Thematics

The economic contribution of broadband, digitization and ICT regulation

The economic contribution of broadband, digitization and ICT regulation

This research study has been prepared for the International Telecommunication Union (ITU) with the collaboration of the ITU Telecommunication Development Bureau (BDT) Regulatory and Market Environment Division based on desk research and on data from the ITU ICT regulatory tracker and the digital ecosystem development index developed with funding from CAF Development Bank for Latin America.

Authors

Raul Katz (Ph.D., Management Science and Political Science, Massachusetts Institute of Technology) is currently Director of Business Strategy Research at the Columbia Institute for Tele-Information, and President of Telecom Advisory Services, LLC. Before founding Telecom Advisory Services, he worked for twenty years at Booz Allen Hamilton, where he was the Head of the Telecommunications Practice in North and Latin America and member of its Leadership Team.

Fernando Callorda (BA, MA, Economics, *Universidad de San Andres-Argentina*) is a project manager with Telecom Advisory Services, an Assistant Professor ESEADE (Argentina) and a Research Fellow with the Economics Department at the *Universidad de San Andres*. Before joining Telecom Advisory Services, he was a staff analyst in the *Congreso de la Nación Argentina*.

ISBN:

978-92-61-27701-7 (Paper version)
978-92-61-27711-6 (Electronic version)
978-92-61-27721-5 (ePub version)
978-92-61-27731-4 (Mobi version)

Please consider the environment before printing this report.

Foreword

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

In our first study on this topic, "The impact of broadband on the economy", launched in 2012, ITU provided initial evidence on the positive economic and social impact of broadband, underlining the importance of data gathering to refine impact measurement. It also explored the policies that have proven to be most successful in stimulating investment in broadband as well as promoting the adoption of broadband services by population and businesses. The study has become an authoritative reference and has informed policy makers across the ITU Membership since.

I am pleased to present the study on "The economic contribution of broadband, digitization and ICT regulation". Given that we have entered the age of digital transformation, where ICTs are recognized as being core to economic and social development, this study builds on years of robust and reliable data resources with a global scope to measure the impact of fixed and mobile broadband and digital transformation on the economy, digitization as a whole, as well as the impact of institutional and regulatory variables to the development of the digital ecosystem.

It quantifies the positive impact of broadband, digital transformation and the interplay of ICT regulation on national economies, based on new-generation, mature econometric modelling techniques. This study also brings additional granularity to the effects of broadband on countries at a different stage of development. It uses top-tier data metrics on the development of the digital ecosystem and the maturity of ICT regulatory frameworks, namely the Digital ecosystem development index and the ITU ICT regulatory tracker.

This landmark study provides evidence of the importance of the regulatory and institutional variable in driving digital growth, and illustrates that broadband technologies, on one hand, and effective ICT regulation, on the other hand, can have positive impact on the growth of national economies and prosperity.

Among the key findings, the study states that fixed broadband had a significant impact on the world economy between 2010 and 2017 and that the impact of fixed broadband is higher in more developed countries than in less developed. On the other hand, the contribution of mobile broadband is higher in less developed countries than in more developed.

The study also shows that the economic impact of digitization is higher than the one from fixed broadband and similar to mobile broadband and also higher on more advanced countries. It also recognizes that the digital ecosystem has an economic impact on productivity.

I am certain that these findings will make the case for broader adoption of digital technologies and digital policies across the globe.

For these reasons, I am delighted to present this ever-growing body of research and look forward to furthering ITU work on the dynamic and exciting broadband ecosystem.

Brahima Sanou
Director, ITU Telecommunication Development Bureau

Table of Contents

List of Tables, Figures and Boxes

Tables

Figures

1 Introduction

Based on econometric modelling, this study provides additional evidence of the contribution of broadband and digital transformation to the economy and the impact of institutional and regulatory variables to the development of the digital ecosystem.

The study is structured around three analyses:

- **The economic impact of fixed and mobile broadband**: This analysis verifies whether the original models, which explain broadband economic contribution developed in 2010, are still valid. In this context, and on the basis of large data sets, the analysis tests whether the economic impact of broadband is increasing with penetration (the so-called return to scale effect). Alternatively, the models may determine that broadband economic impact is undergoing a saturation effect and, therefore, diminishing returns. Finally, the analysis searches for any differences between fixed and mobile broadband economic impact.
- **The economic impact of digitization**: The digitization concept is much larger in scope than broadband, as it encompasses the infrastructure of digital services, connectivity of devices, the digital transformation of households and production, the development of digital industries, and the availability of digital factors of production. In this context, it is pertinent to raise a question that goes beyond the economic impact of broadband: What is the impact of digitization on GDP and productivity?
- **The impact of policy and regulatory frameworks on the growth of markets for digital services and applications**: This analysis looks at the impact of regulation and institutions on the development of the digital economy. Considering that the growth of digitization is primarily driven by the private sector, this analysis also looks at the roles that policy and regulatory variables play, and if these factors are important as drivers of growth in the digital economy. Analysis is structured around a review of the research evidence, a presentation of the econometric models, and a discussion of results.

2 Economic contribution of fixed and mobile broadband

Studies on the economic impact of telecommunications have been produced for the past two decades confirming, to a large extent, that wireline and wireless telephony, as well as fixed and mobile broadband have an impact on economic growth and, in some cases, on employment and productivity[1].

Along these lines, a critical issue of the evolving research on network externalities of telecommunications is the pattern of impact that telecommunication penetration levels may have on output and employment. For example, is there a linear relationship between broadband adoption and economic growth, whereby higher penetration yields a greater impact? Or, are there more complex non-linear causal effects, such as increasing returns to scale[2] and/or diminishing returns due to market saturation?

The increasing returns to scale body of theory, also called the *critical mass* studies[3] indicate that the impact of telecommunications on economic growth may only become significant once the adoption of the technology achieves high penetration levels, and that economic impact increases with penetration.

---

1 Hardy, 1980; Karner and Onyeji, 2007; Jensen, 2007; Katz et al., 2010; Katz, 2011; Katz et al., 2012a; Katz et al, 2012b, Arvin and Pradhan, 2014

2 Generally, r*eturns to scale* describes what happens as the scale of production increases over time, when inputs such as physical capital usage are variable*. The impact of broadband on the economy report (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 Roller and Waverman (2001); Shiu and Lam (2008); Koutroumpis (2009)

On the other hand, at a certain point of adoption, declining effects due to technology saturation emerge[4]. According to this second body of theory, it is the early adopters that are prone to leverage the economic benefits of the technology, while late adopters do not have such a high effect. In other words, while some researchers have raised the question of *return to scale* or the need of countries to reach *critical mass* to maximize impact, others have emphasized the *diminishing returns* as key effects to be considered in the assessment of the economic impact of telecommunications.

This study attempts to combine these two effects and raise two hypotheses:

- First, the economic impact of a single telecommunication technology depends on its stage of adoption. In other words, its economic contribution is driven by a return to scale, whereby increasing adoption is imperative in order to maximize impact. Yet, at some point, following an inverted U pattern, the impact of telecommunications tends to slow down.
- Second, this inverted U pattern is rendered even more complex when assessing the relative effects of different telecommunication technologies, such as mobile telephony, fixed broadband, and wireless broadband. Considering that each technology is following different diffusion cycles, it is hypothesized that while one (say, mobile telephony) is undergoing declining returns, another (such as wireless broadband) exhibits a return to scale.

In a similar vein, fixed broadband exhibits a return to scale, while mobile broadband displays diminishing returns. To test these hypotheses, econometric models have been developed across a cross-sectional time series sample of countries for fixed and mobile broadband.

2.1 Theoretical framework and review of the research literature

In addition to measuring the aggregate economic impact at the macro level, research on the economic impact of telecommunications has focused on two main processes:

- Does the economic impact of telecommunications increase with penetration?
- Can a saturation threshold be pinpointed beyond which decreasing returns to penetration exist?

A further related question is particularly relevant for policy formulation:

- If telecommunications have been proven to have an impact on the economy, could the pattern of impact be different depending on the technology?

2.1.1 The *return to scale* or *critical mass* effect?

It has been suggested that the impact of telecommunication infrastructure on economic output is maximized once the infrastructure reaches critical mass generally associated with levels of penetration.

In the first study to identify this effect, Roeller and Waverman (2001) examined the impact of investment in telecommunication infrastructure on the GDP of 21 OECD countries and 14 developing or newly-industrialized non-OECD countries between 1970 and 1990 and found that the economic contribution of wireline telecommunication was not linear. It was found to be greater in OECD countries than it was in non-OECD countries and in countries that had reached critical mass, and that the critical mass needed to influence economic growth is present when telephone penetration reaches 40 main telephone lines per 100 population.

The study also indicated that once the critical mass level is reached, telecommunication investment has a larger impact on economic growth per dollar of investment than other types of infrastructure investment because telecommunication infrastructure exhibits *network effects*.

---

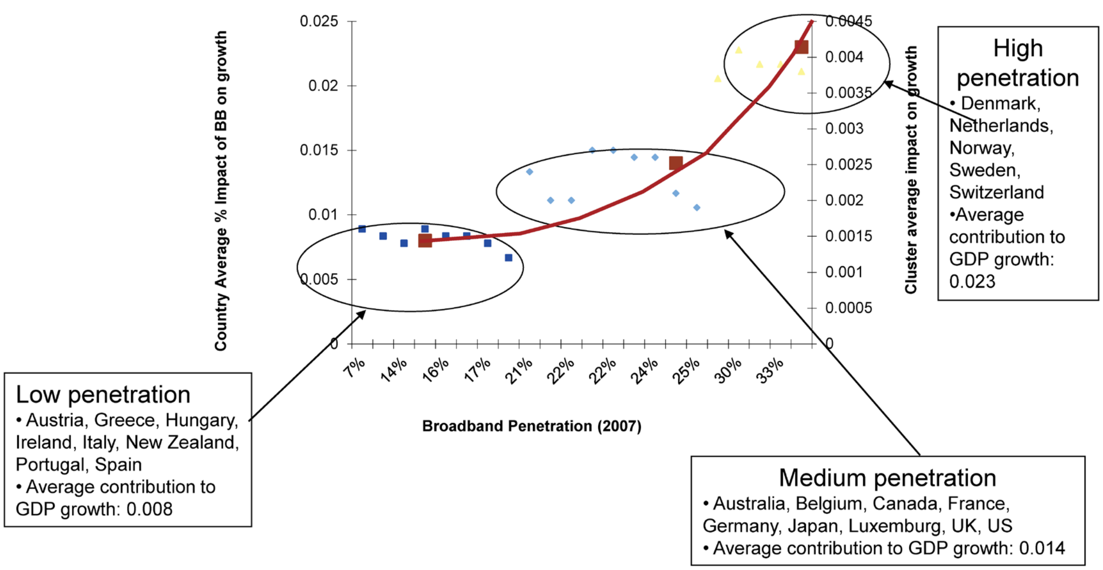
4 Atkinson et al. (2009); Czernich et al. (2009); Gillett et al. (2006)

Further research on the importance of telecommunication development in explaining economic growth was carried out (in 105 countries), and it determined that an increase in teledensity is more effective in raising income levels in high-income countries in Europe than in less developed countries elsewhere[5].

Work carried out in India confirmed that larger growth effects were detected in states that had achieved a critical mass in mobile infrastructure[6]. By splitting the dataset into high and low penetration states based on the median penetration level of 25 per cent achieved in 2008, it was found that the coefficient of impact in the models was higher for high penetration states compared to low penetration states, (0.13 versus 0.10), implying, again, that there is a threshold for critical mass at roughly 25 per cent. Similar evidence has been generated in analysis of mobile telephony in countries in Africa[7].

The findings in wireline and wireless telephony have been extended to fixed broadband[8]. And it was found that for OECD countries the contribution of broadband to economic growth increased with penetration. Further research found that in countries with low broadband penetration (under 20 per cent), an increase of 1 per cent in broadband adoption contributed to 0.008 per cent of GDP growth, while in countries with medium penetration (between 20 per cent and 30 per cent), the effect is of 0.014 per cent and in countries with penetration higher than 30 per cent, the impact of 1 per cent adoption reaches 0.023 per cent of GDP growth. Figure 1 illustrates the distribution of countries with regard to the correlation of broadband penetration and its impact on GDP growth.

Figure 1: Impact of fixed broadband on GDP in OECD countries, 2009 (%)



Source: Adapted from Koutroumpis (2009)

These findings were further supported in a study of Germany's counties (Landkreisse). In this study, the authors split their dataset between counties with high fixed broadband penetration (average 31 per cent) and low (average 24.8 per cent) and found that the coefficient of economic impact was positive and higher in the counties with high penetration.

The implication of this evidence for developing countries is quite significant. Unless emerging economies do not strive to dramatically increase their penetration of broadband, the economic impact of the technology will be quite limited.

5 Shiu et al. (2008)
6 Roller and Waverman. Similarly, Kathuria, et al. (2009)
7 Andrianaivo et al. (2011)
8 Koutroumpis (2009)

2.1.2 The *saturation* and *diminishing returns* effect

At the other end of the diffusion process, some authors have pointed out a potential saturation effect. They have found that, beyond a certain adoption level, the contribution of a telecommunication technology to the economy tends to diminish. There is evidence that supports the argument that network externalities decline with the build out of networks and the maturation of technology over time[9].

It has been demonstrated in diffusion theory that early technology adopters are generally those who can elicit the higher returns of a given innovation. Conversely, network externalities would tend to diminish over time because those effects would not be as strong for late adopters. Along those lines, Gillett et al. (2006) argued that the relation between broadband penetration and economic impact should not be linear "because broadband will be adopted (…) first by those who get the greatest benefit (while) late adopters (…) will realize a lesser benefit" (p. 10).

To test the saturation hypothesis, dummy variables have been added in economic research to account for 10 per cent and 20 per cent broadband penetration to models explaining broadband contribution to OECD economies[10]. It was found that 10 per cent broadband penetration has a significant impact on GDP per capita: between 0.9 and 1.5 percentage points.

However, the transition from 10 per cent to 20 per cent yielded non-significant results. This led the researchers to postulate that broadband saturation and diminishing returns occurs at the 20 per cent point. When saturation was treated as an independent variable it was found to be negatively related to the increase in economic growth (notwithstanding the possible influence of network effects)[11].

It has also be suggested that an economic impact of a 1 per cent increase in broadband is higher in low and middle-income economies and lower in high-income economies[12] and that the economic impact is highest around the mean level of broadband saturation at the county level[13]. Again this was due to diminishing returns to scale.

It has also be suggested that a critical amount of broadband infrastructure may be needed to sizably increase employment, but once a community is completely built out, additional broadband infrastructure will not contribute to further employment growth.

In the case of mobile telephony, it appears that the effects of mobile telephony on GDP growth correlate with wireless penetration growth up until penetration rates reach 60 per cent, at which point effects tend to subside[14].

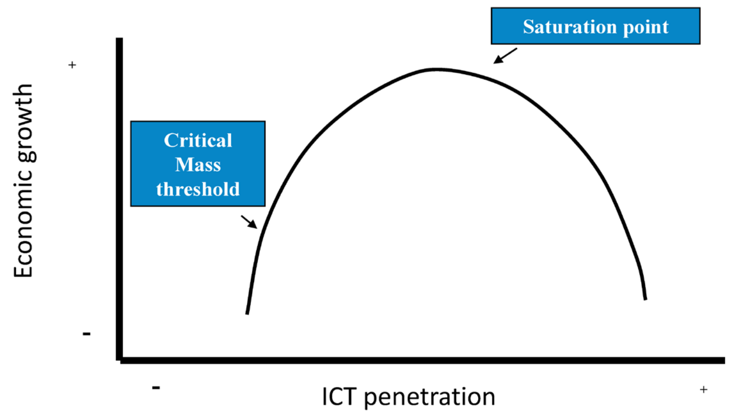
It is important, however, to take care when interpreting the evidence of diminishing returns. The saturation evidence still needs to be carefully tested particularly in terms of revealing the point beyond which the economic impact tends to diminish. Furthermore, even if there were evidence of saturation with regard to contribution to GDP or employment creation, that would not question the need to achieve universal broadband in terms of the other social benefits it yields to end users.

With both points of view in mind, need to achieve critical mass and diminishing returns, it would appear that the strength of the relationship between telecommunications and economic growth is highest once the technology has achieved a certain critical mass but before it reaches saturation. Figure 2 shows an inverted U shape of the non-linear relationship between broadband penetration and output.

---

9 Atkinson at al. (2009)
10 Czernich et al. (2009)
11 Gillett et al. (2006)
12 Qiang et al. (2009)
13 Kentucky, Shideler et al. (2007)
14 Gruber and Koutroumpis (2011)

Figure 2: Conceptual framework for the impact of broadband on economic output over the diffusion process



Source: Katz and Callorda (2017)

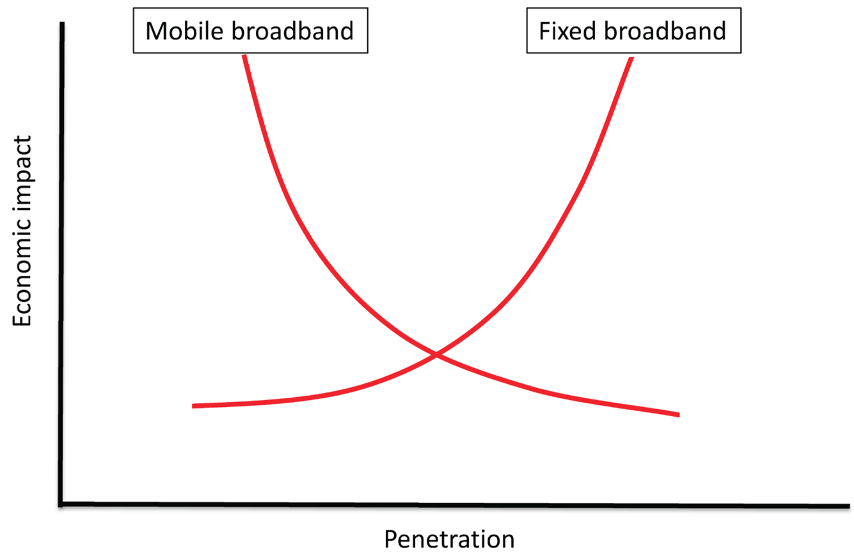
Theoretically, it would appear that there is a non-linear (or inverted U shape) relationship between broadband penetration and output. At low levels of broadband penetration, it is suggested that the impact of broadband on the economy is minimal due to the need to reach critical mass. According to this theory, the impact of telecommunication infrastructure on economic output is maximized once infrastructure reaches critical mass, and in industrialized countries this point is generally associated with levels of penetration. Beyond that point, economic impact tends to slow down, leading to diminishing returns.

As a cautionary point, research shows an important dispersion in the level of penetration that would indicate a saturation point when economic impact declines, ranging between 20 per cent and 60 per cent.

2.1.3 The combined effect

A third hypothesis for which there is no clear evidence so far is how both effects – critical mass and saturation – work in tandem according to the type of telecommunication technology. For example, each of the two technologies, fixed broadband, and mobile broadband, undergoes specific patterns of impact, whereby fixed broadband reflects a return to scale, while mobile broadband reflects a saturation effect. This could be driven by the nature of each technology and its specific externalities combined with substitution patterns. Figure 3 depicts the pattern of impact of both technologies.

Figure 3: Patterns of economic impact of fixed and mobile broadband



Source: Katz and Callorda (2017)

These effects can be tested with econometric models run on large cross-sectional time series datasets:

- overall (aggregated results), mobile broadband appears to have a higher economic impact than fixed broadband;
- the economic impact of fixed broadband is higher in more developed countries than in less developed;
- the economic impact of mobile broadband is higher in less developed countries than in more developed countries.

2.2 Econometric models

2.2.1 Model structure

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[15].

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 is estimated.

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.

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

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)

$$GDPit=a1Kit+a2Lit+a3Mob\_Penit+ eit$$

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)

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

In order to test the current economic impact of telecommunication technology, two models could be 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[16].

2.2.2 Data

To test the three hypotheses presented above with the structural model, a database of 140 countries was built (Annex A for the full list) containing data between 2004 and 2017 for all the variables. The data sources are the International Telecommunications Union, the World Bank, Ovum, and GSMA Intelligence (Annex B for sources of data). As expected, in some countries, not all the data is available, which might have reduced the number of observations for a particular model.

2.2.3 Results and discussion

General model (first hypothesis)

The models, run with the totality of the database (with the exception of one country with missing values, which results in 139 countries), yield statistically significant results, thereby confirming the first hypothesis. The results of each of the first model are reflected in Table 1.

[16] 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."

Table 1: Economic impact of fixed broadband: Results of general model

Variables of fixed broadband model: All countries	
GDP per Capita (PPP)	
Fixed broadband subscriber penetration	0.07715 ***
Capital	0.18922 ***
Education	0.05205 ***
Fixed broadband subscriber penetration	
Fixed telephone subscribers	0.46780 ***
Rural population	-0.12191 ***
GDP per capita	0.83844 ***
Fixed broadband price	-0.30080 ***
HHI fixed broadband	-0.34757 ***
Fixed broadband revenue	
GDP per capita	1.23160 ***
Fixed broadband price	0.18800 ***
HHI fixed broadband	-0.77502 ***
Fixed broadband adoption growth	
Fixed broadband revenue	-0.74541 ***
Observations	3 887
Number of countries	139
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2010-2017
GDP per capita (PPP)	All
R-squared	0.9952

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

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

Source: ITU research

According to the fixed broadband model, this infrastructure has had a significant impact on the world economy from 2010 to 2017. An increase of 1 per cent in fixed broadband penetration yields an increase in 0.08 per cent in GDP. The structural model also provides estimates for other important parameters of the economy.

As expected, fixed capital formation is a strong catalyst of GDP growth, suggesting an important contribution to the economy (0.19 coefficient). Similarly, the labour force critically affects economic growth. It is estimated that 1 per cent more skilled labour would increase GDP by 0.05 per cent[17]. This can be attributed both to a limited expansion of infrastructure and the large dependency on quality of the labour force.

In terms of demand of broadband services, prices are the key enablers for adoption of the technology. Strikingly, a 1 per cent drop in prices will boost adoption by more than 0.30 per cent[18].

Income variation across the sample period seems to have a similar impact on this process. Hence, increasing the average disposable income (proxied by GDP) by 1 per cent yields 0.83 per cent more fixed broadband adoption. Essentially this translates into an increased importance of infrastructure and the subsequent service provided over this.

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) attracts 1.23 per cent more supply (based on the coefficient of GDP in the fixed broadband revenue model or supply equation in Table 1).

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[19]. This is an additional angle supporting the increasing returns to scale of ICT infrastructure.

Moving on to the mobile broadband economic impact, the technology appears to have a higher impact on economic growth than fixed technology.

Table 2: Economic impact of mobile broadband: Results of general model

Variables of mobile broadband model: All countries	
GDP per capita (PPP)	
Mobile broadband unique subscribers penetration	0.15022 ***
Capital	0.21490 ***
Education	0.05569 ***
Mobile broadband unique subscribers penetration	
Mobile unique subscribers penetration	1.6797 ***
Rural population	-0.03596 ***
GDP per capita	0.05968 ***
Mobile broadband price	0.00728
HHI mobile broadband	-0.37128 ***

17 As indicated in Annex B, Education is defined as the World Bank indicator: School enrollment, tertiary (% gross). Ideally, the indicator should be workforce with tertiary education; however, this indicator is only available for a few countries and would reduce the number of countries to run the model by 70 per cent.

18 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 intermediate steps are results that should not be considered general conclusions. For a model on mobile price elasticity in developing countries, see Katz and Berry (2014).

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

Variables of mobile broadband model: All countries	
Mobile broadband revenue	
GDP per capita	0.08839 ***
Mobile broadband price	0.11020 **
HHI mobile broadband	-2.12035 ***
Mobile broadband adoption growth	
Mobile broadband revenue	-1.14176 ***
Observations	3 858
Number of countries	139
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	2010-2017
GDP per capita (PPP)	All
R-Squared first model	0.9950

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

According to the mobile broadband model, an increase of 1 per cent in mobile broadband penetration yields an increase in 0.15 per cent in GDP. The importance of fixed capital formation is even higher in this case than in fixed broadband. Interestingly, service pricing is less significant in driving demand, but the positive sign appears to indicate that affordability is less of a barrier. This could be also driven by the fact that mobile broadband cost is relatively low since it is an addition in the mobile plan.

In sum, mobile broadband appears to have a larger economic impact than fixed broadband (0.15 per cent versus 0.08 per cent increase in GDP as a result of 1 per cent increase in broadband penetration).

Impact of fixed broadband by level of development (second hypothesis)

This model aims to test whether fixed broadband economic impact is affected by a *return to scale* or a *saturation* effect. In order to run models to measure the impact of fixed broadband by level of development[20], the database was split in three groups of countries:

- 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).

Similar structural models were run for each set of countries, yielding the results in Table 3.

[20] Considering the almost complete correlation between GDP per capita and fixed broadband penetration, the three groups of countries could also be considered as representing high medium and low broadband penetration.

Table 3: Economic impact of fixed broadband: Results by economic development level

Variables of fixed broadband model	High income	Middle income	Low income
GDP per capita (PPP)			
Fixed broadband subscriber penetration	0.14047 ***	0.00335	0.05461
Capital	0.30257 ***	0.03667 *	0.21024 ***
Education	-0.11711 ***	0.02658	0.15569 ***
Fixed broadband subscriber penetration			
Fixed telephone subscribers	0.39270 ***	0.14859 ***	0.49262 ***
Rural population	0.04370 ***	-0.28140 ***	-0.81927 ***
GDP per capita	0.15746 ***	0.35670 **	0.53821 ***
Fixed broadband price	0.22080 ***	-1.17015 ***	-0.30159 ***
HHI fixed broadband	-0.21266 ***	-0.33772 ***	-0.38882 ***
Fixed broadband revenue			
GDP per capita	-0.48618 ***	-1.68133 ***	1.24272***
Fixed broadband price	1.46762 ***	-0.23864 **	0.14314 ***
HHI fixed broadband	-0.81781 ***	-0.91915 ***	-0.71760 ***
Fixed broadband adoption growth			
Fixed broadband revenue	-0.82810 ***	-0.46838 ***	-0.74656 ***
Observations	1,364	799	1,724
Number of countries	50	26	63
Country fixed effects	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes
Years	2010-2017	2010-2017	2010-2017
GDP per capita (PPP)	> USD 22 000	> USD 12 000 < USD 22 000	< USD 12 000
R-squared first model	0.9848	0.9365	0.9831

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

The only model where statistically significant positive effects were found for fixed broadband is for countries with GDP per capita higher than USD 22 000 (higher income countries). According to this, 1 per cent increase in broadband penetration yields 0.14 per cent increase in GDP growth. This value is consistent with that calculated in the general model.

On the other hand, while the impact from fixed broadband for middle and low-income countries had a positive sign, both coefficients lack statistical significance. To address the model limitations for middle-income countries, the data set from the third quarter of 2013 to the fourth quarter of 2017 was reduced, following the argument that before 2013, fixed broadband penetration was low and therefore economic effects were negligible. In this case, the economic impact of fixed broadband was positive, and significant at the 5 per cent level.

Table 4: Economic impact of fixed broadband for middle income countries (modified sample)

Variables of fixed broadband model – Middle-income countries, 3Q2013-4Q2017	
GDP per capita (PPP)	
Fixed broadband subscriber penetration	0.05778 **
Capital	0.03944
Education	0.06137 **
Fixed broadband subscriber penetration	
Fixed telephone subscribers	0.32580 ***
Rural population	-0.20962 ***
GDP per capita	0.23660
Fixed broadband price	-0.67094 ***
HHI fixed broadband	-0.53464 ***
Fixed broadband revenue	
GDP per capita	-2.19391 ***
Fixed broadband price	0.38096 **
HHI fixed broadband	-1.42852 ***
Broadband adoption growth fixed	
Revenue fixed broadband	-0.47432 ***
Observations	461
Number of countries	26
Country fixed effects	Yes
Year and quarter fixed effects	Yes
Years	3Q 2013 to 4Q 2017
GDP per capita (PPP)	Middle income
R-squared first model	0.9630

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

This would confirm not only the hypothesis that the impact of fixed broadband appears at higher levels of economic development (critical mass) but also would support the return to scale argument raised earlier.

Consequently, fixed broadband economic impact tends to increase with economic development. Recognizing the correlation between GDP per capita and fixed broadband penetration, it is fair to assert that technology has an economic impact at high penetration levels.

Furthermore, the model results could also indicate an apparent fixed to mobile substitution, whereby in countries that have low fixed broadband penetration (those that have low GDP per capita), it is mobile broadband technology that becomes the pre-eminent technology driving economic growth. However, to prove this point, the results of the third hypothesis need to be examined.

Impact of mobile broadband by level of development (third hypothesis)

In order to run models to measure the impact of mobile broadband by level of development, the database was split into three similar groups of countries (although the number of observations by subset varied from fixed broadband due to more recent diffusion process):

- 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).

Similar structural models were run for each set of countries, yielding the results in Table 5.

Table 5: Economic impact of mobile broadband: Results by economic development level

Variables of mobile broadband model, 2010-2017	High income	Middle income	Low income
GDP per capita (PPP)			
Mobile broadband unique subscribers penetration	-0.021986	0.17577 ***	0.19752 ***
Capital	0.31248 ***	0.07427 ***	0.23190 ***
Education	-0.07062 ***	0.07643 ***	0.12406 ***
Mobile broadband unique subscribers penetration			
Mobile unique subscribers penetration	1.85883 ***	1.87814 ***	1.63963 ***
Rural population	-0.03806 ***	0.01511	-0.08433 ***
GDP per capita	0.26726 ***	-0.00048	0.04384 **
Mobile broadband price	0.00810	0.14930 ***	-0.13139 ***
HHI mobile broadband	-0.43987 ***	-0.71444 ***	-0.27510 ***
Revenue mobile broadband			
GDP per capita	0.86928 ***	-1.74602 ***	0.97739 ***
Mobile broadband price	0.78115 ***	0.18096	-0.47023 ***
HHI mobile broadband	-2.70536 ***	-3.87790 ***	-1.65927 ***
Mobile broadband adoption growth			
Revenue mobile broadband	-0.32202 ***	-1.03256 ***	-1.11108 ***
Observations	1,394	775	1,689
Number of countries	50	26	63

Variables of mobile broadband model, 2010-2017	High income	Middle income	Low income
Country fixed effects	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes
Years	2010-2017	2010-2017	2010-2017
GDP per capita (PPP)	> USD 22 000	> USD 12 000 < USD 22 000	< USD 12 000
R-squared first model	0.9867	0.9457	0.9799
***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.			

Source: ITU research

In this case, two subsets of countries yielded positive and significant impact of broadband on GDP:

- for countries with GDP per capita between USD 12 000 and USD 22 000, 1 per cent increase in mobile broadband penetration yields 0.18 per cent increase in GDP;
- for countries with GDP per capita below USD 12 000, 1 per cent increase in mobile broadband penetration yields 0.20 per cent increase in GDP;
- no impact was detected for countries with GDP per capita above USD 22 000.

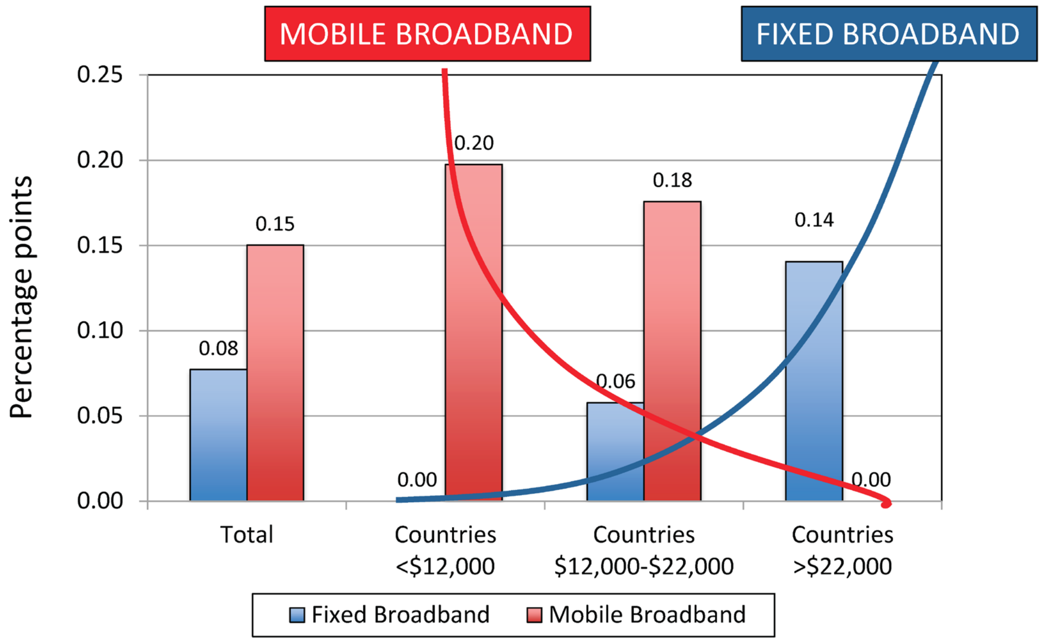
In other words, the model indicated that the lower the level of development, the higher the economic impact of mobile broadband.

In summary, the broadband economic impact models confirm all three hypotheses:

- overall, mobile broadband appears to have a higher economic impact than fixed broadband;
- the economic impact of fixed broadband is higher in more developed countries than in less developed;
- the economic impact of mobile broadband is higher in less developed countries than in more developed countries.

Figure 4 presents the results of all models.

Figure 4: Economic impact of broadband worldwide, 2010-2017



Note: Values expressed as impact on GDP of 1 per cent increase in broadband penetration.

Source: ITU research

3 Economic impact of digitization

Thus far, the economic impact of fixed and mobile broadband has been tested. Rather than measuring the impact of a single communications technology, the economic contribution of the whole digital eco-system will be tested. Digitization *per se*, is the process of converting analogue information to a digital format. 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.

3.1 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 twenty 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. Table 6 shows the original six components used as indices to measure digitization[21].

Table 6: Original structure of the digitization index

Components	Subcomponents	Sub-subcomponents
Affordability	Residential fixed line cost adjusted for GDP per capita	Residential fixed line tariff adjusted for GDP per capita
		Residential fixed line connection fee adjusted for GDP per capita
	Mobile cellular cost adjusted for GDP per capita	Mobile cellular prepaid tariff adjusted for GDP/capita
		Mobile cellular prepaid connection fee adjusted for GDP per capita
	Fixed broadband Internet access cost adjusted for GDP per capita	
Infrastructure reliability	Investment per telecom subscriber (mobile, broadband and fixed)	Mobile investment per telecom subscriber
		Broadband investment per telecom subscriber
		Fixed line investment per telecom subscriber
Network access	Network Penetration	Fixed broadband penetration
		Mobile phone penetration
	Coverage, infrastructure, and investment	Mobile cellular network coverage
		PC population penetration
		3G penetration
Capacity	International Internet bandwidth (kbit/s per user)	
	Percentage of broadband connections higher than 2 Mbit/s	
Usage	Internet retail volume	
	E-government usage	
	Percentage of individuals using the Internet	
	Data as percentage of wireless ARPU	
	Dominant social network unique visitors per month per capita	
	SMS usage	
Human capital	Percentage of engineers in labour force	
	Percentage of skilled labour	

21 The first index of digitization developed by this author (Katz et al., 2013a; Katz et al., 2013b, Katz et al., 2014).

In the original work, the impact of digitization on economic growth was tested. For this purpose 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.

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

The digitization index was found to have a positive and significant effect at the 5 per cent level indicating a strong effect on economic output. A ten-point increase in the digitization index had approximately a 3 per cent impact on GDP from 2004 to 2010 resulting on an annualized effect of 0.50 per cent.[22], [23]

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[24].

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 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**.

---

22 A base case of an 'average' country where the digitization index increased by 10 points.

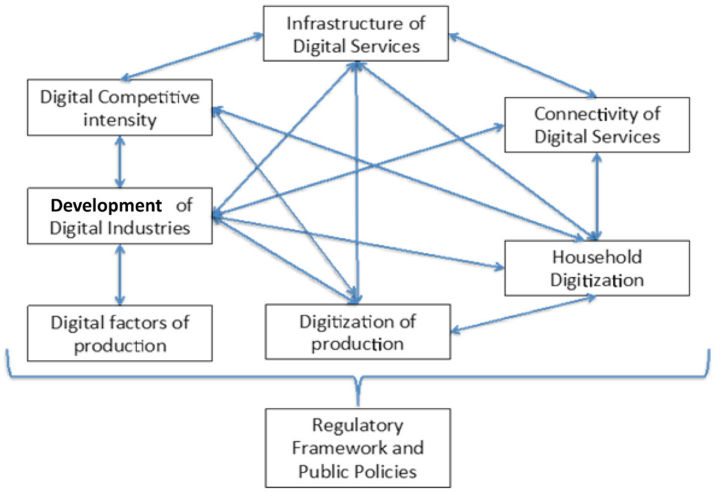
23 CAGR (compound annual growth rate) attributed to digitization derives from formula (1):

$$CAGR = \left[\left(\frac{\frac{Digitization_{2010}}{100-Digitization_{2010}} - \frac{Digitization_{2004}}{100-Digitization_{2004}}}{\frac{Digitization_{2010}}{100-Digitization_{2010}}}\right) * \hat{a}_3 + 1\right]^{1/6}$$

24 Telecommunications services provide value insofar that they allow consumer access to the Internet.

As a result, the digital ecosystem could be defined as a set of interconnected components (or pillars) operating within a socio-economic context. Figure 5 illustrates the correlations between the eight pillars of the original digital ecosystem development index, showing the strong interplay among them.

Figure 5: Conceptual structure of the digital ecosystem development index



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

Source: Katz and Callorda (2017)

Does the digital ecosystem make a similar economic contribution as measured through the original digitization index? From a hypothesis standpoint, the following models will be testing three postulates:

- the economic contribution of digital ecosystems is larger than that of broadband;
- digital ecosystems economic contribution also registers a “return to scale” effect;
- digitization has an impact on labour and total factor productivity, in addition to contribution to GDP growth.

3.2 Econometric models

3.2.1 Model structure

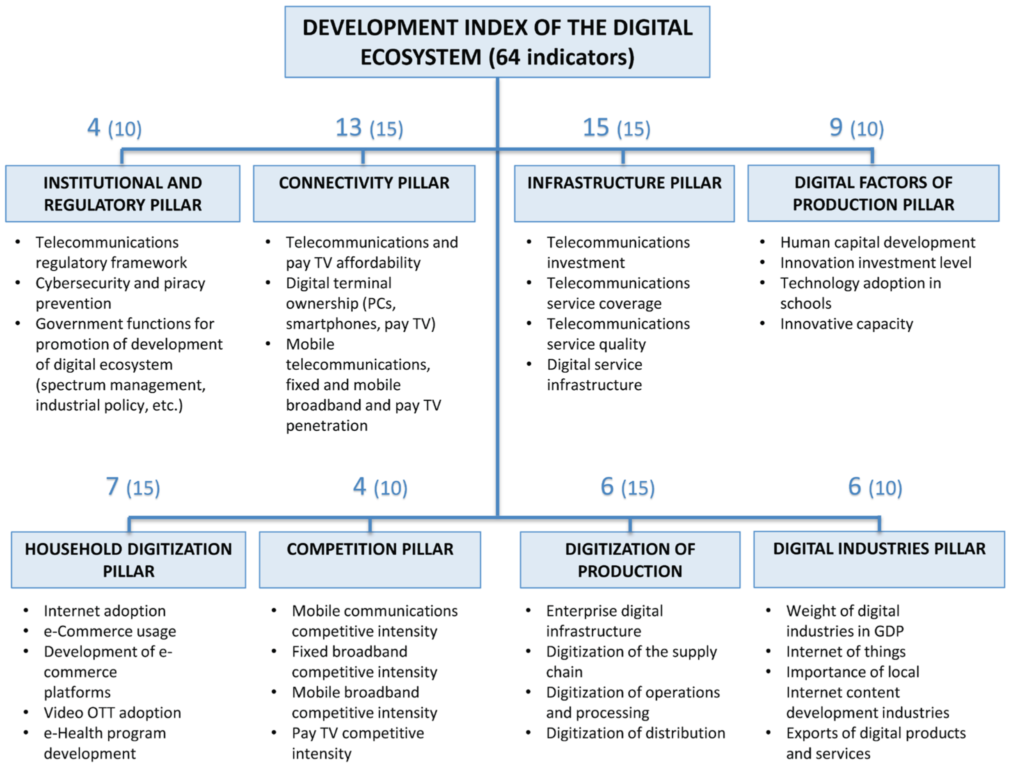
To test these hypotheses, the digital ecosystem development index was relied on for 75 countries and was further built cross-sectional models to test its impact on variables such as GDP, employment and productivity[25].

The digital ecosystem development index was based on 64 indicators, for 75 developed and developing countries and emerging economies[26] between 2004 and 2015 (Figure 6). Countries included in each region are those with GDP per capita higher than USD 5 000 and a population of 5 000 000 or more. Figure 6 outlines the eight pillars of the enhanced digital ecosystem development index as well as main indicators in each pillar.

[25] Katz and Callorda (2017)

[26] See list of countries in Annex A.

Figure 6: Structure of the digital ecosystem development index



Note: Numbers in bold indicate total number of indicators within each pillar (some examples are included below each box), while the numbers in brackets represent the relative weight of the pillar for calculation of the index. See the full list of indicators in Annex A.

Source: Katz and Callorda (2017)

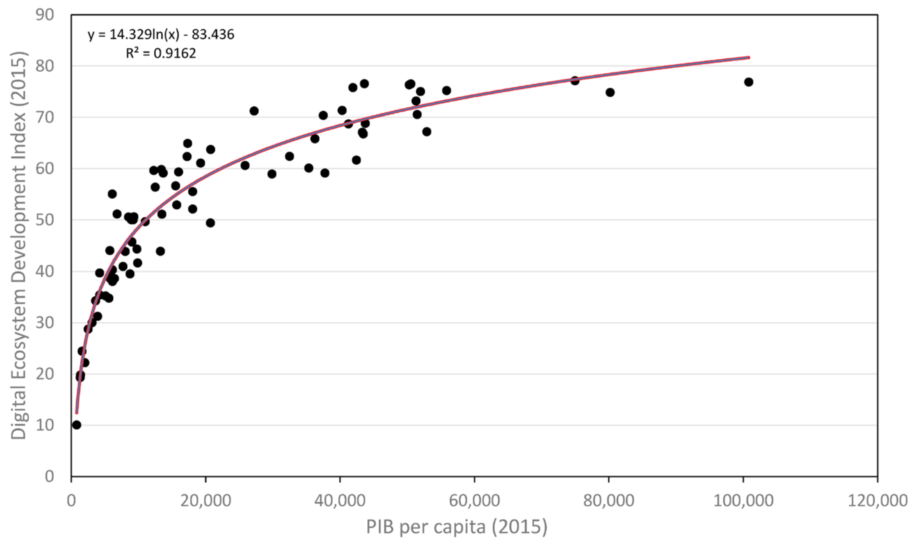
In this case, the following hypotheses were tested.

The economic impact of digitization is higher than that of broadband (first hypothesis)

As it would be expected, the development of a digital ecosystem is correlated with economic development, within the sample of 74 countries around the world[27]. The trend line in Figure 7 presents the correlation between GDP per capita and the digital ecosystem development index using 2015 data.

[27] One country was excluded because of lack of data.

Figure 7: Correlation between GDP per capita and digital ecosystem development index, 2015



Source: ITU research

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 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:

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

Where:

- $K_{(t)}$ measures the level of fixed capital formation
- $L_{(t)}$ measures labour force
- $A_{(t)}$ measures the 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.

The economic impact of digitization is guided by a return to scale effect (second hypothesis)

The hypothesis to be tested is whether the economic contribution of digitization increases at higher development stages. For this purpose, the above model was also run for OECD and non-OECD countries to test for a return to scale effect.

Digitization also has an impact on labour and total factor productivity, in addition to contribution to GDP growth (third hypothesis)

This was tested with the following model:

$$\text{Productivity}_{(t)} = \text{Growth of digitization}_{(t)} \ \text{digitization index}_{(t)}$$

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

$$\text{Log (Productivity}_{it}) = a_1 \log (\text{growth of digitization}_{it}) + a_2 \log (\text{digitization index}_{it}) + \varepsilon_{it}$$

3.2.2 Data

A list of the data series between 2004 and 2015 used to construct the digital ecosystem development index is included in Annex C.

3.2.3 Results and discussion

The economic impact of digitization is higher than that of broadband (first hypothesis)

The model was run for 73 countries (excluding two countries from the original sample due to missing values) for the period 2004-2015, which results in 803 observations, and includes fixed effects by country.

Table 7: Economic impact of digitization: General model

Variables, 2004-2015	General model
Previous GDP	0.7543 *** (0.1937)
Digitization	0.1331 *** (0.0438)
Capital	0.1043 *** (0.0199)
Labour	0.0093 (0.0380)
Constant	1.5027 *** (0.2091)
Observations	803
Year fixed effects	Yes

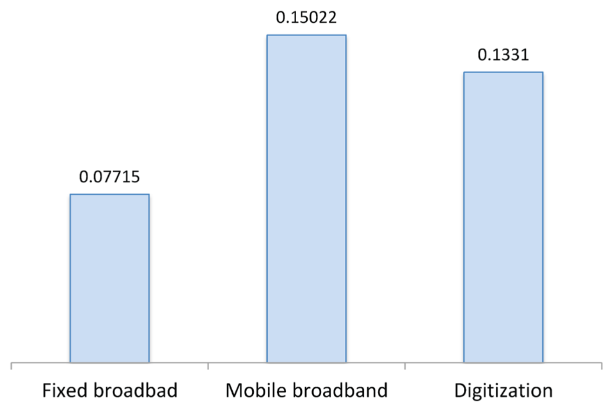
***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: Katz and Callorda (2017)

According to the model, an increase of 1 per cent in the digital ecosystem development index results in a 0.13 per cent growth in GDP per capita. This means, for example, that an increase in the digital ecosystem development index from 50 to 51 will yield an increase of per capita GDP of 0.26 per cent (accounting both for direct and indirect effects on output).

From a comparative standpoint, digitization has a larger economic contribution than fixed broadband, on par with that of mobile broadband, and Figure 8 shows the impact of a one per cent increase in fixed and mobile broadband and digitization.

Figure 8: Impact on GDP of 1 per cent increase in independent variable (2004-2015)



Source: ITU research

The economic impact of digitization is higher than those found in section 2 above for fixed broadband and similar to mobile broadband. This significant finding stipulates that the full economic impact of ICT is achieved through the cumulative adoption of all technologies, in addition to the assimilation and usage in the production and social fabric. Achieving broadband penetration is only one aspect of required policies; maximization of economic impact can only be achieved through a holistic set of policies ranging from telecommunications to computing to adoption of Internet and electronic commerce**.**

The economic impact of digitization is guided by a "return to scale" effect (second hypothesis)

The same model specified to test the first hypothesis was also run for OECD and non-OECD countries to test for a return to scale effect.

Table 8: Economic impact of digitization: Non-OECD country model

Variables, 2004-2015	OECD country model	Non-OECD country model
Previous GDP	0.6783 *** (0.0311)	0.7279 *** (0.0294)
Digitization	0.1351 * (0.0711)	0.1044 * (0.0592)
Capital	0.2105 *** (0.0291)	0.0471 * (0.0279)
Labour	-0.0736 (0.0502)	0.0581 (0.0544)
Constant	2.3371 *** (0.3823)	1.6827 *** (0.2821)
Observations	374	429
Year fixed effects	Yes	Yes

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: Katz and Callorda (2017)

The results indicate that the impact of the digital ecosystem on more advanced economies is higher than emerging countries. Thus, an increase of 1 per cent in the digital ecosystem development index yields an increase of 0.14 per cent in per capita GDP for OECD countries, while the impact of a similar change in non-OECD countries will be 0.10 per cent. In other words, the higher the economic development, the stronger the contribution of the digital ecosystem on economic growth.

As expected, the capital formation is positive and significant although this metric varies considerably across different social, demographic and economic settings. Along these lines, digitization has a disproportionately high effect for developed economies compared to the developing ones. Labour contribution to GDP is also consistent and significant; quality is often crucial in this case but the overarching concept is largely accepted.

Digitization also has an impact on labour and total factor productivity, in addition to contribution to GDP growth (third hypothesis)

A different model was also specified to test the impact of digitization on other economic variables such as labour productivity and total factor productivity.

Table 9: Digitization impact on productivity

Variables, 2004-2015	Labour productivity	Total factor productivity
Increase in digital ecosystem development index	0,2622 (0,0683)***	0,228 (0,0674)***
Digital ecosystem development index	0,0358 (0,0585)	0,0605 (0,0577)
Observations	201	201
R-square	0,6914	0,5832
Period fixed effects	Yes	Yes
Country fixed effects	Yes	Yes

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Note: In both models population and GDP control variables were included.

Source: Katz and Callorda (2017)

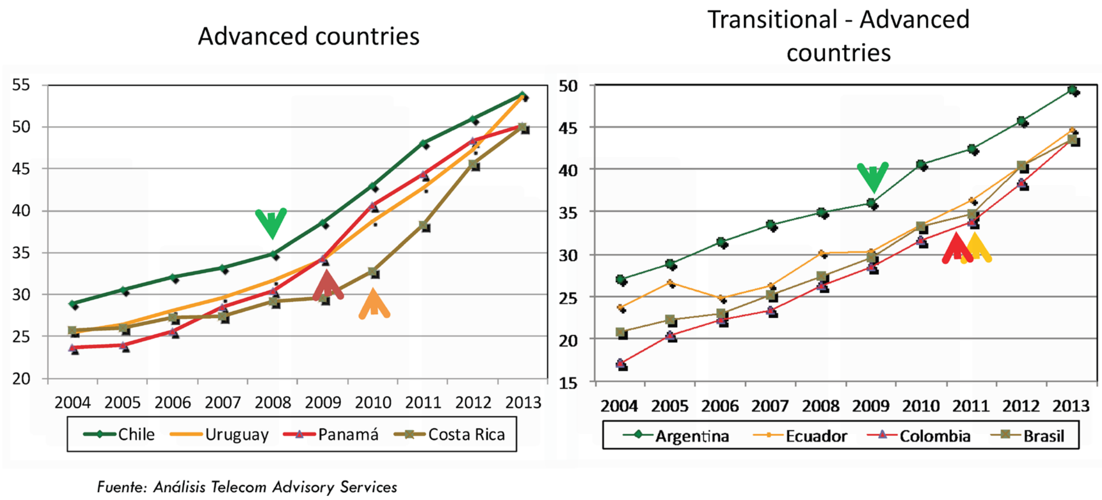
According to the models in Table 9, an increase in the digital ecosystem development index of 1 per cent yields an increase of 0.26 per cent in labour productivity, and 0.23 per cent in total factor productivity.

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

4.1 Regional analysis

Analysis of the digital ecosystem development index indicates that changes are driven not only by endogenous variables (such as economic growth, as demonstrated above) but also by institutional and regulatory factors. Accordingly, once a country introduces structural changes in its public policies, and in the institutional context influencing the diffusion and adoption of digital technologies, a change in the digital ecosystem development vector can be observed after a time lag. Figure 9 illustrates such changes to some digital ecosystems in a number of Americas region countries.

Figure 9: Evolution of the digital ecosystem development index (Latin America 2004-2013)



Source: Katz and Callorda (2015)

The analysis of the digitization index time series of Latin American countries included in Figure 9 indicates that at a certain point in time, digitization development appears to accelerate. This point in time can be associated to a modification in the policy and institutional context regarding the ICT sector, such as the launch of a broadband national plan or a change in ICT policy making institutions, as shown in Table 10.

Table 10: Political and institutional factors that impact the rate of change of the digitization index

Country	Change in digitization rate of development	CAGR		Political/institutional change
		Before	After	
Argentina	2009	6,00%	8,15%	• Development of "Argentina Conectada" Plan • Creation of general coordination of the "Argentina Conectada" Plan within the Planning Ministry
Brazil	2011	7,53%	11,99%	• Launch of the National Broadband Plan
Chile	2008	4,79%	9,10%	• Digital Agenda • Creation of an Interministerial Committee for Digital Development

Country	Change in digitization rate of development	CAGR		Political/institutional change
		Before	After	
Colombia	2011	10,22%	13,56%	• Creation of the ICT Ministry • Launch of the “Vive Digital” plan
Costa Rica	2010	4,06%	15,21%	• National broadband strategy • Transfer of Vice-Ministry of Telecommunications to the Ministry of Science and Technology
Ecuador	2011	6,32%	10,89%	• Launch of the “Ecuador Digital” Plan • Creation of the Ministry of Telecommunications and Information Society (8/2009)
Panamá	2008	6,45%	10,55%	• Plan "Internet for All" • Creation of the National Authority for Governmental Innovation (2009)
Uruguay	2009	6,09%	11,91%	• Launch of “Plan Ceibal”

Source: ITU research

As all countries in Table 10 show, the change in the digitization index growth CAGR is directly related to changes in the institutional and policy environment. This would imply that the variable has an impact on the rate of digitization growth. This impact can take place through different mechanisms:

- In some cases, changes of a policy and/or institutional nature yield an acceleration in public ICT investment, which results in an improvement in the network reliability and affordability sub-indices.
- In other cases, institutional changes yield a higher efficiency in the development of public policy initiatives; this could result in institutional centralization and/or policy coordination for the development of a national digital agenda or a broadband plan or the creation of legislative consensus. For example, in Colombia, the *Vive Digital* plan was launched by the ICT ministry created in 2010 with the stated purpose of universal Internet usage. The plan was coordinated with efforts in demand promotion, stimuli to the launch of start-ups focused on content and applications development, and a reduction of taxation on the purchase of ICT products and services.
- Yet in other situations, the institutional change implies the “signaling” sent by the public sector to private enterprises that ICT and digital development represent a key factor in the development of the country; in a response to this “signal” the private sector (operators and other Internet

players) react positively accelerating their investment level and commercial aggressiveness. Thus, the public initiative may act as an implicit multiplier.

As expected, all three effects could manifest themselves simultaneously.

4.2 Review of the research literature

There is some evidence regarding the impact of the regulatory and/or institutional framework on service adoption and sector economic performance. Initially, research focused on testing the importance of the regulatory variable in explaining telecommunication sector development. As the theory postulates, if the telecommunication sector comprises a number of competing private sector operators, the presence of an independent regulator is critical to prevent the emergence of any market failures.

While this concept is valid and supported by the theory of competition, the econometric evidence conducted so far to measure the importance of the regulatory variable on telecommunication sector development is less conclusive[28]. Theoretically, telecommunication sector regulatory enforcement and efficiency benefit consumers by leading to wireless price reduction and, consequently enhancing service adoption.

Similarly, an improved institutional framework (e.g. independent regulatory authority, lower corruption, and contract enforcement) has been shown to lead to better telecommunication sector performance[29].

On the other hand, it has also been shown that investment in the telecommunication sector is more influenced by economic and demographic variables (that is to say market potential) than by institutional variables[30]. Likewise, while the degree of regulatory independence has some impact on the development of the telecommunication sector, an important portion of the variance of this development is not explained by the independent variable[31]. This is where aspects such as regulatory framework and enforcement power of the authority come into play.

Beyond the importance of the regulatory framework, specific policies have been found to exert significant impact on telecommunication service adoption and sector economic performance. For example, competition in wireline has a positive statistically significant impact on network deployment[32].

In the case of wireless, the policy framework was found to have an impact on the diffusion and pricing of wireless services. For example, competition and number portability (when combined with regulatory autonomy) have a positive impact on wireless prices and penetration, while number portability has a negative impact on prices[33].

In the case of broadband, access regulation discourages investment by incumbents and individual entrants even as entrants total investments increase. With very few caveats, platform-based competition appears to be the key variable explaining broadband deployment[34]. It has also been shown that the impact of platform-based competition is stronger when the share of technologies reaches parity (this is related to competitive intensity)[35]. The only study that failed to identify an impact of competition policy on broadband penetration could be related to the early time at which the research was

---

28 Levy and Spiller (1996)
29 Maiorano et al. (2007); Waverman et al. (2007)
30 Gutierrez and Berg (1998)
31 Baudrier (2001)
32 Li et al. (2004); Grzybowski (2008); Wallsten (2001)
33 Maiorano et al. (2007); Grzybowski (2005)
34 Distaso et al. (2006), Cava-Ferreruela et al. (2006), Boyle (2008), Wallsten (2006) and Garcia-Murillo (2005), in the case of high-income countries
35 Lee et al. (2008)

conducted therefore relying on very preliminary data sets[36], others have determined that unbundling prices had a positive impact on broadband availability[37].

Beyond these findings, the impact of policy on the level of innovation as well as the comprehensive impact of all policy variables on sector performance has not been yet fully analyzed. More specifically, research on the assessment of the impact of policy variables on the rate of sector innovation is non-existent. Similarly, there is limited analysis on the impact of trade regulation on sector performance.

Finally, no comprehensive study between all regulatory and policy variables and full digital sector performance has been identified. This has led to quantitative analysis focusing on areas that require additional insight in terms of the relationship between policy and digital eco-system performance.

4.3 Econometric models

The following analysis relies on the ICT regulatory tracker as the independent variable to test its impact on the digital ecosystem development index. For this purpose, two models were developed initially: the first tests the correlation between the ICT regulatory tracker and the digital ecosystem development index. The underlying premise is that higher regulatory performance is directly related to the development of the digital economy:

$$\mathrm{Dig.\,Index}_{it} = \beta_1 \mathrm{Reg.\,Index}_{it} + \mathrm{Year\ F.E.} + \mathrm{Country\ F.E.} + e_{it}$$

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

$$\mathrm{Dig.\,Index}_{it} = \beta_1 \mathrm{Reg.\,Index}_{it} + \beta_2 \mathrm{Reg.\,Index}_{it-1} + \mathrm{Year\ F.E.} + \mathrm{Country\ F.E.} + e_{it}$$

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

$$\ln(\mathrm{Dig.\,Index}_{it}) = \beta_1 \ln(\mathrm{Dig.\,Index}_{it-1}) + \beta_2 \ln(\mathrm{Reg.\,Index}_{it-1}) + \mathrm{Year\ F.E.} + \mathrm{Country\ F.E.} + e_{it}$$

4.4 Data

The models use the ICT regulatory tracker and the digital ecosystem development index for the period 2007-2015. As indicated in the section above, the digital ecosystem development index includes an institutional and regulatory pillar, which would have to be excluded in order to avoid co-linearity. Once that is done and the index is recalculated, it would be possible to test the impact of the ICT regulatory tracker on digitization.

4.5 Results and discussion

The correlational model determined that one point in the ICT regulatory tracker yields a 0.4895 point increase in the digital ecosystem development index (without the regulatory pillar).

36 Bauer et al. (2004)

37 Ford and Spiwak (2004)

Table 11: Correlation between the ICT regulatory tracker and the digital ecosystem development index (without the regulatory pillar)

Digital ecosystem development index (without the regulatory pillar)	Coefficient (standard deviation)
ICT regulatory tracker	0.4895 (0.0202)***
Constant	8.8008 (1.4289) ***
R-square	0.4955
Fixed effects for year and country	Yes
Countries	75
Observations	675
Years	2007-2015

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

In order to test for the causal link, a control of a one-year lag of the ICT regulatory tracker was added.

Table 12: Impact of the lagged ICT regulatory tracker on the digital ecosystem development index (without the regulatory sub-index)

Digital ecosystem development index (without the regulatory sub-index)	Coefficient (Standard deviation)
Digital ecosystem development index (w/o regulation pillar)	0.2352 (0.0373)***
ICT regulatory tracker (t-1)	0.2862 (0.0310)***
Constant	7.6562 (1.6573) ***
R-squared	0.5232
Fixed effects for year and country	Yes
Groups	75
Observations	600
Years	2008-2015

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

In this model, an additional point in the ICT regulatory tracker yields a 0.2352 points higher in the digital ecosystem development index (without the regulatory sub-index) in the same period and 0.2862 higher in the subsequent period, which, by adding both effects, yields a total coefficient of 0.5214.

Considering that the two previous models test the correlation between both indices, the model is specified through logarithms of all variables to assess change, and also the digital ecosystem development index is recalculated without the regulatory and the competition pillars (since the potential with co-linearity with the ICT regulatory tracker is high).

Table 13: Impact of the lagged ICT regulatory tracker on the digital ecosystem development index (without regulatory and competition pillars)

Log Digital ecosystem development index (without the regulatory and competition pillars)	Coefficient (Standard deviation)
Log digital ecosystem development index (w/o regulation and competition pillars) (t-1)	0.9349 (0.0138)***
Log ICT regulatory tracker (t-1)	0.0348 (0.0111)***
Constant	0.0609 (0.0438)
R-squared	0.9342
Fixed effects for year and country	Yes
Groups	75
Observations	600
Years	2008-2015

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

This case proves the hypothesis: An increase of 1 per cent in the ICT regulatory tracker yields a positive increase in the ecosystem development index of 0.0348 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 were run.

Table 14: Correlations between ICT regulatory tracker and digital ecosystem development index pillars

Pillars	ICT regulatory tracker	ICT regulatory tracker (w/o Competition component)	Regulatory authority component	Regulatory mandate component	Regulatory regime component	Competition framework component
Digital ecosystem development index	0.5109 (0.0277) ***	0.4353 (0.0246) ***	0.3565 (0.0427) ***	0.3600 (0.0271) ***	0.3429 (0.0155) ***	0.3637 (0.0266) ***

Pillars	ICT regulatory tracker	ICT regulatory tracker (w/o Competition component)	Regulatory authority component	Regulatory mandate component	Regulatory regime component	Competition framework component
Infrastructure of Digital Services	0.6394 (0.0434) ***	0.5769 (0.0378) ***	0.4649 (0.0629) ***	0.4767 (0.0400) ***	0.4294 (0.0241) ***	0.4141 (0.0405) ***
Connectivity of Digital Services	0.8058 (0.0538) ***	0.6764 (0.0479) ***	0.5791 (0.0802) ***	0.5484 (0.0515) ***	0.5811 (0.0299) ***	0.6067 (0.0497) ***
Household digitization	0.7179 (0.0375) ***	0.6030 (0.0337) ***	0.5478 (0.0590) ***	0.5189 (0.0367) ***	0.4521 (0.0219) ***	0.5094 (0.0363) ***
Digitization of production	0.3214 (0.0396) ***	0.2956 (0.0345) ***	0.1785 (0.0523) ***	0.2384 (0.0358) ***	0.2388 (0.0236) ***	0.1777 (0.0360) ***
Digital Competitive Intensity	0.3076 (0.0343) ***	0.2563 (0.0304) ***	0.1851 (0.0462) ***	0.1832 (0.0312) ***	0.1988 (0.0203) ***	0.2397 (0.0301) ***
Development of Digital Industries	0.3419 (0.0377) ***	0.3011 (0.0330) ***	0.2370 (0.0523) ***	0.2584 (0.0342) ***	0.2191 (0.0229) ***	0.2384 (0.0341) ***
Digital factors of production	0.7688 (0.0472) ***	0.6403 (0.0422) ***	0.5025 (0.0721) ***	0.5386 (0.0454) ***	0.5151 (0.0271) ***	0.6228 (0.0430) ***

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

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

Source: ITU research

As indicated in Table 14, an increase in the ICT regulatory tracker (with and without the competition pillar) is positively and significantly correlated with an increase in the digital ecosystem development index as well as with every one of its pillars. In particular, an increase in the ICT regulatory tracker is signficantly correlated (with a coefficient higher than 0.60) with an increase in the pillars measuring the development of infrastructure of digital services, connectivity of digital services, household digitization and digital factors of production.

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 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 shows that the regulatory regime component of the ICT regulatory tracker appears to be the main path of impact of the digital ecosystem development index.

Table 15: Impact of the ICT regulatory tracker components of the digital ecosystem development index pillars

	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	-0.1646 (0.0507) ***	-0.2209 (0.0806) ***	-0.2255 (0.0992) **	-0.1743 (0.0743) **	-0.1974 (0.0765) **	-0.0746 (0.0669)	-0.1162 (0.0777)	-0.3123 (0.0907) ***
Regulatory mandate component	-0.0899 (0.0463) *	-0.0980 (0.0736)	-0.3433 (0.0906) ***	-0.0084 (0.0679)	0.0000 (0.0698)	-0.1927 (0.0610) ***	0.0831 (0.0710)	-0.0934 (0.0828)
Regulatory regime component	0.4207 (0.0244) ***	0.5253 (0.0389) ***	0.7966 (0.0479) ***	0.4983 (0.0359) ***	0.2701 (0.0369) ***	0.2983 (0.0322) ***	0.2011 (0.0375) ***	0.6356 (0.0438) ***
Constant	3.1659 (0.0978) ***	2.7548 (0.1558) ***	3.0748 (0.1914) ***	2.6408 (0.1434) ***	3.3221 (0.1476) ***	4.0243 (0.1297) ***	2.7272 (0.1499) ***	2.6227 (0.1750) ***
Observations	656							
R-squared	0.4730	0.3599	0.4188	0.4189	0.1476	0.1589	0.1271	0.3947

***, **, * Significant at 1 per cent, 5 per cent, and 10 per cent critical value respectively.

Source: ITU research

Table 15 indicates that the regulatory regime component always has a positive and significant impact on every single pillar of the digital ecosystem development index[38]. This could indicate that this could be the component that has a higher impact on digital development[39].

5 Conclusions

The purpose of this study was to provide additional evidence based on econometric modelling of the impact of broadband and digital transformation on the economy and the impact of institutional and regulatory variables on the growth of the digital ecosystem. The analysis conducted has yielded the following conclusions:

- **The economic impact of fixed and mobile broadband**: Large data sets tested whether the economic impact of broadband is increasing with penetration (the return to scale effect), or whether broadband economic impact is undergoing a saturation effect and, therefore, diminishing returns.

  In the first place, fixed broadband has had a significant impact on the world economy during the last seven years (2010-2017). An increase of 1 per cent in fixed broadband penetration yields an increase in 0.08 per cent in GDP.

  Secondly, according to the mobile broadband model, an increase of 1 per cent in mobile broadband penetration yields an increase in 0.15 per cent in GDP.

38 The regulatory regime component includes indicators such as type of licenses provided to offer telecommunications 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.

39 While the first two components of the ICT regulatory tracker has sometimes a negative sign, the coefficient of regulatory regime and regulatory mandate is always bigger and positive.

Third, fixed broadband economic impact is guided by a return to scale effect, according to which the economic impact of fixed broadband is higher in more developed countries than in less developed. On the other hand, 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.

- **The economic impact of digitization**: the purpose of this analysis was to determine the impact of digitization on GDP, and productivity.

  First, the economic impact of digitization is higher than the one found for fixed broadband and similar to mobile broadband. An increase of 1 per cent in the digital ecosystem development index results in a 0.13 per cent growth in GDP per capita.

  Second, the impact of the digital ecosystem on more advanced economies is higher than developing countries. An increase of 1 per cent in the digital ecosystem development index yields an increase of 0.14 per cent in per capita GDP for OECD countries, while the impact of a similar change in non-OECD countries will have a 0.10 per cent increase.

  Third, the digital ecosystem has an economic impact on productivity (both labour and total factor). An increase in the digitization index of 1 per cent yields an increase in labour productivity of 0.26 per cent and in total factor productivity of 0.23 per cent.

- **The impact of policy and regulatory framework on the growth of markets for digital services and applications**: In this analysis, the impact of regulation and institutions on the development of the digital economy were tested. The analysis provided further evidence of the importance of the regulatory and institutional variable in driving digital ecosystem growth. An increase of 1 per cent in the ICT regulatory tracker yields a positive increase in the ecosystem development index of 0.0348 per cent in the subsequent time period. Furthermore, an increase in the ICT regulatory tracker is signficantly correlated (with a coefficient higher than 0.60) with an increase in the pillars measuring the development of infrastructure of digital services, connectivity of digital services, household digitization and digital factors of production. Furthermore, the cluster analysis of the tracker shows that the regulatory regime component always has a positive and significant impact on every pillar of the digital ecosystem development index. This could indicate that the regulatory regime in place could be the component that has higher impact on digital development than the structure, autonomy, and mandate of the regulatory authority.

Annex A: List of countries analyzed in the economic impact of fixed and mobile broadband

- Argentina
- Australia
- Austria
- Azerbaijan
- Barbados
- Belarus
- Belgium
- Bolivia
- Brazil
- Bulgaria
- Canada
- Chile
- China
- Colombia
- Costa Rica
- Côte d'Ivoire
- Cuba
- Czech Republic
- Denmark
- Dominican Rep.
- Ecuador
- Egypt
- El Salvador
- Estonia
- Finland
- France
- Germany
- Greece
- Guatemala
- Haiti
- Honduras
- Hong Kong, China
- Hungary
- Iceland
- India
- Ireland
- Israel
- Italy
- Jamaica
- Japan
- Kazakhstan
- Kenya
- Korea (Rep.)
- Latvia
- Lebanon
- Luxembourg
- Malaysia
- Mexico
- Netherlands
- New Zealand
- Nicaragua
- Norway
- Panama
- Paraguay
- Peru
- Poland
- Portugal
- Romania
- Russian Federation
- Saudi Arabia
- Singapore
- Slovakia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Thailand
- Trinidad and Tobago
- Turkey
- United Arab Emirates
- United Kingdom
- United States of America
- Uruguay
- Venezuela

Annex B: 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 C: Indicators included in digital ecosystem development index

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	Fiber 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

Pillar	Sub-pillar	Indicator	Source
Factors of digital production	Economic development	Electric energy consumption (kWh per capita)	World Bank
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

Bibliography

Andrianaivo, M. and Kpodar, K. (2001). *ICT, Financial Inclusion and Growth: Evidence from African Countries*. IMF Working Paper WP/11/73.

Arvin, M. and Pradhan, R. (2014) "Broadband penetration and economic growth nexus: evidence from cross-country panel data". *Journal of Applied Economics*, Volume 46- Issue 35

Atkinson, R., Castro, D. and Ezell, S.J. (2009). *The digital road to recovery: a stimulus plan to create jobs, boost productivity and revitalize America*. The Information Technology and Innovation Foundation, Washington, DC.

Baudrier, A. (2001). *Independent regulation and telecommunications performance in developing countries*. Presentation to the Annual ISNIE Conference: Institutions and Governance. Berkeley, California, September 13-15

Bauer J., Kim J and Wildman S. (2004). *Effects of national policy on the diffusion of broadband in OECD countries.* Paper prepared for presentation at the UFL-LBS workshop "The Future of Broadband: Wired and Wireless" Gainesville, FL, February 24-25.

Boyle G., Howell B., and Zhang W. (2008) *Catching Up in Broadband Regressions: Does Local Loop Unbundling Really Lead to Material Increases in OECD Broadband Uptake?* NZ Institute for the Study of Competition and Regulation

Cava-Ferreruela I., Alabau-Munoz A. (2006) "Broadband policy assessment: A cross-national empirical analysis" *Telecommunications Policy* 30, 445–463

Czernich, N., Falck, O., Kretschmer T., and Woessman, L. (2009, December). *Broadband infrastructure and economic growth* (CESifo Working Paper No. 2861). Retrieved from www.ifo.de/DocCIDL/cesifo1_wp2861.pdf

Distaso W, Lupi P., and Manenti F., (2006) "Platform competition and broadband uptake: Theory and empirical evidence from the European Union" *Information Economics and Policy* 18, p 87–106

Freeman, C. and Perez, C. (1988), 'Structural crises of adjustment, business cycles and investment behavior', in G.Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds.), Technical Change in the Twenty-first Century, London: Pinter.

Garbacz and Thompson (2008). "Broadband Impacts on State GDP: Direct and Indirect Impacts", Paper submitted to the Telecommunications Policy Research Conference.

Garcia-Murillo M. (2005). "International Broadband Deployment: The Impact of Unbundling" *Communications & Strategies*, No 57 1st quarter.

Gillett, S., Lehr, W., Osorio, C., and Sirbu, M. A. (2006). *Measuring Broadband's Economic Impact.* Technical Report 99-07-13829, National Technical Assistance, Training, Research, and Evaluation Project.

Gruber, H., and Koutroumpis, P. (2011). "Mobile Telecommunications and the impact on Economic Development". *Telecommunications Policy*, *67*, 278-286.

Gutierrez, L. H. y Berg, S. (1998). *Telecommunications liberalization and regulatory governance: lessons from Latin America*. Presentation a Conference on Privatization, Deregulation and Institutional Framework sponsored by the Institute of Developing Economies, Tokyo, December 7-8, 1998.

Grzybowski L. (2005). "Regulation of mobile Telephony across the European Union: An Empirical Analysis" *Journal of Regulatory Economics*; 28:1 47-67.

Grzybowski L. (2008). “The impact of regulation on the retail prices on fixed-line telephony across the European Union” *Telecommunications Policy* 32, 131-144.

Gutierrez L. (2003). “The Effect of Endogenous Regulation on Telecommunications Expansion and Efficiency in Latin America” *Journal of Regulatory Economics* 23:3 257-286.

Hardy, (1980). “The role of the telephone in Economic Development”, *Telecommunications Policy*, 4 (4), pp.278-286.

Jensen, R. (2007). “The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector”. *Quarterly Journal of Economics*, *122*(3), 879-924.

Karner, J and Onyeji, R. (2007). *Telecom Private Investment and Economic Growth: the case of African and Central & East European Countries*. Jonkoping International Business School

Kathuria, R., Uppal, M., and Mamta, M. (2009). *An Econometric Analysis of the Impact of Mobile*, The Vodafone Policy Paper Series (9), pp. 5-20.

Katz, R. (2011). "The impact of broadband on the economy: research to date and

policy issues", *Trends in Telecommunication reform 2010-11*. Geneva: International Telecommunication Union.

Katz, R. (2012). *The impact of broadband on the economy: research to date and policy issues*. Geneva: International Telecommunications Union.

Katz, R. (2015). *La economía y el ecosistema digital en América Latina.* Madrid: Ariel.

Katz, R. and Suter, S. (2009). *Estimating the economic impact of the broadband stimulus plan*. Presentation at the National Press Club, Washington, DC, February 19.

Katz, R. , Vaterlaus, S., Zenhäusern, P. and Suter, S. (2012). “The Impact of Broadband on Jobs and the German Economy”. *Intereconomics*, 45 (1), 26-34.

Katz, R. and Koutroumpis, P. (2012a). *The economic impact of broadband on the Philippines*. Geneva: International Broadband Commission.

Katz, R. and Koutroumpis, P. (2012b). “The economic impact of telecommunications in Senegal”, *Digiworld Economic Journal*, no. 86, 2nd Q.

Katz, R. and Koutroumpis, P. (2013a). “Measuring digitization: a growth and welfare multiplier”. *Technovation* 33 (10), 314-319, 2013.

Katz, R., Koutroumpis, P. and Callorda, F. (2013b), “The Latin American path towards digitization”. *Info*, Vol. 15, No. 3, pp. 6-24.

Katz, R., Koutroumpis, P. and Callorda, F. (2014). “Using a digitization index to measure the economic and social impact of digital agendas”, *Info*, Vol. 16, No. 1, pp. 32-44.

Katz, R. and Berry, T. (2014*). Driving demand for broadband services*. London: Springer.

Katz, R. and Callorda, F. (2014). *Assessment of the Economic Impact of Telecommunications in Senegal (2003-2014)*. Columbia Institute for Tele-information Working Paper.

Katz, R. and Callorda, F. (2016). *Assessment of the Economic Impact of Telecommunications in Senegal (2003-2014)*. Columbia Institute for Tele-information Working Paper.

Katz, R. and Callorda, F. (2017). “Accelerating the development of Latin American digital ecosystem and implications for broadband policy”, *Telecom Policy* (in print)

Koutroumpis, P. (2009). The Economic Impact of Broadband on Growth: A Simultaneous Approach. *Telecommunications Policy*, 33, 471-485.

Levy, Brian, and Pablo T. Spiller. (1996). Regulations, Institutions, and Commitment: Comparative Studies of Telecommunications. New York: Cambridge University Press.

Li W., and Xu L.(2004) "The impact of privatization and competition in the telecommunications sector around the world" *Journal of Law and Economics* 47, 395-430

Maiorano F., Stern J. (2007) *Institutions and Telecommunications Infrastructure in Low and Middle-Income Countries: The Case of Mobile Telephony* AEI-Brookings Joint Center for Regulatory Studies. May.

Qiang, C. Z., and Rossotto, C. M. (2009). Economic Impacts of Broadband. In *Information and Communications for Development 2009: Extending Reach and Increasing Impact*, 35–50.Washington, DC: World Bank

Roeller, L-E, and Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *The American Economic Review*, 91 (4), 909-923.

Sabbag, K., Friedrich, R., El-Darwiche, B., Singh, M., Ganediwalla, S. and Katz, R. (2012), ''Maximizing the impact of digitization'', in Dutta, S. and Bilbao-Osorio, B. (Eds.), *The Global Information Technology Report 2012*, World Economic Forum and Insead, Geneva.

Shideler, D., Badasyan, N., and Taylor, L. (2007, September 28-30). "The economic impact of broadband deployment in Kentucky". *Telecommunication Policy Research Conference*, Washington D.C.

Shiu, A., and Lam, P. (2008, June 25). "Relationships between Economic Growth, Telecommunications Development and Productivity Growth: Evidence around the World". In *Africa-Asia-Australasia Regional Conference of the International Telecommunications Society*. Retrieved from www.apeaweb .org/confer/hk10/papers/shiu_alice.pdf

Wallsten S. (2001). "An Econometric Analysis of Telecom Competition Privatization Competition Privatization and Regulation in Africa and Latin America" *The Journal of Industrial Economics*, XLIX, March.

Wallsten S. (2006) *Broadband and Unbundling Regulations in OECD Countries* AEI-Brookings Joint Center for Regulatory Studies. Working Paper 06-16 June.

Waverman L., Meschi M., Reillier B and Dasgupta K. (2007). *Access Regulation and Infrastructure Investment in the Telecommunication Sector: An Empirical Investigation*. LECG Ltda.

Telecommunication Development Bureau (BDT)
Office of the Director
Place des Nations
CH-1211 Geneva 20 – Switzerland
Email: bdtdirector@itu.int
Tel.: +41 22 730 5035/5435
Fax: +41 22 730 5484

Deputy to the Director and Chief，Administration and Operations Coordination Department (DDR)
Email: bdtdeputydir@itu.int
Tel.: +41 22 730 5784
Fax: +41 22 730 5484

Infrastructure Enabling Environment and e-Applications Department (IEE)
Email: bdtiee@itu.int
Tel.: +41 22 730 5421
Fax: +41 22 730 5484

Innovation and Partnership Department (IP)
Email: bdtip@itu.int
Tel.: +41 22 730 5900
Fax: +41 22 730 5484

Projects and Knowledge Management Department (PKM)
Email: bdtpkm@itu.int
Tel.: +41 22 730 5447
Fax: +41 22 730 5484

Africa

Ethiopia
International Telecommunication Union (ITU)
Regional Office
P.O. Box 60 005
Gambia Rd., Leghar ETC Building
3rd floor
Addis Ababa – Ethiopia

Email: ituaddis@itu.int
Tel.: +251 11 551 4977
Tel.: +251 11 551 4855
Tel.: +251 11 551 8328
Fax: +251 11 551 7299

Cameroon
Union internationale des télécommunications (UIT)
Bureau de zone
Immeuble CAMPOST, 3e étage
Boulevard du 20 mai
Boîte postale 11017
Yaoundé – Cameroun

Email: itu-yaounde@itu.int
Tel.: + 237 22 22 9292
Tel.: + 237 22 22 9291
Fax: + 237 22 22 9297

Senegal
Union internationale des télécommunications (UIT)
Bureau de zone
8, Route du Méridien
Immeuble Rokhaya
B.P. 29471 Dakar-Yoff
Dakar – Sénégal

Email: itu-dakar@itu.int
Tel.: +221 33 859 7010
Tel.: +221 33 859 7021
Fax: +221 33 868 6386

Zimbabwe
International Telecommunication Union (ITU)
Area Office
TelOne Centre for Learning
Corner Samora Machel and Hampton Road
P.O. Box BE 792 Belvedere
Harare – Zimbabwe

Email: itu-harare@itu.int
Tel.: +263 4 77 5939
Tel.: +263 4 77 5941
Fax: +263 4 77 1257

Americas

Brazil
União Internacional de Telecomunicações (UIT)
Regional Office
SAUS Quadra 06, Bloco "E"
10º andar, Ala Sul
Ed. Luis Eduardo Magalhães (Anatel)
70070-940 Brasilia, DF – Brazil

Email: itubrasilia@itu.int
Tel.: +55 61 2312 2730-1
Tel.: +55 61 2312 2733-5
Fax: +55 61 2312 2738

Barbados
International Telecommunication Union (ITU)
Area Office
United Nations House
Marine Gardens
Hastings, Christ Church
P.O. Box 1047
Bridgetown – Barbados

Email: itubridgetown@itu.int
Tel.: +1 246 431 0343/4
Fax: +1 246 437 7403

Chile
Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Merced 753, Piso 4
Casilla 50484, Plaza de Armas
Santiago de Chile – Chile

Email: itusantiago@itu.int
Tel.: +56 2 632 6134/6147
Fax: +56 2 632 6154

Honduras
Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Colonia Palmira, Avenida Brasil
Ed. COMTELCA/UIT, 4.º piso
P.O. Box 976
Tegucigalpa – Honduras

Email: itutegucigalpa@itu.int
Tel.: +504 22 201 074
Fax: +504 22 201 075

Arab States

Egypt
International Telecommunication Union (ITU)
Regional Office
Smart Village, Building B 147, 3rd floor
Km 28 Cairo – Alexandria Desert Road
Giza Governorate
Cairo – Egypt

Email: itu-ro-arabstates@itu.int
Tel.: +202 3537 1777
Fax: +202 3537 1888

Asia and the Pacific

Thailand
International Telecommunication Union (ITU)
Regional Office
Thailand Post Training Center, 5th floor,
111 Chaengwattana Road, Laksi
Bangkok 10210 – Thailand

Mailing address
P.O. Box 178, Laksi Post Office
Laksi, Bangkok 10210 – Thailand

Email: itubangkok@itu.int
Tel.: +66 2 575 0055
Fax: +66 2 575 3507

Indonesia
International Telecommunication Union (ITU)
Area Office
Sapta Pesona Building, 13th floor
JI. Merdan Merdeka Barat No. 17
Jakarta 10110 – Indonesia

Mailing address:
c/o UNDP – P.O. Box 2338
Jakarta 10110 – Indonesia

Email: itujakarta@itu.int
Tel.: +62 21 381 3572
Tel.: +62 21 380 2322/2324
Fax: +62 21 389 05521

CIS countries

Russian Federation
International Telecommunication Union (ITU)
Area Office
4, Building 1
Sergiy Radonezhsky Str.
Moscow 105120
Russian Federation

Mailing address:
P.O. Box 47 – Moscow 105120
Russian Federation

Email: itumoskow@itu.int
Tel.: +7 495 926 6070
Fax: +7 495 926 6073

Europe

Switzerland
International Telecommunication Union (ITU)
Telecommunication Development Bureau (BDT)
Area Office
Place des Nations
CH-1211 Geneva 20 – Switzerland
Switzerland

International Telecommunication Union
Telecommunication Development Bureau
Place des Nations
CH-1211 Geneva 20
Switzerland

ISBN: 978-92-61-27711-6

9 789261 277116

Published in Switzerland
Geneva, 2018