58 per cent in the subsequent time period. On a comparative basis, the effect of policy on digitization, as depicted by the model above is higher than that one detected in other regions. This could be due to the fact that the ITU ICT Regulatory Tracker Indices for Kazakhstan, Russian Federation, Tajikistan, Turkmenistan, and Uzbekistan do not cover all pillars due to some missing data.

In order to further test the relationship between the regulatory and the digital ecosystem indices, a set of alternative regressions between pillars of both indices was run (see Table 10).

Table 10: Regression between ITU ICT Regulatory Tracker and CAF Digital Ecosystem Development Index pillars (CIS region)

Pillars	ICT Regulatory Tracker	ICT Regulatory Tracker (without Competition)	Regulatory authority component	Regulatory mandate component	Regulatory regime component	Competition framework component
CAF Digital Ecosystem Development Index	**0.8954** **(0.2208)** ***	**0.9291** **(0.1000)** ***	0.3188 (0.1300) ***	**1.2908** **(0.1480)** ***	0.5684 (0.0545) ***	0.5687 (0.1270) ***
Infrastructure of Digital Services	**1.2278** **(0.1134)** ***	**1.2826** **(0.1186)** ***	0.5744 (0.1683) ***	**1.7667** **(0.1789)** ***	**0.6940** **(0.0709)** ***	**0.8619** **(0.1558)** ***
Connectivity of Digital Services	**1.0449** **(0.1176)** ***	**1.0806** **(0.1240)** ***	0.3228 (0.1534) **	**1.4916** **(0.1838)** ***	**0.6606** **(0.0666)** ***	**0.6527** **(0.1544)** ***
Household digitization	**1.2396** **(0.1416)** ***	**1.2763** **(0.1498)** ***	0.4596 (0.1877) **	**1.6167** **(0.2327)** ***	**0.7869** **(0.0792)** ***	**0.8079** **(0.1835)** ***
Digitization of production	0.5708 (0.0903) ***	0.5405 (0.0978) ***	0.0690 (0.0767)	**0.9014** **(0.1330)** ***	0.4244 (0.0563) ***	0.2567 (0.1109) **
Digital Competitive Intensity	**0.6189** **(0.0749)** ***	**0.6611** **(0.0771)** ***	0.2062 (0.1003) **	**1.0050** **(0.1060)** ***	0.3140 (0.0491) ***	0.3785 (0.0964) ***
Development of Digital Industries	**1.0340** **(0.1285)** ***	**1.0534** **(0.1365)** ***	0.5354 (0.1700) ***	**1.4229** **(0.2033)** ***	**0.6904** **(0.0748)** ***	**0.7284** **(0.1598)** ***
Digital factors of production	**0.9146** **(0.1320)** ***	**0.9727** **(0.1368)** ***	0.2050 (0.1633)	**1.3841** **(0.1979)** ***	0.5864 (0.0750) ***	0.5532 (0.1618) ***

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

NOTE: The values in bold have a relationship higher than 0.60. All the regression models include fixed effects by country and year.

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 (see Table 11).

Table 11: Impact of the ITU ICT Regulatory Tracker components on the CAF Digital Ecosystem Development Index pillars (CIS 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	-0.1092 (0.0907)	0.0451 (0.1239)	-0.1771 (0.1072)	-0.1580 (0.1307)	-0.0940 (0.0719)	-0.0588 (0.0843)	0.0718 (0.1388)	-0.3089 (0.1238) **
Regulatory mandate component	0.5783 (0.1851) ***	0.9712 (0.2527) ***	0.5742 (0.2188) **	0.6793 (0.2666) **	0.2285 (0.1466)	0.5466 (0.1720) ***	0.7872 (0.2833) ***	0.4756 (0.2525) *
Regulatory regime component	0.4484 (0.0718) ***	0.4507 (0.0980) ***	0.5372 (0.0849) ***	0.6892 (0.1034) ***	0.2274 (0.0569) ***	0.1455 (0.0667) **	0.5370 (0.1099) ***	0.5495 (0.0980) ***
Constant	1.2960 (0.3914) ***	-0.0231 (0.5343)	1.8622 (0.4626) ***	0.5282 (0.5638)	2.2550 (0.3100) ***	2.1954 (0.3637) ***	-0.4016 (0.5990)	1.5541 (0.5339) ***
R-squared	0.6227	0.5890	0.5993	0.6214	0.3619	0.3382	0.5551	0.5047

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

Table 11 indicates that the regulatory regime component and the regulatory mandate component always[14] has a positive and significant impact on every single pillar of the digital ecosystem development index[15]. This could indicate that the regulatory regime and the regulatory mandate could be the components that have a higher impact on digital development[16] in the CIS region.

4 Conclusion

The purpose of this study was to test the findings of the ITU 2018 global study on the economic contribution of broadband and digitization as well as the impact of regulation and policy on the digital economy development of countries in the CIS region.

An assessment of the research literature on broadband economic contribution in the CIS region, as indicated in section 3.1, provided some limited validation of the findings on the ITU 2018 global study. Considering the evidence generated in the global study that preceded this analysis, three different types of effects for the CIS region were stipulated:

- The impact of fixed broadband in the CIS region is expected to be somewhat in the middle of the contribution between low-income and high-income countries as measured in the global sample.

[14] The only exception is the digital competitive intensity for the regulatory regime component, and development of digital industries for the regulatory mandate component.

[15] The regulatory regime component includes indicators such as types of licence 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.

[16] While the first component of the ITU ICT Regulatory Tracker has sometimes a negative sign, the coefficient of regulatory regime and regulatory mandate is always bigger and positive.

- Similarly, the impact of mobile broadband in the CIS region should be somewhat in the middle of the contribution between low-income and high-income countries as estimated in the global sample.
- A comparable prorated effect would be expected in the case of digitization in the CIS region.

The evidence yielded by the econometric analysis confirms the hypotheses, although the reduced number of observations in the digitization economic model reduces the model robustness (see Table 12).

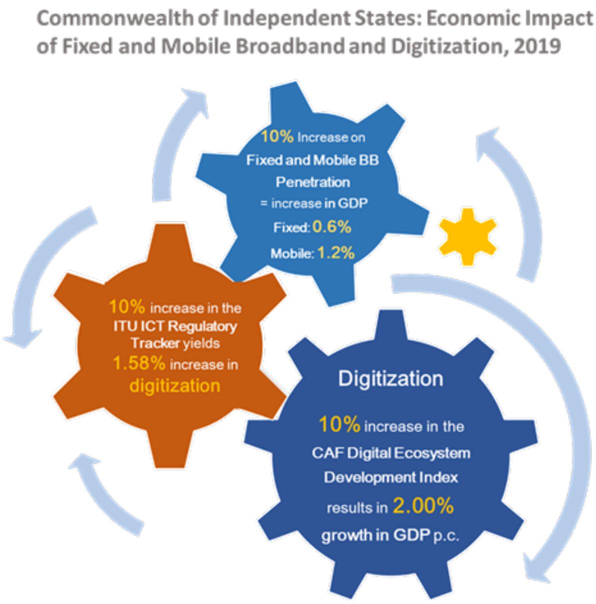
Table 12: Summary of results of econometric models (CIS region compared to low-income countries)

Hypothesis	10% increase impact on GDP per capita growth	
	CIS region	Global study Low-income countries
Economic impact of fixed broadband in the CIS region is higher than the impact estimated for low income countries in the global sample **(return to scale effect)**	0.6	0.5 (not significant)
Economic impact of mobile broadband in the CIS region is lower than the impact estimated for low income countries in the global sample **(saturation effect)**	1.3	2.0
Economic Impact of digitization in the CIS region is higher than that calculated for the global sample **(return to scale effect)**	2.1	1.0 (non-OECD countries)

In summary, the coefficient of economic impact of fixed broadband for countries in the CIS region (0.6) is higher than low-Income countries (0.5) but lower than high-income countries (1.4). The coefficient of economic impact of mobile broadband for the same geopolitical unit (1.3) is lower than that of low-income countries (2.0) but positive and statistically significant relative to high-income countries. Similarly, the impact of digitization for countries in the CIS region is higher than non-OECD countries.

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

Figure 2: Main findings for the CIS region



Source: ITU

The impact of policy and regulatory frameworks on the development of digitization was also tested. In the case of countries in the CIS region, the results also validated the positive impact of the policy and regulatory variable. As noted, an increase of 10 per cent in the ITU ICT Regulatory Tracker yields a positive increase in the CAF Digital Ecosystem Development Index of 1.58 per cent in the CIS region. A second set of regressions shows, again, that of all the components of the 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	IMF
Fixed broadband subscriber penetration	ITU- OVUM
Capital- Gross capital formation (percentage of GDP)	World Bank
Price of oil barrel	Oil price.com
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 subscriber penetration	GSMA
Mobile unique subscriber penetration	GSMA
Mobile broadband price/ARPU	ITU- GSMA
HHI mobile broadband	GSMA
Mobile broadband revenue	GSMA

Annex B: Indicators included in CAF 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	Percentage of enterprises with Internet access	UNCTADstat; TAS; Eurostats
Digitization of production	Digital supply chain	Percentage of enterprises using Internet for electronic banking	UNCTADstat; TAS; Eurostats
Digitization of production	Digital supply chain	Percentage of enterprises using Internet for purchasing inputs	UNCTADstat; TAS; Eurostats
Digitization of production	Digital distribution	Percentage of enterprises that sell products over the Internet	UNCTADstat; TAS; Eurostats
Digitization of production	Digital processing	Percentage of workforce using the Internet	UNCTADstat; TAS; Eurostats
Digitization of production	Digital processing	Percentage of 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; Regulatory entities
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	Telecommunication 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 enrolment (per cent population)	World Bank; UNESCO
Factors of digital production	Schools	Per cent educational establishments with Internet access	UNESCO; ECLAC
Factors of digital production	Schools	Computers per student ratio	UNESCO; ECLAC
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 (percentage 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	Percentage 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	Percentage of regulatory agency attributions based on ITU regulatory tracker	ITU; TAS
Institutional and regulatory	Government role	Percentage 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

Annex C: Econometric methodology[17]

Economic contribution of fixed and mobile broadband

The state-of-the-art econometric models currently in use consist of four equations: an aggregate production function modelling the economy and, subsequently, three functions: demand, supply and output[18].

In the case of mobile telecommunications, for example, the last three functions model the mobile market operation and, controlling for the reverse effects, the actual impact of the infrastructure, as follows:

1. In the production function, GDP is linked to the fixed stock of capital, labour and the mobile infrastructure proxied by mobile penetration.
2. The demand function links mobile penetration to the average consumption propensity of individuals proxied by GDP per capita, the price of a mobile service proxied by ARPU (average revenue per user), the per cent rural population, and the level of competitive intensity in the mobile market measured by the HHI (Herfindahl Hirschman) index.
3. The supply function links aggregate mobile revenues to mobile price levels proxied by ARPU, the industry concentration index of the mobile market (HHI), and GDP per capita.

The output equation links annual change in mobile penetration to mobile revenues, used as a proxy of the capital invested in a country in the same year. The econometric specification of the model is:

Aggregate Production function: (1)

$$GDP_{it} = a_1K_{it} + a_2L_{it} + a_3Mob\_Pen_{it} + e_{it}$$

Demand function: (2)

$$Mob\_Pen_{it} = b_1Rural_{it} + b_2Mob\_Price_{it} + b_3GDPC_{it} + b_4HHI_{it} + e_{it}$$

Supply function: (3)

$$Mob\_Rev_{it} = c_1MobPr_{it} + c_2GDPC_{it} + c_3HHI_{it} +$$

Output function: (4)

$$\Delta Mob\_Pen_{it} = d_1Mob\_Rev_{it} + \varepsilon 4_{it}$$

In order to test the current economic impact of telecommunication technology, two models were constructed (one for fixed broadband and another one for mobile broadband) and specify them for two cross-sectional samples of countries. This methodology would allow the three hypotheses explained above to be tested while controlling for endogeneity effects[19].

[17] Extracted from the ITU Global study The economic contribution of broadband, digitization and ICT regulation (https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and-Digital-Transformation-E.pdf)

[18] Originally developed by Roller and Waverman (2001) and implemented by Koutroumpis (2009), Katz and Koutroumpis (2012a; 2012b), and Katz and Callorda (2014; 2016; 2018)

[19] As explained by Roller and Waverman, "This approach uses all the exogenous variable in the system of equations (i.e., those that can reasonably be assumed are not determined by the other variables in the system, such as the amount of labour and the amount of total capital) as "instruments" for the endogenous variables (output, the level of penetration, and the prices). Instrumenting the endogenous variables essentially involves isolating that component of the given endogenous variable that is explained by the exogenous variables in the system ("the instruments") and then using this component as a regressor."

Economic impact of digitization

Digitization, as a social process, refers to the transformation of the techno-economic environment and socio-institutional operations through digital communications and applications. Unlike other technological innovations, digitization builds on the evolution of network access technologies (mobile or fixed broadband networks), semiconductor technologies (computers/laptops, wireless devices/tablets), software engineering (increased functionality of operating systems) and the spillover effects resulting from their use (common platforms for application development, electronic delivery of government services, electronic commerce, social networks, and availability of online information in fora, blogs and portals). In order to measure the economic impact of digitization it is necessary to develop metrics that determine a country's level of digital eco-system development.

Theoretical framework and review of the research literature

The study of a country or region stage of development in the adoption of ICTs (information and communication technologies) has been progressing over the last 20 years. While the original focus was to assess the deployment and adoption of telecommunication and information technology infrastructure (broadband, mobile telephony, computers), research has been gradually expanding its focus to include dimensions such as the use of digital technologies (electronic commerce, electronic government, social networks) as well as the development of industries within the full digital value chain (Internet platforms, collaborative Internet services, etc.). In this process, a number of indices have been developed along the way, including the International Telecommunications Union ICT Development Index, the World Bank Knowledge Economy Index, the World Economic Forum Network Readiness Index, and the Inter-American Development Bank Broadband Development Index. However, most of the indices developed so far tend to either address a particular aspect of the digital ecosystem, such as broadband penetration, or include a limited number of indicators.

For the application of this methodology an endogenous growth model was used, which links GDP to the fixed stock of capital, labour force, and the digitization index as a proxy of technology progress. This model for economic output stems from the simple Cobb-Douglas form:

$$Y = A_{(t)} K^{1-b} L^{b}$$

where

$A_{(t)}$ represents the level of technology progress (in our case the digitization index),

K corresponds to the fixed capital formation, and

L to the labour force.

By converting all terms to logarithms, the coefficients can be estimated through an econometric model.

$$\log(GDP_{it}) = a_1 \log(k_{it}) + a_2 \log(L_{it}) + a_3 \log(D_{it}) + \varepsilon_{it}$$

Since the development of the original digitization index, a number of changes occurred within this phenomenon, adding complexity that was not accounted for in the original index. For example, the development of the **infrastructure of digital services** provides individuals, businesses and public organizations access to digital content and services. It also supplies interconnectivity to players within the digital value chain (e.g. developers of digital content, Internet platforms, etc.) so they can deliver a value proposition to users[20].

Digital connectivity measures the adoption of terminals (computers, smartphones) and services (broadband, wireless telephony) in order to allow individuals and organizations to gain access to networks. Network access enables the use of digital products and services, which is defined as

[20] Telecommunications services provide value insofar that they allow consumer access to the Internet.

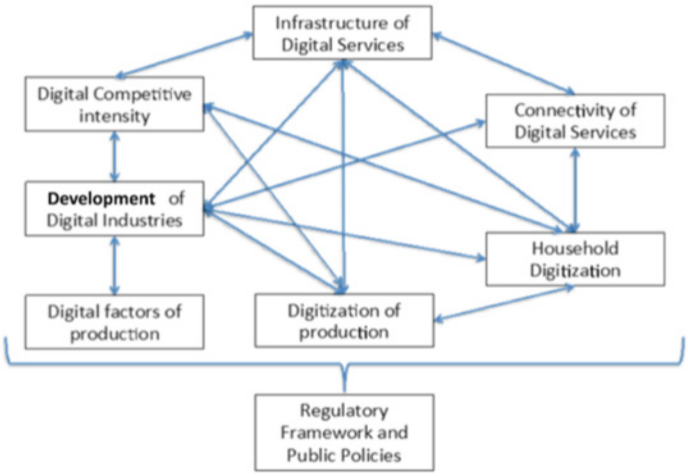
digitization. This term is used to measure not only the use of digital services by individual consumers (**household digitization**) but also its assimilation by enterprises (**digitization of production)**.

The demand of digital products and services by individual consumers, enterprises and governments is met by the offer supplied by **digital industries** (which comprise Internet platforms, media companies, telecommunication operators, and equipment manufacturers, among others). These firms can be located within the country where demand is located or, enabled by virtual business models, can be based beyond its frontiers. In order to develop digital industries within a country, they require conventional **factors of production** ranging from human to investment capital.

Finally, for digital industries to generate static and dynamic consumer benefits, they need to operate within a sustainable **competitive environment**, and receive the appropriate incentives and controls embodied in a **regulatory framework and public policies**.

As a result, the digital ecosystem could be defined as a set of interconnected components (or pillars) operating within a socio-economic context. Figure C1 illustrates the correlations between the eight pillars of the original CAF Digital Ecosystem Development Index, showing the strong interplay among them.

Figure C1: Conceptual structure of the CAF Digital Ecosystem Development Index



Source: Katz and Callorda (2017)

Note: Figure C1 links are drawn only for relatively strong causal relationships (see analysis below).

In order to assess the existence and strength of the causal link between digital ecosystem development and economic development, an endogenous growth model based on the Cobb-Douglas production function was specified linking the stock of fixed capital, labour force, and the CAF Digital Ecosystem Development Index. The model also controls for GDP per capita for previous year to account for inertia effects:

$$Y_{(t)} = A_{(t)} K_{(t)}^{1-b} L_{(t)}^{b}$$

By converting all equation terms to logarithms, the level of impact of each independent variable of the growth of the digital ecosystem was estimated:

$$\log (GDP_{it}) = a_1 \log (K_{it}) + a_2 \log (L_{it}) + a_3 \log (A_{it}) + \varepsilon_{it}$$

Where:

$K_{(t)}$ measures the level of fixed capital formation

$L_{(t)}$ measures labour force

$A_{(t)}$ measures the CAF Digital Ecosystem Development Index

In this model, since both the dependent and independent variables are indices, the analysis is essentially correlational. In that sense, from a policy standpoint, if regulation improves in a given country, the digital ecosystem is expected to grow as well. The reverse causality hurdle is partly addressed by measuring how the rate of change in the ICT regulatory tracker affects the rate of development of the digital ecosystem.

Economic impact of policy and regulatory framework on the growth of markets for digital service

The analysis of the economic impact of policy and regulatory framework on the growth of markets for digital service relies on the ITU ICT regulatory tracker as the independent variable to test its impact on the CAF Digital Ecosystem Development Index. For this purpose, two models were developed initially: the first tests the correlation between the ICT regulatory tracker and the CAF Digital Ecosystem Development Index. The underlying premise is that higher regulatory performance is directly related to the development of the digital economy:

$$Dig.Index_{it} = \beta_1 Reg.Index_{it} + \text{Year F.E.} + \text{Country F.E.} + e_{it}$$

Beyond measuring the correlation between both variables, a model with lagged variables was developed. In this case, the specified model is as follows:

$$Dig.Index_{it} = \beta_1 Reg.Index_{it} + \beta_2 Reg.Index_{it-1} + \text{Year F.E.} + \text{Country F.E.} + e_{it}$$

Finally, the variables were converted to logarithms to test causality of change in values of both indices:

$$In\ (Dig.Index_{it}) = \beta_1 In\ (Dig.Index_{it}) + \beta_2 In\ (Dig.Index_{it-1}) + \text{Year F.E.} + \text{Country F.E.} + e_{it}$$

Furthermore, one cannot detect in this analysis a component of the ICT regulatory tracker that has higher importance than the rest when correlated with the CAF Digital Ecosystem Development Index and its pillars. It is clear that growth in the ICT regulatory tracker components go in tandem with an improvement in all pillars of the digital ecosystem. A second set of regressions showed that the regulatory regime component of the ICT regulatory tracker appears to be the main path of impact of the CAF Digital Ecosystem Development Index.

ICT regulatory tracker and CAF Digital Ecosystem Development Index pillars

ICT Regulatory Tracker	ICT regulatory tracker (w/o Competition component)	Regulatory authority component	Regulatory mandate component	Regulatory regime component	competition framework		
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

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