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The impact of digital transformation on the economy

Econometric modelling

April 2025

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Foreword

This research applies econometric modelling techniques to examine the economic contribution of fixed and mobile broadband as well as digitization around the world. Building on a series of studies published by the ITU Telecommunication Development Bureau (BDT) it provides significant evidence on the economic importance of ICT.

The findings underscore the critical role of ICT in driving future global economic growth. As digital infrastructure continues to expand, new opportunities emerge for innovation, productivity, and inclusion. While the pace of growth has moderated, the ICT sector remains a fundamental pillar of economic transformation, with ongoing advancements in connectivity and technology expected to sustain its long-term impact.

The initial surge in broadband service adoption, driven by the pandemic, has since slowed. However, the adoption of these services is still progressing, fuelled by increasing service coverage and affordability. A significant driver of the ongoing increase in broadband adoption has been the reduction in service prices. Maintaining this affordability will be crucial for sustaining the upward trajectory of ICT adoption worldwide.

The confirmed economic benefits of ICT underscore the importance of policy measures aimed at bridging the digital divide. To achieve this, it is relevant to implement initiatives that reverse the decline in capital spending and stimulate investment, ensuring the continuous expansion of infrastructure.

I hope this report will serve stakeholders in the ICT sector and beyond to further explore these economic trends and identify opportunities for improving digital transformation initiatives.

Dr Cosmas Luckyson Zavazava
Director of the Telecommunication Development Bureau
International Telecommunication Union

Executive summary

The following research applies econometric modelling techniques to examine the economic contribution of fixed and mobile broadband as well as digitization around the world through the end of 2023. A series of studies published by the ITU Telecommunication Development Bureau (BDT) between 2018 and 2021 estimated through quantitative analysis the economic contribution of broadband and digitization.[1] Supported by econometric models built with data from a sample of up to 139 countries between 2010 and 2020[2], the studies provided significant evidence on the economic importance of ICT before the pandemic and as a builder of resilience during COVID-19, these studies will be referred to collectively hereinafter as "the 2021 study" (the year the global summary was published). Since 2021 the threat of COVID-19 has been receding, and this raises two critical questions:

- Will the ICT industry and consumers return to their pre-pandemic behaviour and trends or, alternatively, have the changes originated in 2020 become a permanent fixture of the sector going forward?
- Accordingly, have the estimates of ICT economic impact generated at the time of the pandemic, fostered by the significant increase in adoption registered in 2020, declined in 2021, 2022 and 2023?

With the objective to addresses these questions and building on the 2021 study, the following research relies on similar econometric models and examines the fixed and mobile broadband as well as digitization impact on the economy through the end of 2023.

The boost to broadband that started in 2020 in response to COVID-19 is slowing down, although adoption is still growing thanks to improved affordability and coverage:

- As documented in the 2021 study, **fixed broadband** adoption jumped in 2020 because, under lockdown conditions, even late adopters had to resort to the service to keep up with impacted activities including telework, education, commerce and telemedicine. Since then, the global figure for fixed-broadband connectivity has continued to grow, reaching 70.55 per cent of households in 2023. The rate of growth has decreased, however, possibly a sign that the connectivity needs have largely been met (in other words, a diminished need for additional digital service is behind the slowing rate of growth of fixed broadband). The same trend can be seen in all regions except for Africa, where the rate of growth in connectivity has increased between 2022 and 2023.
- In the case of **mobile broadband**, the 2023 statistics for unique mobile subscribers (as opposed to total connections, which would include IoT cards and dual phone ownership, among other drivers) indicate a continuing growth pattern worldwide, although the year-to-year growth rate in some regions continues to decline, indicating either saturation (in advanced economies) or the persistence of supply-side barriers (such as service coverage limitations, in some developing and least developed countries, or affordability constraints in the developing world, as detailed below). Growth rates for last year remain vigorous in Africa, the Arab States and the Asia and Pacific countries.

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[1] See the ITU series entitled *The economic contribution of broadband, digitization and ICT regulation and Regional Econometric Modelling*. The reports are available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx.

[2] Note that the studies relied on data sets through 2017 and 2020.

- **Pricing reduction also contributed** to the ongoing **growth** in broadband adoption, enabled by lower prices for services and packages. In the context of increasing income per capita in the world, **fixed-broadband prices**[3] **as a percentage of gross national income (GNI) per capita declined worldwide by 6.29 per cent**, with most of the effect realized in Arab-States (14.10 per cent), the CIS (10.50 per cent), Africa (7.73 per cent) and Asia and the Pacific (6.08 per cent).[4] As of 2023, the weighted affordability level measured through fixed broadband service pricing as a percentage of GNI in the CIS and Europe was below 2 per cent. It is only in Africa that the price of fixed broadband reaches over 10 per cent of per capita GNI. As for **mobile broadband prices**, they have been below 2 per cent of GNI since 2019 in Latin American and the Caribbean, Asia and the Pacific, the Arab States, the CIS, Europe, and North America. This means that, on average[5], except for Africa, the digital divide in the case of mobile broadband is driven by non-economic factors (low digital literacy, cultural relevance of content, and network coverage).
- **Worldwide, coverage with fixed broadband** (as a percentage of households) by 2023 is reaching an estimated weighted average of 76 per cent, with the Americas, Europe, the CIS, and Arab States exceeding 90 per cent. Asia and the Pacific and Africa exhibited a lower coverage rate (75 per cent and 30 per cent respectively). Fibre-to-the-home (FTTH) is rapidly gaining share in fixed broadband coverage. It is estimated that approximately 44 per cent of world households are already covered by FTTH.[6] By contrast, wireless technology, especially 4G, has reached near-universal coverage: world coverage of 4G has reached 96.09 per cent, with Europe and North America having attained 99.00 per cent, and Africa 77.92 per cent.
- On the other hand, while **5G coverage** is increasing, the gap between advanced economies and developing countries remains significant. In the countries of the Organisation for Economic Co-operation and Development (OECD), 5G coverage jumped 4.3 per cent in one year, from 73.84 per cent in 2022 to 78.14 per cent in 2023. Meanwhile, Africa has remained relatively uncovered by 5G at 8.65 per cent, with Latin America at 37.15 per cent and Asia and the Pacific (which includes OECD nations such as Australia, Japan, Korea (Rep. of), and New Zealand) at 37.75 per cent. In other words, 5G remains a technology mostly prevalent in the industrialized world.

Despite the increase in adoption and coverage presented above (with the consequent growth in traffic), worldwide telecommunication/ICT capital expenses (CAPEX) per capita measured in current terms has continued to decrease:

- The only region with a consistent increase in CAPEX since 2019 is Europe.
- While the worldwide trend for decreasing CAPEX per capita appears to be slowing down (2.37 per cent in 2022 vs 0.27 in 2023), it should be noted that, given the global inflation rate of 4.3 per cent[7], capital spending per capita in real terms continues to diminish. For example, the figure for Africa, 1.84 per cent increase in current prices, is the equivalent of a 2.17 per cent decrease in real terms; in Americas, a decrease of 1.69 per cent in 2023 in current prices translates to a 5.56 per cent decrease in real terms. This trend should be a source of concern considering the dichotomy between the advanced economies and the developing countries in FTTH deployment and 5G coverage investment, challenging the ability of the telecommunication/ICT sector to close the digital divide.

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3 The ITU surveys prices of the least expensive plan from the operator with the largest market share.

4 The increase in fixed broadband affordability is a critical piece of evidence in terms of the overall target of the Broadband Commission, which stipulated that by 2025, entry-level broadband services should be made affordable in low- and middle-income countries at less than 2 per cent of monthly GNI per capita. See Broadband Commission for Sustainable Development (2023). *Achieving the 2023 advocacy targets*. Retrieved in: https://www.broadbandcommission.org/advocacy-targets/

5 As expected, since these values are calculated as an average, they do not address the economic barriers at the base of the socio-economic pyramid.

6 Estimates by the author based on IDATE sources.

7 IMF. Inflation rate, average consumer prices 2023. Retrieved in: https://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/ADVEC/WEOWORLD

The changes that took place in the ICT ecosystem at the end of the pandemic have not substantially altered the importance of ICT as a driver of economic growth:

- In a context of an increase in broadband penetration, and a decline in service prices, the 2010-2023 fixed broadband model indicates that this infrastructure continues to have a significant impact on the world economy. In fact, the coefficient of impact has slightly increased since the 2021 study: with a dataset extending through the end of 2023 worldwide, a hypothetical 10 per cent increase in fixed-broadband penetration would yield a 1.59 per cent increase in gross domestic product (GDP) per capita.
- The **economic contribution of fixed broadband** continues to be greater in countries with GDP per capita higher than USD 22 000 (higher income countries), and countries with GDP per capita between USD 12 000 and USD 22 000. Of note, the coefficient of impact in high-income countries has increased from 1.25 in the 2021 study to 1.43 in 2023, suggesting the existence of increasing returns to scale becoming manifest as fixed-broadband penetration in this group of countries has risen. Additionally, this study also finds a positive, but lower, effect in low-income countries, indicating that expanding broadband fixed access can contribute to economic growth across all income levels, fostering greater digital inclusion and economic opportunities.
- In the context of an **increase in mobile-broadband penetration**, propelled by a generalized decline in service prices, the 2010-2023 mobile broadband model indicates that the technology exhibits higher impact than in 2021 on the world economy. The coefficient of impact has increased since the 2021 study: with a dataset extended through the end of 2023, an increase of 10 per cent in unique mobile broadband subscriber penetration yields a GDP increase of 2.29 per cent.
- The economic dividend of mobile broadband continues to be greater in countries with lower levels of economic development (3.02 per cent increase in GDP per capita for a 10 per cent increase in broadband penetration), diminishing in countries and regions with higher levels penetration and development (1.96 per cent in middle-income countries and 1.72 per cent in high-income ones), confirming the diminishing returns effect linked to mobile broadband saturation and highly adopted fixed broadband capturing a large portion of the economic contribution.
- A similar effect as that of **fixed broadband was found with a digitization composite index** that captures all dimensions of the digital economy. The impact of digitization in developed countries is higher (a 2.48 per cent increase in GDP per capita for a 10 per cent increase in the index) than in emerging countries (1.29 per cent), corroborating the existence of increasing returns to scale. Digitization was also found to be associated with higher labour productivity (a 2.8 per cent increase for a 10 per cent increase in the digitization index) and total factor productivity (a 3.1 per cent increase).

The confirmation of the economic contribution of ICT through 2023 provides support for policy measures to address the digital divide. Policy-makers and regulators in developing countries need to evaluate initiatives that should reverse the declining capital spending trend and lead to stimulation of telecommunications investment to ensure continuous roll-out of networks[8]:

- A **modernization of the telecommunication/ICT regulatory framework** should include, among other initiatives, the granting of convergent licences, the availability of sufficient amounts of radio spectrum at reasonable prices, the possibility to trade this resource in the secondary market with the acquiescence of the regulator, as well as to carry out its

[8] See ITU (2021). *The impact of policies, regulation, and institutions on ICT sector performance.* Retrieved in: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx.

refarming, and the definition of the concept of significant market power (SMP) based on criteria that go beyond simple market share.[9]

- Of the aforementioned elements, the case of the **radio-frequency spectrum** is particularly noteworthy. Firstly, the assigned spectrum resources are insufficient. Secondly, empirical evidence shows that when state revenue is prioritized in determining spectrum prices, network deployment can be seriously compromised. By contrast, a 1 per cent reduction in spectrum licence payments is associated with a 0.45 per cent increase in 4G coverage in developing countries.[10] The benefits of reducing the cost of the spectrum are very significant, both directly (greater investment and adoption of services) and indirectly (through GDP growth associated with greater penetration). A **higher penetration of telecommunication services and the associated GDP growth will generate increases in tax revenues** that could compensate for what the state does not collect by lowering the cost of the spectrum.
- The implementation of a **balanced tax and contribution framework** should include a ceiling on regulatory fees and on the size of the obligatory contribution to the universal service fund (USF), combined with the elimination of specific telecommunications taxes, and the elimination, if possible, of import tariffs on equipment such as fibre optics, cabling and consumer devices such as smartphones. Beyond the reduced contribution to the USF, collected funds should be used in the sector in an agile and transparent process with a clear emphasis on reducing the coverage gap in rural areas. If funds are not invested, it would be desirable to reduce the contribution until the effective use of these resources takes place.
- Moderate **competition in telecommunications**, as opposed to a model of unrestricted competition and unlimited consolidation, is the framework that represents a proper incentive to capital investment, guaranteeing an adequate level of investment and innovation.

In addition, governments should emphasize initiatives to promote digital literacy among the vulnerable and disadvantaged population:

- Programmes oriented to fostering **digital literacy** through formal education, embedding ICT training in curricula at the primary and secondary school level should be complemented with targeted programmes focused on teachers. Digital literacy programmes in the formal educational system should be, by definition, large-scale and centrally driven, generally hosted within ministries of education.
- **Targeted digital literacy programmes** can be of many varieties, potentially addressing several objectives, not all necessarily consistent. In designing such programmes, policy-makers need to consider what the goals of the programme should be, since these goals will frame the methods of intervention and application. Among the goals to be considered in designing digital literacy programmes, the following issues need to be considered:

    - What is the overall objective of the programme? Digital literacy, conceived as a skill, represents the means to achieve a diverse set of goals, such as improving the quality of life, fostering civic values, promoting democratic participation, and improving social inclusion. By outlining the ultimate objective, policy-makers will help frame the programme.
    - What is the target group? Targeted digital literacy programmes take different shapes according to the population they will address. As an example, the type of content to be emphasized in programme delivery will change significantly if the programme aims to target the elderly (requiring access to e-mail, e-government applications for social

[9] Other criteria that may influence market power are geography, control of essential facilities, access to financial resources, and economies of scale. In turn, a modern regulatory approach should periodically review market boundaries since, partly due to convergence, markets may be transformed as a result of the emergence of services provided from different platforms, but which may be substitutes in the eyes of users.

[10] Bahia, K., & Castells, P. (2021). The impact of spectrum assignment policies on consumer welfare. *Telecommunications Policy*, 102228.

inclusion, and fostering of social and family ties) versus adults of working age (in need of applications to build employability skills, online education) and rural areas. Even within a single targeted group there might be a variety of diverse needs.

- Usage and adoption versus accessibility? Some digital literacy programmes emphasize training and skills transmission, while others complement this with infrastructure for public broadband access. This is a critical policy choice, since access and adoption do not necessarily equate to the capability to use broadband in a productive and beneficial manner. In fact, if the primary objective is usage, experience indicates that tailored courses, complemented with intense coaching, are the more appropriate approach.
- Formal versus informal delivery mode? Formal digital literacy training entails structured programmes based on established curricula, learning tools and certification. Informal training is not delivered in specific training environments and lacks a structured pedagogical process. While it might not be intuitively appropriate for targeted programmes, the emergence of new digital platforms might lead to the adoption of informal approaches.
- Scale of implementation? This question addresses whether programmes will be focused on a particular region or deployed on a national scale.

Abbreviations

ARPU	average revenue per user
BDT	ITU Telecommunication Development Bureau
CAPEX	capital expenses
CIS	Commonwealth of Independent States
FTTH	fibre-to-the-home
GDP	gross domestic product
GMM	generalized method of moments
GNI	gross national income
GSR	Global Symposium for Regulators
HHI	Herfindahl-Hirschman Index
ICT	information and communications technology
IMF	International Monetary Fund
IoT	Internet of Things
ITU	International Telecommunication Union
LDCs	least developed countries
LLDCs	landlocked developing countries
M2M	machine-to-machine
OECD	Organisation for Economic Co-operation and Development
PPP	purchasing power parity
R&D	research and development
SIDS	small island developing States
SMEs	small and medium-sized enterprises
SMP	significant market power
USF	universal service fund
VPN	virtual private network

1 Introduction

A series of studies published by the ITU Telecommunication Development Bureau (BDT) between 2018 and 2021 used quantitative analysis to estimate the economic contribution of broadband and digitization around the world.[1] Supported by econometric models built with data gathered between 2010 and 2020 from 139 countries, the studies provided significant evidence on the economic importance of information and communication technology (ICT), first during the period leading up to the COVID-19 outbreak and then as a builder of resilience during the pandemic. Based on the evidence generated in the latest research, incorporated in the global study that was published in 2021 (hereinafter "the 2021 study"), three findings emerged that were of critical importance for policy-makers and regulators in the telecommunication/ICT arena:

- Changes in the ICT ecosystem driven by the disruption caused by the pandemic (continuing capital spending on infrastructure roll-out in developed countries, a jump in broadband penetration, and the decline in pricing, especially for mobile broadband) have not led to any substantial change in the importance of ICTs as a driver of economic growth.
- The economic losses resulting from the COVID-19 pandemic in 2020 were not the same for every country affected. Controlling for a range of variables, the countries with better digital infrastructure were able to mitigate part of the negative economic impact, allowing households, enterprises and governments to continue their social and economic activities.
- The confirmation of the economic contribution of ICTs throughout 2020 and the assessment that broadband and digitization helped mitigate economic disruption caused by the pandemic are a vindication of the measures taken by policy-makers and regulators to face the challenges it involved.

The end of the pandemic confronts us with a new set of questions:

- Will the economic impact of ICT, estimated using data compiled during the pandemic, subside to pre-pandemic levels now that the COVID-19 threat has almost disappeared? It will be recalled that the econometric models in the 2021 study, built with datasets through 2020, indicated that ICT had a significant economic contribution:
  - A 10 per cent increase in fixed-broadband penetration is associated with 0.80 per cent growth in GDP per capita (more in developed economies).
  - A 10 per cent increase in mobile-broadband penetration gives 1.60 per cent growth in GDP per capita (more in developing countries).
  - A 10 per cent increase in digitization is associated with a 1.35 per cent increase in GDP per capita.

The structural models used to calculate these coefficients were based on some variables that have been subject to major change during 2021-23 (for example, investment in telecommunications has declined in real terms[2], broadband service adoption has continued to grow across regions, and GDP per capita has been affected by the pandemic disruption). Are those effects (which may be partially captured in the model year controls) continuing to affect the rate of economic impact? Is the differential impact across geographies constant or has it changed?

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1 The study reports, published as part of the ITU series *The economic contribution of broadband, digitization and ICT regulation and Regional Econometric Modelling*, are available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx

2 While, strictly speaking, the investment variable is not included in the econometric models, it is influenced indirectly by industry output.

What is the role of ICT infrastructure in building the economic resilience of countries going forward? First and foremost, the digital divide has been highlighted as a critical barrier to the mitigation value of digitization. Second, while large enterprises benefit from access to well-established digital solutions already in place (collaboration tools, employee devices, cloud, virtual private networks (VPNs), digital platforms, etc.) and connectivity, this is not the case for many small and medium-sized enterprises (SMEs), particularly in developing countries. Datasets compiled through the end of 2023 should allow for a quantitative assessment of the ongoing role of ICT in mitigating future economic and social disruption.

The research presented here builds on the 2021 study (with its datasets through 2020), using econometric models that rely on the same structure and methodology but extending the study of the economic impact of fixed and mobile broadband and digitization and their contribution to increasing social and economic resilience to the end of 2023. Chapter 2 presents the descriptive statistics characterizing the changes that have taken place since 2021 in ICT investment, deployment, adoption and use. Chapter 3 presents the econometric models and compares the economic impact coefficients for fixed broadband calculated in the 2021 study with the coefficients calculated to the end of 2023. Chapter 4 does the same comparison for mobile broadband and Chapter 6 for digitization. Finally, Chapter 7 briefly summarizes the conclusions and policy implications generated through each analysis. The results of all models and the econometric methodology are included in the appendices.

2 The evolution of ICT after the pandemic: descriptive statistics

The adoption and use of digital technologies is moving forward, however the pandemic spurred dramatic changes. To compensate for the isolation associated with lockdowns and to provide a measure of economic and social continuity, rapid changes took place in broadband adoption and use, Internet traffic volume and patterns, and the adoption of Internet platforms. The telecommunication industry responded by increasing capital spending to foster network deployment in some geographies, while regulators around the world implemented novel approaches to stimulate technological upgrades. As the threat of COVID-19 has receded since 2021, the question became: will the ICT industry and consumers return to pre-pandemic behaviour and trends, or have the changes that started in 2020 become permanent?

From a user perspective, the pandemic led to an increase in the use of digital platforms for telecommuting, e-commerce and social activities. The videoconference platform Zoom saw its usage volume increase tenfold, while Microsoft Teams registered 2.7 billion meeting minutes in March 2020, a 200 per cent increase from one year earlier (Nosratzadeh et al., 2022). It was appropriate to ask then whether these behavioural changes would remain after the epidemic-related disruption was over. Some researchers (Hu, 2020) expected that changes in digital services use would continue, while others (Maikomo et al., 2021) argued that users would revert to earlier patterns of social and economic behaviour and reliance on digital technology will decline.

The evidence indicates that the situation is more complex than either hypothesis would have us believe. First, where the use of digital services is seen to be receding this is not necessarily an across-the-board phenomenon (i.e. a "return to the office"); in some locations and sectors it takes the form of a movement towards new norms, such as "3:2" formulas where workers spend three days at the office and work from home two days. Similarly, researchers have identified a post-lockdown decline in online shopping (Inoue and Todo, 2023). Second, the reduction in the use of digital services in the post-pandemic period may be limited to certain segments of the population. Thus, users whose broadband service during the pandemic was plagued by poor quality and reliability (e.g. rural populations) were expected to return promptly to physical interactions. Third, it is to be expected that those activities where the physical interaction conveys an additional social value, such as many leisure activities and in-person shopping, will bounce back. These factors indicate a mixed picture in terms of returning to pre-pandemic behaviour, and it is relevant to inquire how this has been impacted by macro variables such as broadband connectivity, affordability, service coverage and capital spending.

2.1 Progress in broadband connectivity

The 2021 study documented how fixed broadband adoption jumped in 2020, as even late adopters were forced[3] to acquire the service to continue activities that could not be conducted otherwise under a lockdown (education, commerce, telemedicine). As indicated in Table 1, worldwide adoption increased by 7.27 per cent in 2020 and 8.25 per cent in 2021. The increase was particularly significant in the Arab States (16.98 per cent in 2021), the Americas (6.64 per cent in 2021), and even Africa, albeit from a lower base (15.45 per cent in 2020 and 9.76 per cent in 2021).

[3] A forced adoption of technology emerges when alternative behaviour requiring physical interaction disappears (Reinders et al., 2008).

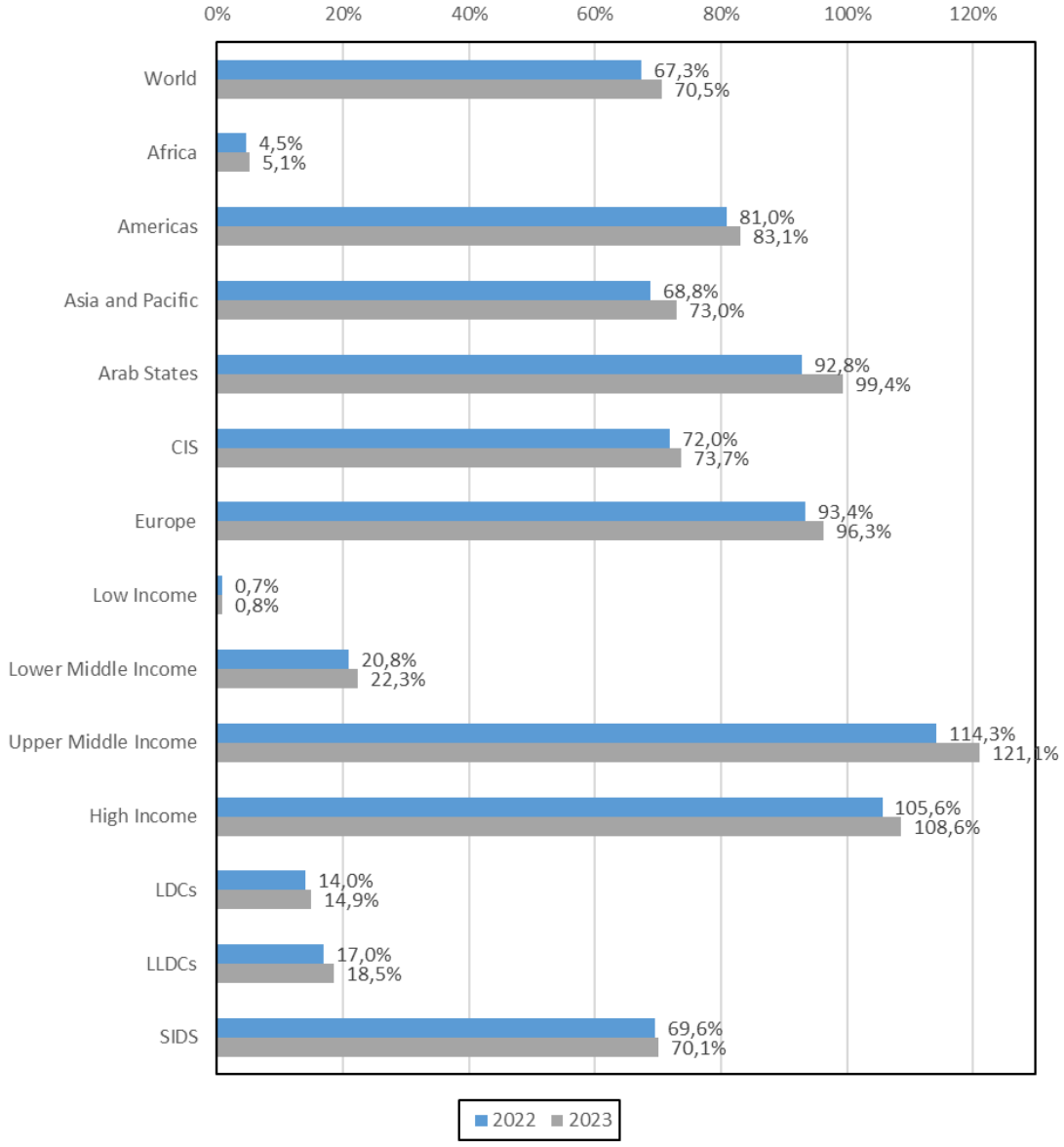
Statistics released by ITU for 2023 indicate that adoption of fixed broadband has continued to increase on all continents and in all regions, albeit at a declining rate of growth (except in Africa) (see Table 1).

Table 1: Growth in fixed-broadband connectivity (per cent of households) (2019-2023)

Region	2019	2020	2021	2022	2023	Delta 2019-20	Delta 2020-21	Delta 2021-22	Delta 2022-23
World	54.35%	58.30%	63.11%	67.27%	70.55%	7.27%	8.25%	6.59%	4.88%
Africa	3.22%	3.71%	4.08%	4.54%	5.10%	15.45%	9.76%	11.37%	12.45%
Americas	67.70%	73.06%	77.90%	80.96%	83.06%	7.91%	6.64%	3.92%	2.59%
Asia-Pacific	53.61%	57.79%	63.56%	68.83%	73.00%	7.80%	9.98%	8.29%	6.07%
Arab States	61.66%	69.58%	81.39%	92.84%	99.37%	12.85%	16.98%	14.07%	7.03%
CIS	66.41%	68.35%	69.77%	71.96%	73.66%	2.93%	2.08%	3.13%	2.37%
Europe	84.64%	88.75%	91.64%	93.38%	96.28%	4.86%	3.27%	1.90%	3.11%
Low income	0.71%	0.70%	0.71%	0.74%	0.79%	-0.49%	0.77%	4.17%	7.52%
Lower middle-income	14.66%	16.86%	19.17%	20.80%	22.25%	15.02%	13.68%	8.51%	6.99%
Upper middle-income	88.93%	96.02%	105.32%	114.25%	121.15%	7.98%	9.68%	8.49%	6.03%
High income	93.86%	97.82%	102.31%	105.60%	108.56%	4.23%	4.59%	3.22%	2.80%
LDCs	10.16%	12.11%	13.01%	13.98%	14.88%	19.22%	7.46%	7.46%	6.40%
LLDCs	14.48%	15.38%	16.38%	16.95%	18.54%	6.24%	6.50%	3.45%	9.35%
SIDS	60.03%	63.14%	67.76%	69.60%	70.10%	5.17%	7.33%	2.71%	0.72%

Note: The differences with the statistics published in the 2021 study are due to the fact that they reflected preliminary estimates.
Source: Analysis by the authors based on data available at ITU Data Hub.

Figure 1: Growth in fixed-broadband connectivity (per cent of households) (2022-2023)



Source: Analysis by the authors based on data available at ITU Data Hub

World fixed-broadband connectivity has continued to grow, reaching 70.55 per cent of households in 2023. The rate of growth was lower than in the previous years, possibly indicating the ending of the COVID-induced effect on connectivity needs (in other words, a diminished need for digital services has driven a decrease in the rate of growth of fixed broadband). The trend identified for world connectivity is replicated in all regions except Africa, where the year-on-year rate of growth of connectivity increased in 2022 **and** 2023.

The broadband-penetration rate in North America, Europe and the Arab States has moved beyond 90 per cent of households. However, figures such as 102.6 per cent penetration in North America (Canada and United States) do not imply that the region has fully addressed the digital divide, since that number includes enterprise connectivity. In Africa, broadband penetration, historically very low, continues to grow: the weighted figure for the region reached 5.10 per cent in 2023, with individual countries being much higher (Botswana: 14.20 per cent, South

Africa: 15.21 per cent, and Senegal: 16.83 per cent). The same is true of Latin America and the Caribbean, albeit with a higher adoption level as the starting point: the weighted regional average reached 71.46 per cent, with individual countries much higher (Argentina 92.69 per cent, Barbados 96.50 per cent, Chile 89.51 per cent, Mexico 87.98 per cent, Trinidad and Tobago 96.50 per cent).

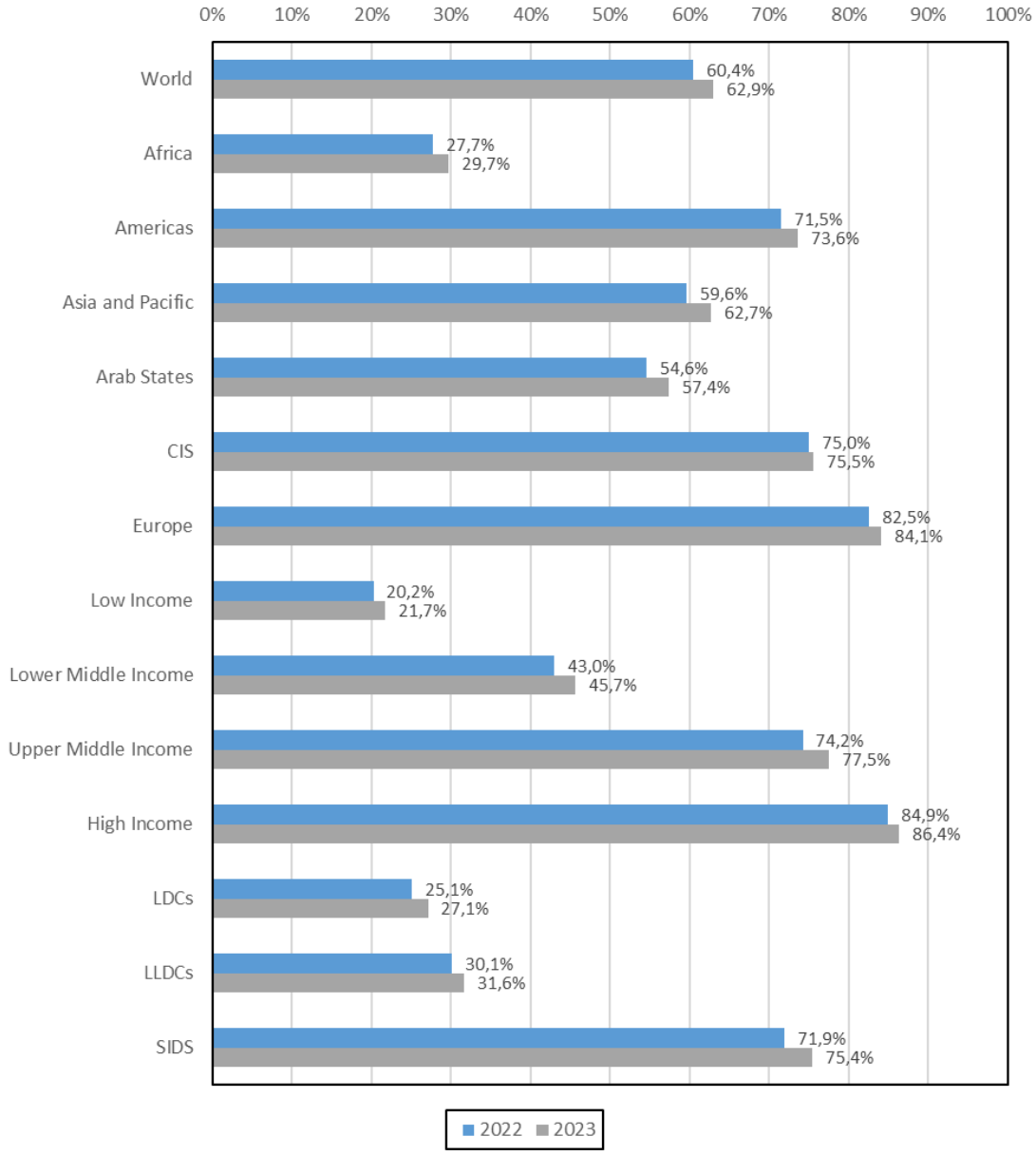
In the case of mobile broadband, the 2023 statistics for unique mobile subscribers (as opposed to all subscriptions, which would include IoT cards and dual phone ownership) indicate continuing growth worldwide. While that growth rate continues to decline on a year-on-year basis, indicating that adoption is coming up against supply barriers (either service coverage limitations or affordability constraints), which has not been the case in Asia-Pacific and Europe in the last year (see Table 2).

Table 2: Unique mobile broadband subscribers (per cent of population) (2019-2023)

Region	2019	2020	2021	2021	2023	Delta 2019-20	Delta 2020-21	Delta 2021-22	Delta 2022-23
World	51.48	55.04	58.26	60.42	62.94	6.91	5.84	3.71	4.16
Africa	22.40	24.00	25.73	27.72	29.67	7.13	7.20	7.74	7.03
Americas	64.04	66.71	69.22	71.54	73.63	4.16	3.77	3.35	2.92
Asia-Pacific	49.05	53.39	57.24	59.63	62.70	8.83%	7.23	4.17	5.14
Arab States	45.39	48.42	51.34	54.59	57.40	6.67	6.04	6.33	5.13
CIS	70.53	72.03	73.46	74.96	75.52	2.12	1.99	2.03	0.75
Europe	74.31	77.96	81.25	82.52	84.11	4.92	4.22	1.56	1.93
Low income	16.26	17.50	18.84	20.24	21.70	7.66	7.64	7.44	7.19
Lower middle-income	32.99	37.24	40.89	42.98	45.66	12.89	9.80	5.12	6.24
Upper middle-income	65.14	68.41	71.67	74.23	77.45	5.01	4.77	3.57	4.35
High income	76.33	79.69	82.68	84.89	86.36	4.40	3.75	2.67	1.73
LDCs	19.21	21.04	23.09	25.12	27.09	9.56	9.75	8.75	7.86
LLDCs	26.06	27.24	28.56	30.06	31.58	4.54	4.82	5.26	5.05
SIDS	60.11	64.31	68.35	71.88	75.38	6.98	6.29	5.16	4.86

Source: GSMA Intelligence; Cet.la; analysis by the authors

Figure 2: Unique mobile broadband subscribers (per cent of population) (2022-2023)



Source: GSMA Intelligence; Cet.la; analysis by the authors.

It is worthwhile to draw attention to some regional disparities in mobile broadband penetration. First, the advanced economies (North America and Europe) are approaching the saturation point. Second, penetration in upper middle-income countries is growing steadily at a rate of around 4 per cent. Third, and most interesting, in Africa it continues to grow at a rate of around 7 per cent, which is welcome news for reducing the digital divide in emerging economies.

2.2 Increasing broadband affordability

It was not only the demand-side stimulus associated with COVID-19 that led to the increase in broadband penetration; lower service prices also contributed. Even in the context of increasing income per capita in the post-COVID world, it is important **to point out that, on a global average, fixed-broadband prices as a percentage of GNI per capita declined by 6.29 per**

cent, with most of the effect realized in Arab-States (14.10 per cent), the CIS (10.50 per cent), Africa (7.73 per cent) and Asia and the Pacific (6.08 per cent) (see Table 3).

Table 3: Fixed-broadband affordability

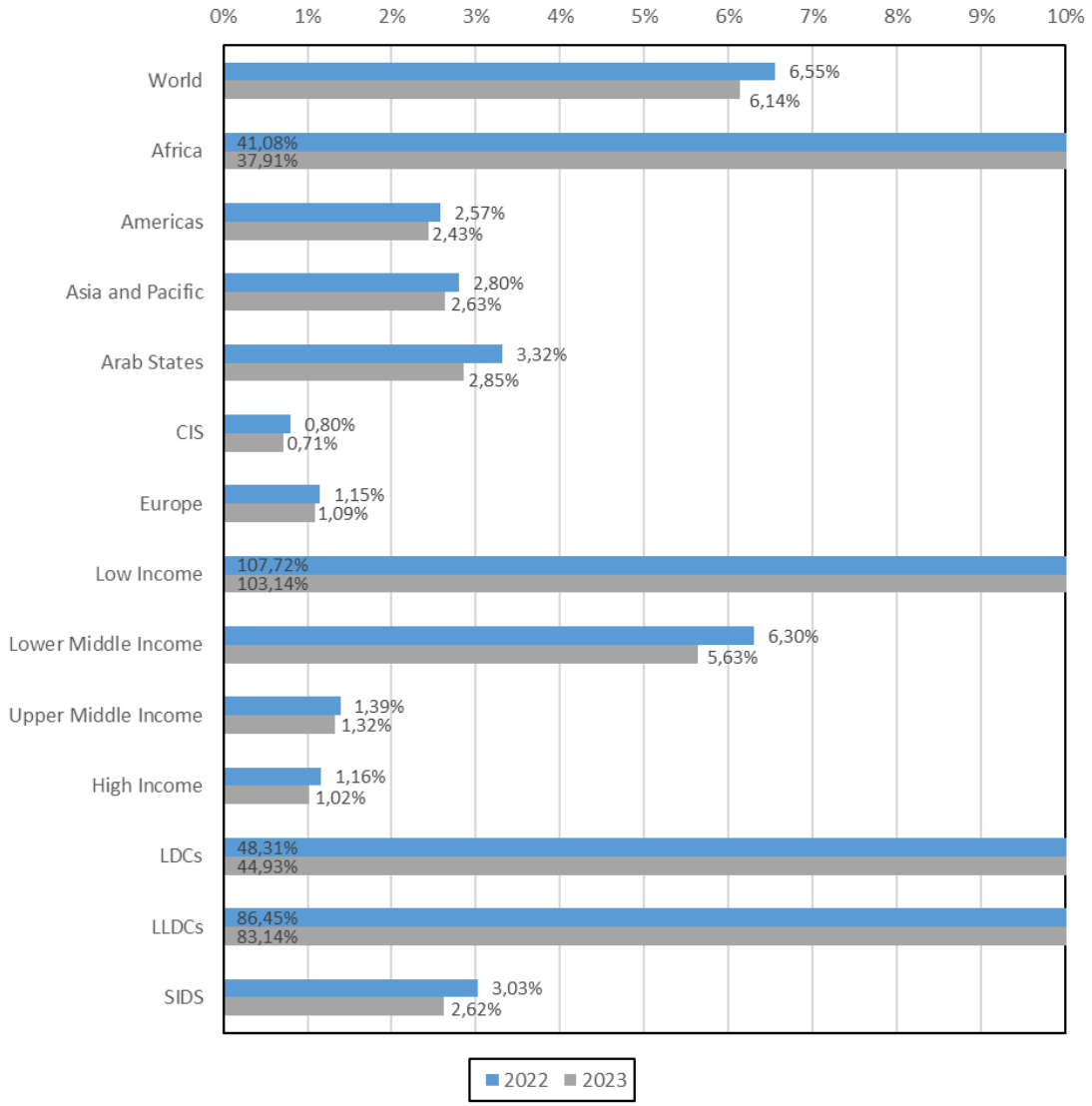
(Service pricing[4] as a percentage of Gross National Income (GNI) per capita)

Region	2019	2020	2021	2022	2023	Delta 2019-20	Delta 2020-21	Delta 2021-22	Delta 2022-23
World	7.36	7.16	7.29	6.55	6.14	-2.81	1.81	-10.06	-6.29
Africa	51.43	46.21	45.42	41.08	37.91	-10.16	-1.71	-9.55	-7.73
Americas	2.31	2.64	2.86	2.57	2.43	14.42	8.30	-10.03	-5.52
Asia-Pacific	2.84	3.14	3.29	2.80	2.63	10.59	4.92	-14.81	-6.08
Arab States	3.22	3.57	3.67	3.32	2.85	11.00	2.73	-9.45	-14.10
CIS	0.88	0.76	0.78	0.80	0.71	-12.85	2.80	1.73	-10.50
Europe	1.32	1.28	1.32	1.15	1.09	-3.49	3.69	-13.24	-5.34
Low Income	135.67	123.22	118.45	107.72	103.14	-9.18	-3.87	-9.05	-4.26
Lower middle-income	6.94	6.97	7.28	6.30	103.14	0.47	4.45	-13.45	-4.26
Upper middle-income	1.42	1.44	1.53	1.39	5.63	1.00	6.58	-9.35	-10.67
High income	1.12	1.24	1.28	1.16	1.32	10.96	2.74	-8.94	-4.88
LDCs	59.50	54.21	52.99	48.31	44.93	-8.90	-2.24	-8.84	-7.00
LLDCs	96.40	90.39	86.57	86.45	83.14	-6.24	-4.23	-0.13	-3.84
SIDS	2.75	2.52	3.14	3.03	2.62	-8.37	24.19	-3.43	-13.46

Note: Regional figures are population-weighted averages.
Source: ITU (2023) ICT Price Baskets; analysis by the authors

[4] Least expensive product from operator with largest market share.

Figure 3: Fixed broadband affordability (service pricing as a percentage of GNI per capita) (2022-2023)



Source: ITU (2023) ICT Price Baskets; analysis by the authors

The increase in fixed broadband affordability is of great relevance to the recommendation made by the Broadband Commission that, by 2025, entry-level broadband services should be made affordable in low-and middle-income countries with prices below 2 per cent of monthly GNI per capita.[5] As of 2023, the affordability objective was met in the CIS and Europe, with weighted prices for fixed broadband service below 2 per cent of GNI. The big outlier is Africa, where the price charged for a fixed broadband subscription makes up over 10 per cent of per capita GNI. It is true that this figure has been steadily declining, but it remains well beyond the means of ordinary consumers.

In the case of mobile broadband, service prices had dropped to levels close to those for fixed broadband in the aggregate, with particularly large and more generalized declines in Africa, Arab-States, Asia-Pacific and the CIS. In other words, in all the world there is a constant and

[5] Broadband Commission for Sustainable Development (2023). *Achieving the 2023 advocacy targets*. Retrieved in: https://www.broadbandcommission.org/advocacy-targets/

significant reduction in broadband prices compared to the previous year (15.46 per cent in 2023 versus 10.9 per cent in 2022). Regions such as the CIS lead this reduction with 37.10 per cent as well as the Arab States with 27.58 per cent (see Table 4).

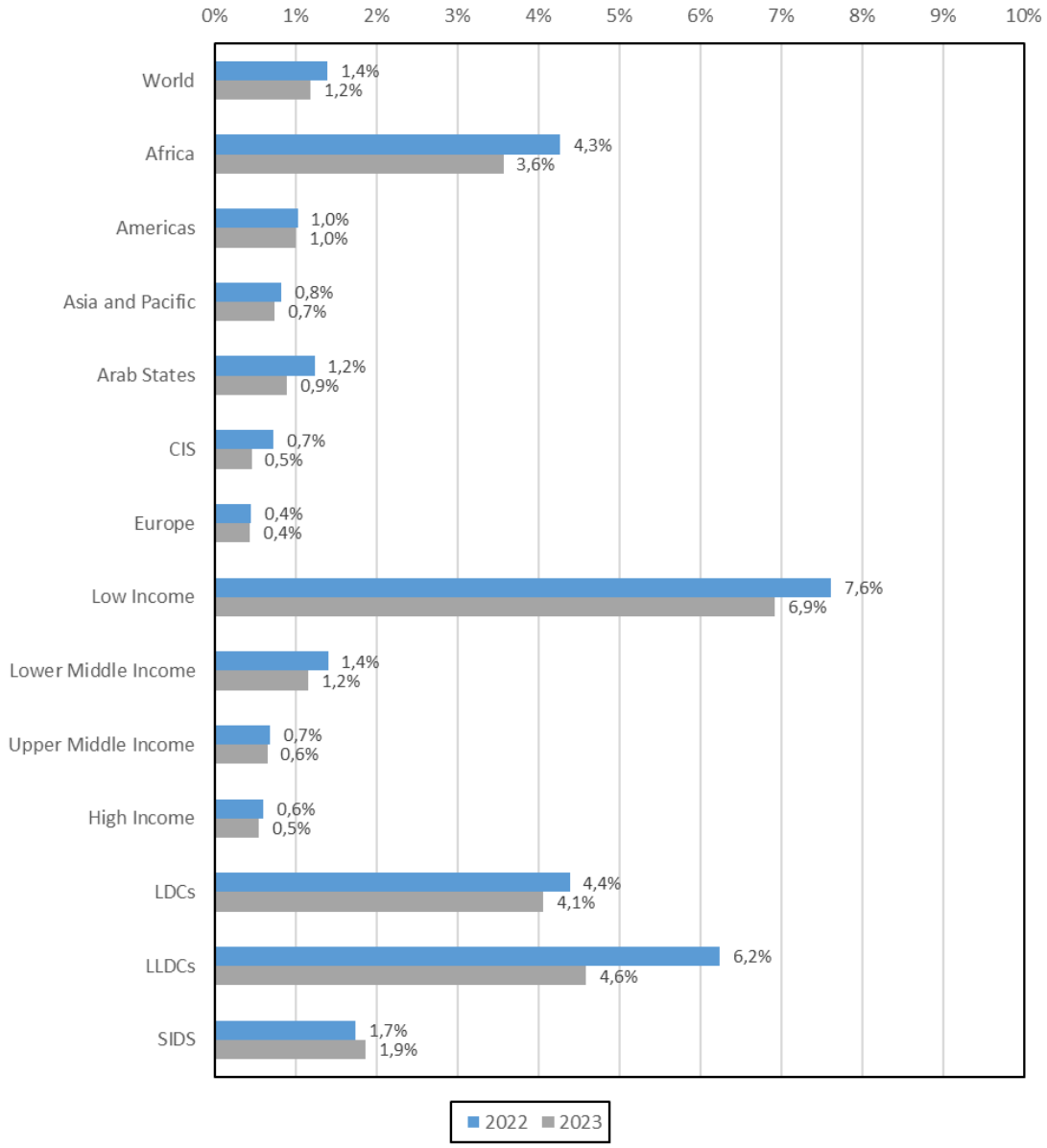
Table 4: Increase in mobile broadband affordability

(Service pricing as a percentage of Gross National Income (GNI) per capita)

Region	2019	2020	2021	2022	2023	Delta 2019-20	Delta 2020-21	Delta 2021-22	Delta 2022-23
World	1.80	1.73	1.57	1.40	1.18	-4.33	-9.22	-10.90	-15.46
Africa	7.01	5.70	5.41	4.27	3.57	-18.60	-5.22	-21.04	-16.41
Americas	1.36	1.22	1.17	1.02	1.00	-10.01	-4.27	-12.51	-1.95
Asia-Pacific	0.95	1.07	0.86	0.83	0.74	12.82	-20.27	-3.55	-10.80
Arab States	1.27	1.05	1.26	1.23	0.89	-16.96	19.02	-1.91	-27.58
CIS	0.99	0.86	0.91	0.72	0.46	-12.54	5.09	-20.16	-37.10
Europe	0.60	0.61	0.55	0.45	0.43	1.86	-9.52	-18.75	-3.41
Low income	13.56	10.95	10.09	7.62	6.92	-19.22	-7.87	-24.49	-9.14
Lower middle-income	1.55	1.80	1.52	1.40	1.16	16.05	-15.56	-7.76	-17.13
Upper middle-income	1.25	0.89	0.81	0.69	0.65	-28.80	-8.84	-15.03	-5.52
High income	0.56	0.56	0.64	0.60	0.54	-0.56	13.77	-5.81	-8.95
LDCs	7.60	6.26	5.61	4.39	4.06	-17.55	-10.39	-21.79	-7.45
LLDCs	11.28	9.34	8.60	6.25	4.59	-17.20	-7.88	-27.41	-26.51
SIDS	2.70	2.18	2.02	1.74	1.87	-19.18	-7.63	-13.92	7.52

Note: Regional figures are population-weighted averages.
Source: ITU (2023) ICT Price Baskets; analysis by the authors

Figure 4: Mobile broadband affordability (service pricing as a percentage of GNI per capita) (2022-2023)



Source: ITU (2023) ICT Price Baskets; analysis by the authors.

Between 2019 and 2023 mobile broadband prices in the Americas, Asia and the Pacific, the Arab States, the CIS, and Europe never exceeded 2 per cent of GNI. This means that, on average[6], except for Africa, the digital divide in the case of mobile broadband is driven by non-economic demand factors (e.g.: low digital literacy, low cultural relevance of content, and poor network coverage).[7]

2.3 Dichotomy of broadband coverage

By 2023, coverage with fixed broadband had reached an estimated 76 per cent of households worldwide (weighted average). That figure was above 90 per cent in the Americas, Europe, the

[6] As expected, since these values are calculated as an average, they do not address the economic barriers at the base of the socio-economic pyramid.

[7] See Katz, R. and Berry, T. (2014). *Driving demand of broadband networks and services*. London: Springer.

CIS, and the Arab States. The Asia and the Pacific region and Africa exhibited a lower coverage rate of 75 per cent and 30 per cent respectively.[8]

Fibre-to-the-home (FTTH) is rapidly gaining share in fixed broadband coverage, currently reaching an estimated 44 per cent of households worldwide. In advanced economies this infrastructure is more developed, covering 69 per cent of European and 88.19 per cent of North American households, for example,[9] followed by 69 per cent coverage in Latin America and the Caribbean and over 43 per cent in Asia and the Pacific. As expected, FTTH is marginal in Africa, being available in only 1 per cent of households.

On the other hand, wireless technology, especially 4G, has achieved near-universal coverage, at 96.09 per cent of the global population, and fully 99.20 per cent in Europe. In Africa, it increased from 74.49 per cent in 2022 to 77.92 per cent in 2023 (a 4.60 per cent growth rate). In the Americas region 4G coverage increased by just 0.62 per cent, compared to with 1.26 per cent in the prior year. Coverage in Asia and the Pacific in 2023 also grew marginally, reaching 98.51 per cent - a 0.39 per cent increase, compared with 0.05 per cent in the preceding period. For upper middle-income countries, in 2023 the proportion of the population having access to 4G mobile broadband reached 98.59 per cent, leaving a supply gap of 1.41 per cent (see Table 5).

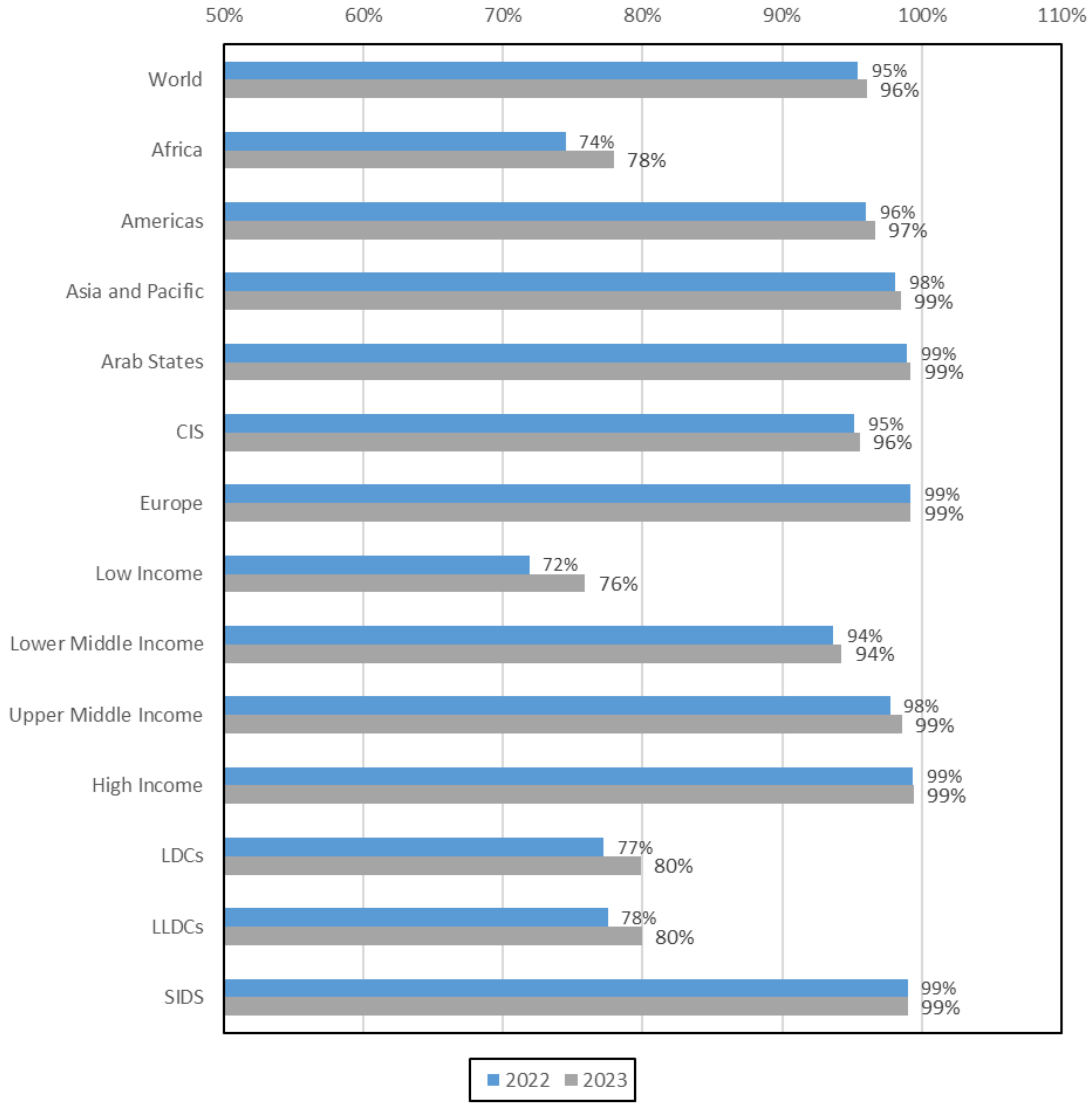
Table 5: 4G coverage (percentage of population)

Region	2019	2020	2021	2022	2023
World	90.71	92.67	94.51	95.43	96.09
Africa	48.18	58.10	67.70	74.49	77.92
Americas	92.42	93.53	94.78	96.04	96.66
Asia and the Pacific	96.55	97.35	98.07	98.12	98.51
Arab States	86.66	93.04	98.67	98.97	99.22
CIS	91.53	93.68	94.51	95.18	95.54
Europe	97.02	98.01	98.87	99.19	99.20
Low income	37.24	46.24	62.37	71.89	75.87
Lower middle-income	86.64	90.03	92.63	93.67	94.26
Upper middle-income	95.79	96.43	97.16	97.74	98.59
High income	98.93	99.12	99.26	99.37	99.43
LDCs	56.55	62.76	71.42	77.21	79.87
LLDCs	52.68	59.13	70.96	77.52	79.98
SIDS	94.91	97.23	98.20	99.00	99.01

Source: GSMA Intelligence; Cet.la; analysis by the authors

[8] Analysis by ITU based on OECD and regulator data.
[9] These values include both FTTH furnished by telecommunications service providers and high-speed broadband from cable TV operators.

Figure 5: 4G coverage (percentage of population) (2022-2023)



Source: GSMA Intelligence; Cet.la; analysis by the authors.

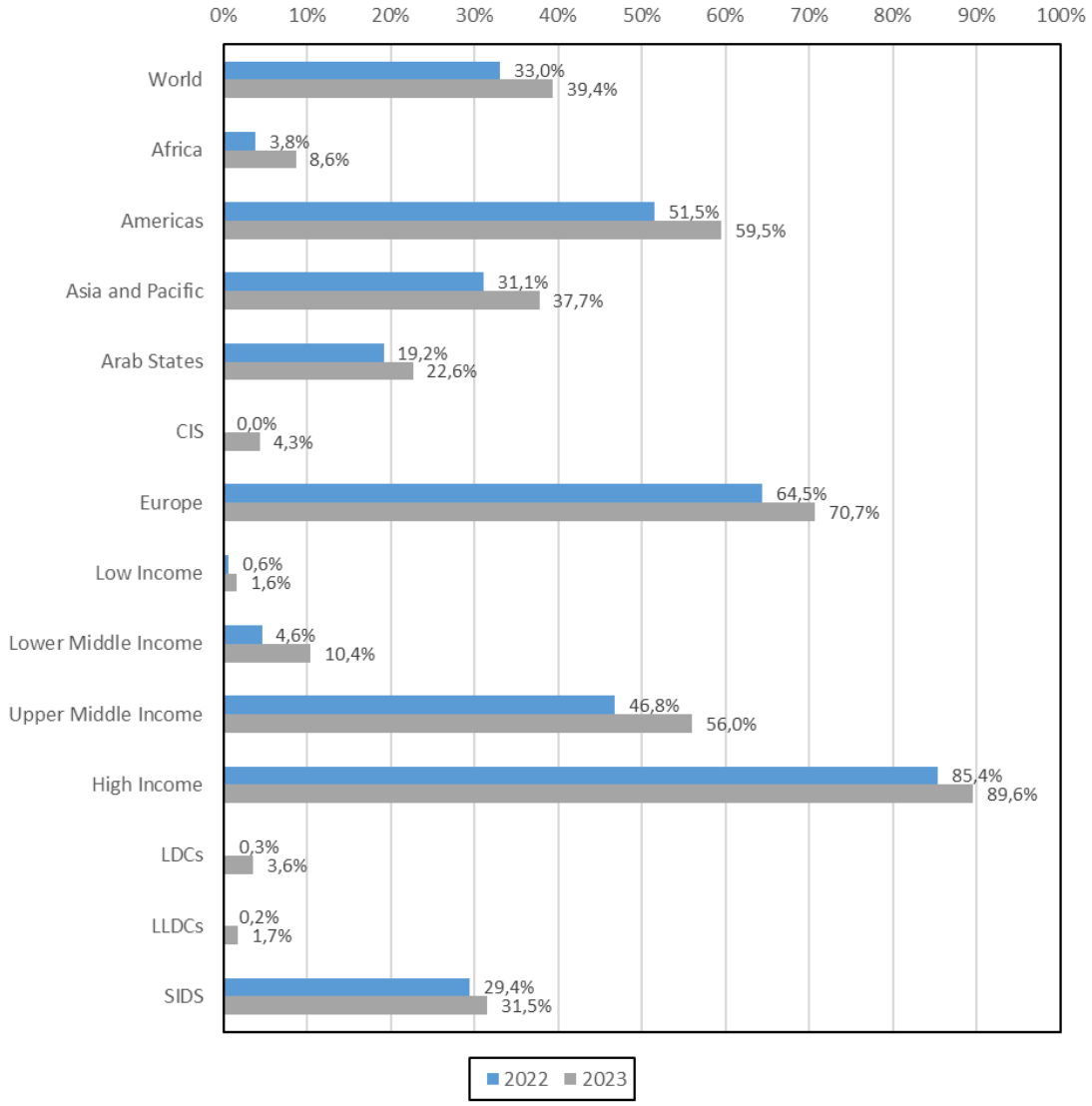
Meanwhile, 5G coverage is increasing, albeit with a significant and persistent gap between advanced economies and the developing countries. The proportion of the population in OECD countries having 5G coverage jumped 4.3 per cent in one year, from 73.84 per cent in 2022 to 78.14 per cent in 2023. This is in stark contrast to Africa (8.65 per cent), Arab States (22.65 per cent), and Asia and the Pacific (37.75 per cent, a figure that is skewed because the region includes OECD nations such as Japan, Korea (Rep. of), New Zealand and Australia). In other words, 5G technology remains mostly confined to the industrialized world (see Table 6).

Table 6: 5G coverage (percentage of population)

Region	2019	2020	2021	2022	2023
World	5.17	17.77	28.63	33.05	39.41
Africa	0.00	0.61	1.18	3.81	8.65
Americas	10.11	29.19	39.75	51.51	59.46
Asia-Pacific	4.05	17.39	28.60	31.07	37.75
Arab States	7.37	12.35	17.14	19.16	22.65
CIS	0.00	0.00	0.00	2.00	4.32
Europe	10.57	28.11	54.14	64.45	70.66
Low income	0.00	0.03	0.05	0.63	1.62
Lower middle-income	0.00	0.41	2.82	4.64	10.37
Upper middle-income	4.43	24.60	40.23	46.80	56.04
High income	20.62	51.47	77.10	85.42	89.62
LDCs	0.00	0.01	0.02	0.25	3.56
LLDCs	0.00	0.00	0.00	0.18	1.71
SIDS	4.05	24.60	27.98	29.42	31.53

Source: GSMA Intelligence; Cet.la; analysis by the authors

Figure 6: 5G coverage (percentage of population) (2022-2023)



Source: GSMA Intelligence; Cet.la; analysis by the authors.

The contrast in 5G coverage between advanced economies and developing countries suggests a new type of divide, as consumers in the former countries have access to high-quality service but in the latter have to make do with older technology (with the exception of upscale metropolitan areas).

2.4 Stagnating capital investment in telecommunications

Given the gulf in 5G coverage between advanced economies and developing countries, the decreasing levels of capital spending in telecommunications do not bode well for a significant improvement anytime soon. An important finding in the 2021 study was that capital investment in developing regions (Latin America and the Caribbean, Asia and the Pacific, and Arab States) declined in 2020 while it was increasing in advanced economies (Europe and North America), the CIS and, marginally, Africa.

The data for 2023 allow some additional findings to be drawn. First, the adoption (with the consequent growth in traffic) and worldwide telecommunication CAPEX per capita in current

terms have increased. Since 2019 the only region with consistent growth in CAPEX has been Europe, while the Asia and the Pacific and the Arab States regions have seen steadily decreasing levels of investment between 2019 and 2021 (see Table 7).

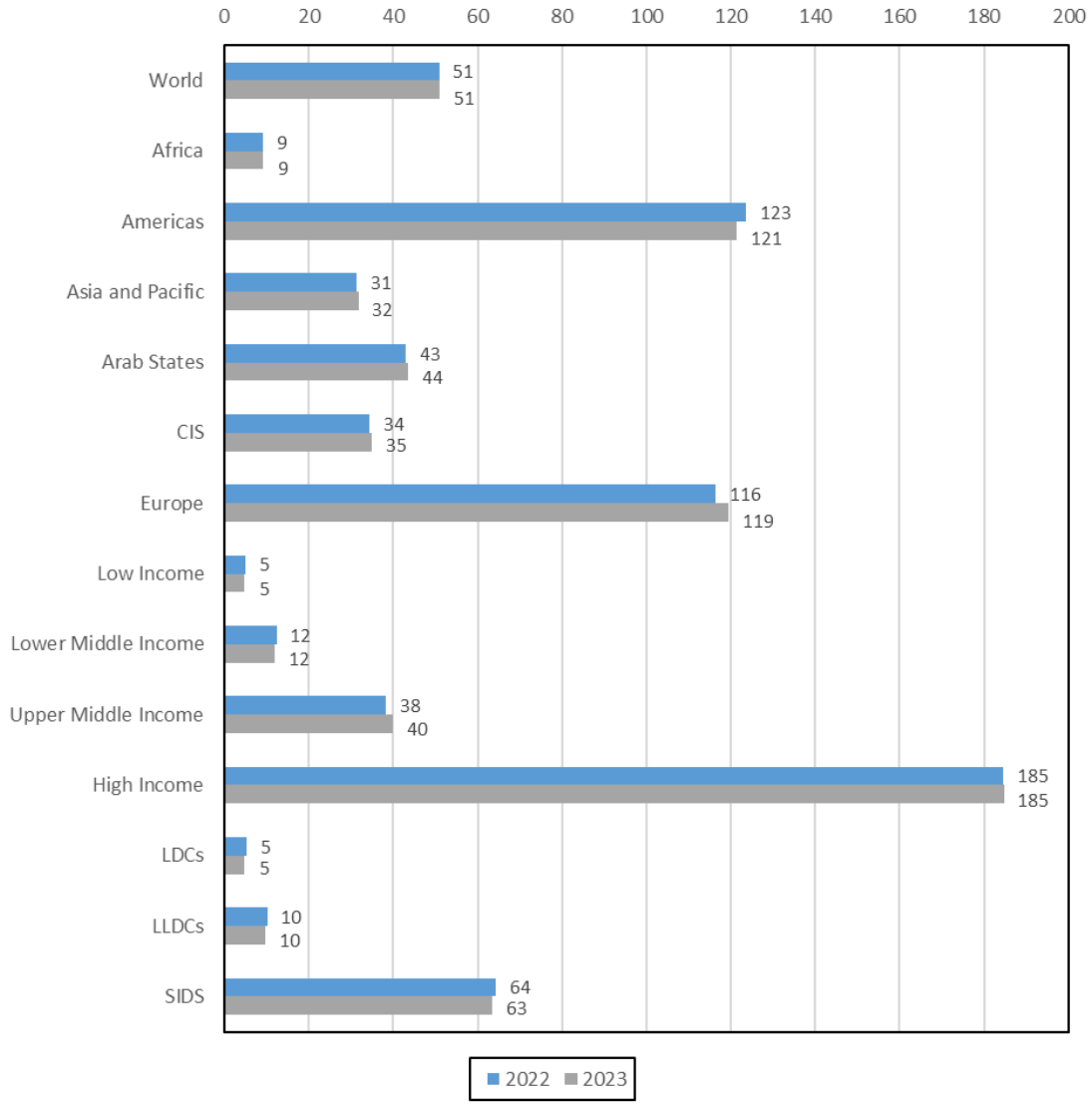
Table 7: Investment in telecommunications per capita

(in USD prices, mean value 2015-2023)

Region	2019	2020	2021	2022	2023	Delta 2019-20	Delta 2020-21	Delta 2021-22	Delta 2022-23
World	49.87	49.39	49.70	50.88	51.02	-0.95	0.62	2.37	0.27
Africa	9.88	9.24	9.22	9.00	9.17	-6.44	-0.20	-2.37	1.84
Americas	127.01	124.15	123.19	123.49	121.40	-2.25	-0.77	0.24	-1.69
Asia-Pacific	30.55	30.24	30.10	31.35	31.71	-1.02	-0.48	4.18	1.13
Arab States	45.73	44.51	42.98	43.04	43.53	-2.66	-3.43	0.13	1.14
CIS	31.97	32.36	34.64	34.43	34.96	1.23	7.05	-0.61	1.52
Europe	101.49	104.47	111.08	116.48	119.37	2.94	6.32	4.86	2.48
OECD	148.43	149.42	155.36	160.65	161.32	0.67	3.98	3.40	0.42
EU-27	115.08	115.40	119.46	126.49	131.20	0.28	3.51	5.89	3.72
Low income	6.67	6.34	6.18	4.83	4.79	-4.98	-2.58	-21.80	-0.78
Lower middle-income	13.39	13.45	12.23	12.40	11.90	0.45	-9.07	1.38	-4.05
Upper middle-income	39.23	37.77	37.36	38.33	39.92	-3.73	-1.08	2.59	4.17
High income	170.57	171.76	178.84	184.64	184.72	0.70	4.12	3.24	0.05
LDCs	7.26	6.70	6.10	5.11	4.77	-7.69	-9.04	-16.12	-6.82
LLDCs	13.06	12.05	11.70	10.19	9.76	-7.74	-2.91	-12.87	-4.23
SIDS	74.51	72.08	68.36	64.27	63.41	-3.25	-5.17	-5.98	-1.33

Note: 2023 numbers reflect ITU preliminary data complemented with GSMA Intelligence.
Source: ITU Data Hub; GSMA Intelligence; analysis by the authors

Figure 7: Investment in telecommunications per capita (in USD prices, mean value last five years) (2022-2023)



Source: ITU Data Hub; GSMA Intelligence; analysis by the authors.

While the worldwide drop of CAPEX per capita in current prices appears to be slowing down (2.37 per cent in 2022 versus 0.27 per cent in 2023), the situation looks different in real terms (constant prices), given the world inflation rate of 4.3 per cent.[10]. For example, the figure for Africa, 1.84 per cent in current prices, is the equivalent of a 2.17 per cent decrease in real terms; in the Americas, a decrease of 1.69 per cent in 2023 in current prices translates to a 5.56 per cent decrease in real terms. This trend should be a source of concern considering the dichotomy between the advanced economies and the developing countries in fibre optics deployment and 5G coverage investment, challenging the ability of the telecommunication/ICT sector to close the digital divide.

In the first place, while Table 7 indicates a decline in the world aggregate for capital investment in telecommunications, that aggregate includes the growing investments in the high-income

[10] IMF. Inflation rate, average consumer prices 2023. Retrieved in: https://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/ADVEC/WEOWORLD

economies, which means that the situation in the regions that most need investment to bridge the digital divide is even more dire than the aggregate decline would indicate.

Second, the decrease in investment in telecommunications in the developing countries conceals a second effect in terms of the regional trend. Capital spending on network deployment in these countries tends to flow to the geographies with high-income populations and enterprises, which represent the most promising market segment for returns on investment. This is another obstacle to addressing the digital divide. Finally, from an economic standpoint, the decline in investment negatively affects telecommunication network coverage, which ultimately limits the growth in broadband penetration and consequently its beneficial impact on the economy.

3 The economic impact of fixed broadband through 2023

Having assessed the changes in connectivity, affordability, network coverage and investment precipitated by the COVID-19 pandemic and thereafter, the next important question is whether the economic impact of ICT estimated on the basis of data compiled during the pandemic can be expected to remain at the same level, or if it will decline to pre-pandemic levels. To address this question, this chapter compares the results obtained with the econometric models published in the 2021 ITU study *"The economic impact and broadband and digitization through the COVID-19 pandemic*[11]*"* (hereinafter referred to as the 2021 study), based on time series between 2010 and 2020, with the results obtained when the same models are run on datasets extended through the end of 2023 (hereinafter as "the 2023 study").

3.1 Fixed broadband and its impact on the economy to the end of 2020

It will be recalled that the 2021 study relied on structural models based on four functions:

aggregate production function	GDP per capita $_{it}$ = a_1(Capital $_{it}$) + a_2(Education $_{it}$) + a_3(Broadband_Penetration $_{it}$) + e_{it} (1)
demand function	Broadband_Penetration$_{it}$=b_1(Rural_population) $_{it}$ +b_2(Broadband_Price) $_{it}$+b_3(GDP per capita)$_{it}$+b_4(HHI)$_{it}$+e_{it} (2)
supply function	Broadband_Revenue $_{it}$=c_1(Broadband Price) $_{it}$ + c_2(GDP per capita) $_{it}$+c_3(HHI Fixed broadband) $_{it}$+ e_{it} (3)
output function	Δ Broadband_Penetration $_{it}$ = d_1 (Fixed_Broadband_Revenue it)+ ε4it (4)

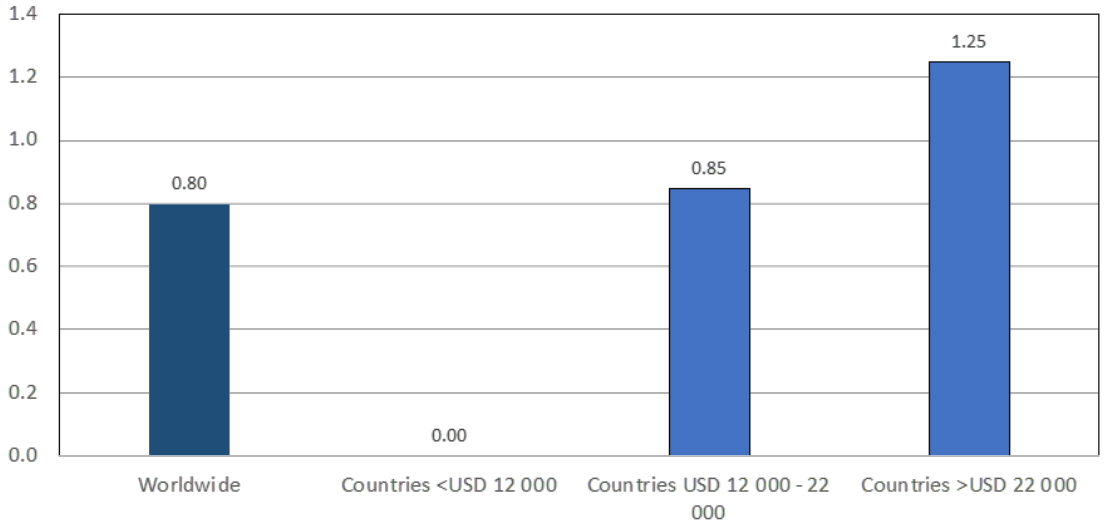
The 2021 study examined data for 139 countries between 2010 and 2020, running the econometric models first *for all countries* and then *for distinct groups of countries* categorized by level of economic development, using the proxy of GDP per capita:

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

The 2021 study results indicated that the economic impact of fixed broadband tends to increase with economic development (see Figure 8).

[11] ITU Publication: The Economic impact of broadband and digitization through the COVID-19 pandemic: Econometric modelling, available at https://www.itu.int/pub/D-PREF-EF.COV_ECO_IMPACT_B-2021

Figure 8: GDP growth impact of a 10 per cent increase in fixed-broadband penetration (2021 study: by economic development)



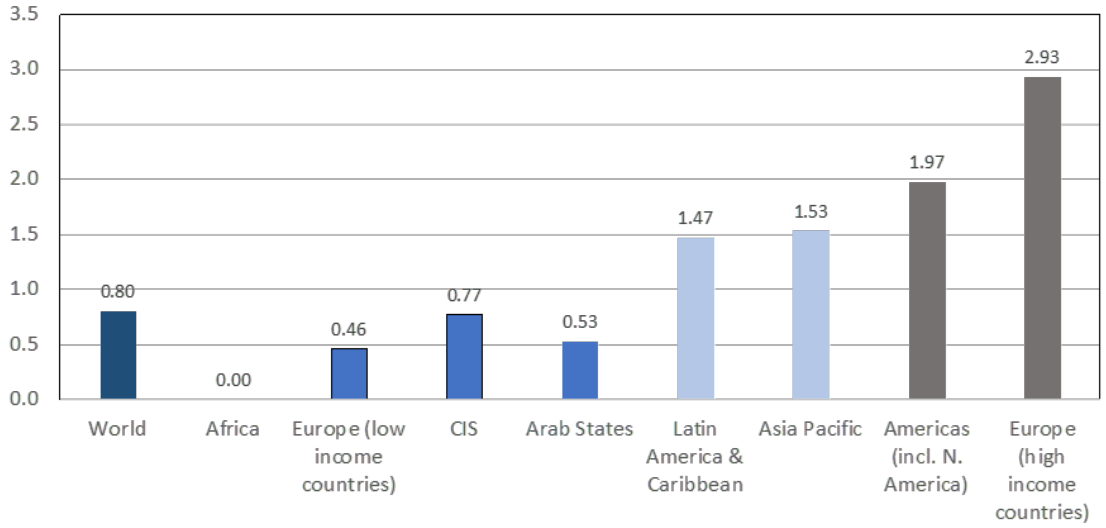
Source: International Telecommunication Union. The economic impact of broadband and digitization through the COVID-19 pandemic: Econometric modelling. June 2021

The economic impact of fixed broadband was also measured by region:

- Africa (34 countries)
- Americas (18 countries)
- Arab States (14 countries)
- Asia-Pacific (18 countries)
- CIS (8 countries)
- Europe (38 countries)

The results by region confirmed that the economic impact of fixed broadband was higher for regions with more developed countries than for subregions with developing countries (see Figure 9).

Figure 9: GDP growth impact of a 10 per cent increase in fixed broadband penetration (2021 study: by economic development)



Source: International Telecommunication Union. The economic impact of broadband and digitization through the COVID-19 pandemic: Econometric modelling. June 2021

Identical econometric models have been used to calculate the impact of fixed broadband for datasets running through the end of 2023 and compare these results with those of the 2021 study.

3.2 Fixed broadband and its impact on the economy through 2023

The same models were run with data between 2010 and 2023 but only for those countries with a fixed broadband adoption level higher than five per cent (which yielded a sample of 107 countries and 5'107 observations). Despite the smaller sample, the model generated statistically significant results, confirming those of the 2021 study, which used data through 2020 (see Table 8).

Table 8: Economic impact of fixed broadband (2021 vs 2023 studies)

Variables of fixed broadband model	2021 study	2023 study
Log(GDP per capita)		
Fixed broadband subscriber penetration	0.080***	0.1586***
Gross fixed capital formation	0.109***	0.0508***
Skilled labour force	0.051***	0.0439***
Log(fixed broadband penetration)		
Fixed telephone subscribers	0.447***	0.0021
Mobile penetration	-0.312***	0.2028***
Rural population	-0.083***	-0.3548***
GDP per capita	0.882***	2.9146***
Fixed broadband price	-0.416***	-0.0720***
HHI fixed broadband	-0.500***	-0.0474***
Log(fixed broadband revenue)		
GDP per capita	1.301***	0.7966***
Fixed broadband price	0.375***	0.5765***
HHI fixed broadband	-0.869***	-0.6692***
Fixed broadband adoption growth		
Fixed broadband revenue	-0.446***	-0.4264***
Details		
Observations	5 328	5 107
Number of countries	139	107
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2020	2010-2023
R-Squared	0.992	0.991

***, **, * significant at 1%, 5% and 10% critical value respectively
Note: all variables are expressed in logarithms
Sources: ITU; analysis by the authors.

In the context of an increase in broadband penetration, a decline in service prices, and a decrease in GDP per capita, the updated study indicates that this infrastructure continues to have a significant impact on the world economy. In fact, the coefficient of the impact has slightly increased from the 2021 study: with a dataset extending through the end of 2023 worldwide, an increase of 10 per cent in fixed broadband penetration yields an increase of 1.59 per cent in GDP per capita. The increase since the previous study can be attributed to

the greater reliance on digital technologies, suggesting that some relevant trends (such as the transition to 3:2 hybrid working schemes) have persisted past the end of the pandemic. Moreover, the structural model continues to provide estimates for other important parameters of the economy. As expected, fixed capital formation and skilled labour force continues to be a catalyst of GDP growth, suggesting an important contribution to the economy (positive and significant coefficient in both studies).

Demand for fixed broadband services depends heavily on price. According to the 2023 model, a one per cent drop in prices will boost adoption by 0.07 per cent. While lower than the 0.42 per cent calculated in the 2021 study, it continues to be statistically significant. The lower price elasticity of demand may be explained by the fact that countries with extremely low penetration, with a more price-conscious population[12], were excluded from the study. Income variation across the sample period seems to have a larger impact in driving demand. Hence, increasing the average disposable income (proxied by GDP per capita) by one per cent yields 2.91 per cent more fixed broadband adoption (up from 0.88 in the 2021 study); further corroboration of the continuing relevance of affordability to fixed broadband penetration.

Supply dynamics suggest that, as expected, income levels positively affect the revenues and investments of operators. At a global level, the consumption propensity for broadband services seems to have a significant impact on increasing the supply of digital offerings. Increasing the disposable income (proxied by GDP per capita) by one per cent attracts 0.80 per cent more supply in 2023 (a decrease from 1.30 per cent in the 2021 study). Finally, fixed broadband operator 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[13]. This is an additional aspect that corroborates the existence of increasing returns to scale of ICT infrastructure, while the coefficient in the 2023 model has increased.

The structural model was also run for selected countries sorted by development level to test whether fixed broadband economic impact is affected by increasing returns to scale. As in the 2020 study, the database was split into three groups of countries as measured by their GDP per capita:

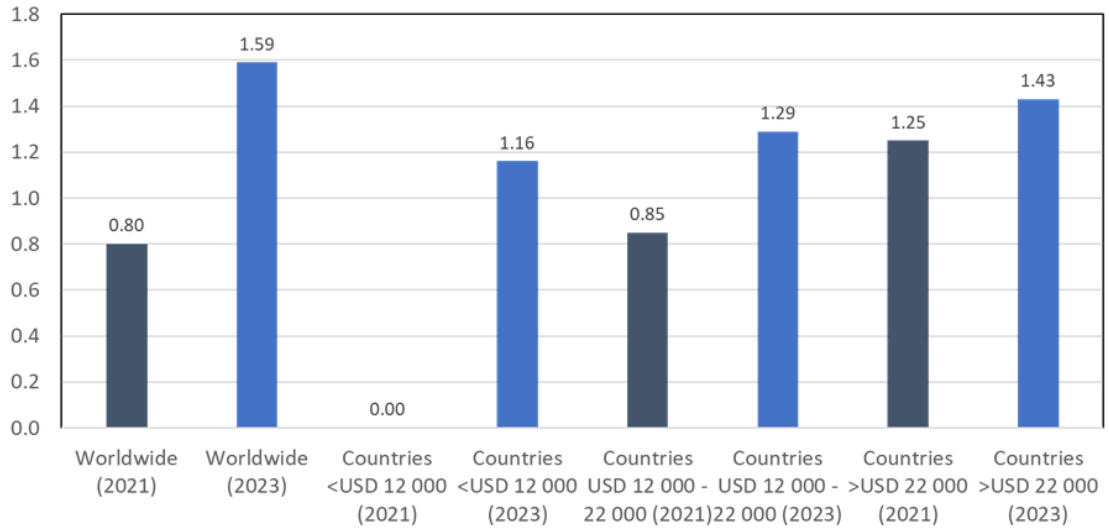
- GDP per capita higher than USD 22 000 (53 countries);
- GDP per capita between USD 12 000 and USD 22 000 (28 countries);
- GDP per capita lower than USD 12 000 (26 countries).

Similar structural models were run for each set of countries, yielding the following results (see Figure 10).

[12] A word of caution: since this is a structural model based on a system of equations, the results of intermediate equations are inputs for the final result. For this reason, the coefficients obtained in intermediate steps should not be considered general conclusions. For a model on mobile price elasticity in developing countries, see Katz and Berry (2014).

[13] This is particularly relevant for markets undergoing high growth, but it is not the case in saturated markets.

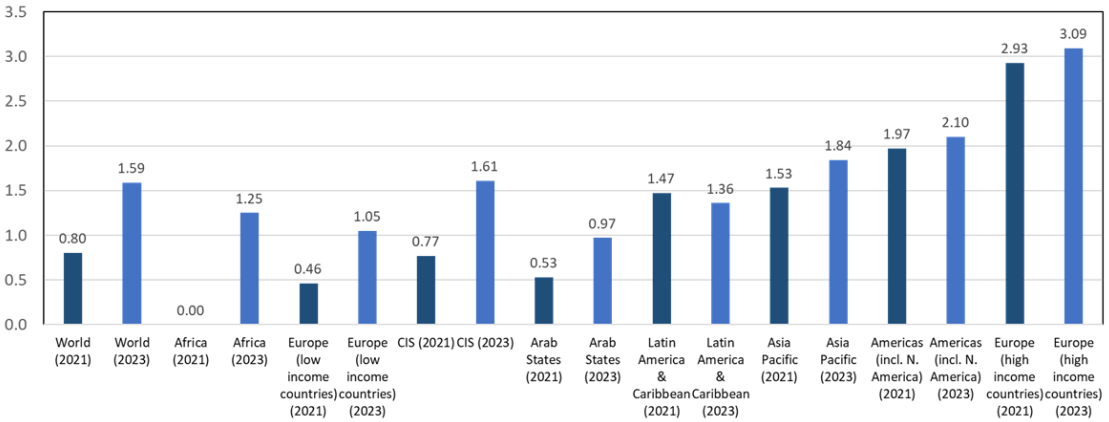
Figure 10: GDP growth impact of a 10 per cent increase in fixed broadband penetration (2021 vs 2023 studies)



Note: The 2021 study provides evidence of trends in 2010-2020 while the 2023 study is based on 2010-2023 data.
Source: ITU

The results of the models run with data through 2023 confirmed the effect identified in the earlier study. But now, the three models indicate a statistically significant positive effect of fixed broadband, but with an incremental effect in the countries with higher GDP. Of note, the effect on high-income countries has increased from a coefficient of 1.25 to 1.43, suggesting the existence of increasing returns to scale driven by the rise in fixed-broadband penetration in this group of countries. Also, the effect for middle-income countries has increased from a coefficient of 0.85 to 1.29, and for the low-incomes countries has increased from a not significant effect to 1.16. These findings were corroborated by running the model by world region (see Figure 11).

Figure 11: Regional GDP growth impact of a 10 per cent increase in fixed broadband penetration (2021 vs 2023 studies)



Source: ITU

The structural model was applied to all world regions with the 2010-2023 dataset, calculating the effect of a hypothetical 10 per cent increase in fixed broadband penetration on GDP per capita. The models yielded results consistent with those generated in the 2021 study:

- **Africa region**: reflecting the growth in fixed-broadband adoption that has taken place in Africa in the last two years, the technology has emerged as a contributor to economic growth.
- **Americas region**: driven by the increasing returns to scale, countries across this region (North America, Latin America and the Caribbean) continue to benefit from the increase in broadband penetration, with a GDP increase of 2.10 per cent (up slightly from 1.97 per cent).
- **Europe region**: the 2021 study determined that an increase of 10 per cent in fixed-broadband penetration in high-income countries in this region would yield an increase of around 2.93 per cent in GDP per capita. This increased slightly to 3.09 per cent using the data through 2023. Also, for low-income countries in the region in the same period the coefficient increased from 0.46 per cent to 1.05. This confirms again the increasing returns to scale effect driven by higher broadband penetration.
- **CIS region**: with the 2010-2020 dataset the model estimated that the region would see an increase of 0.77 per cent in GDP per capita, while in the period ending in 2023 that increased to 1.61 per cent.
- **Asia and the Pacific region**: in the timespan ending in 2023, the GDP impact of broadband adoption increased to 1.84 per cent from an impact of 1.53 per cent, which might indicate an increasing return to scale of higher adoption levels.
- **Arab States region**: A similar effect might exist in the case of Arab States countries, although the change in per cent GDP impact of broadband adoption (0.53 per cent in the period ending in 2021 to 0.97 per cent in the series ending in 2023) might be also due to additional effects yet difficult to tease out.

In summary, the comparison between the results of the structural model run on fixed broadband datasets for the period 2010-2020 with those for 2010-2023 yields the following conclusions:

- First, as shown in Figure 10, the increase in broadband penetration and the decline in service prices that took place in 2023 led to a higher coefficient of economic impact of fixed broadband than in the earlier study. This might indicate, in a confirmation of the prior study, that those countries with higher broadband development were able to better mitigate the negative pandemic disruption.
- Second, as shown in Figure 11, suggesting an increasing returns to scale effect, the increase in fixed-broadband penetration in the Americas, Asia Pacific, Europe, the CIS and the Arab States, resulted in a slightly higher coefficient of GDP per capita resulting from increase in penetration. Further research will be needed to confirm this trend in the future, as in some cases the current differences lie within the boundaries of the confidence intervals.
- Third, for the first time in these studies, the Africa region has increased its fixed-broadband penetration and, consequently, the economic contribution of the technology.

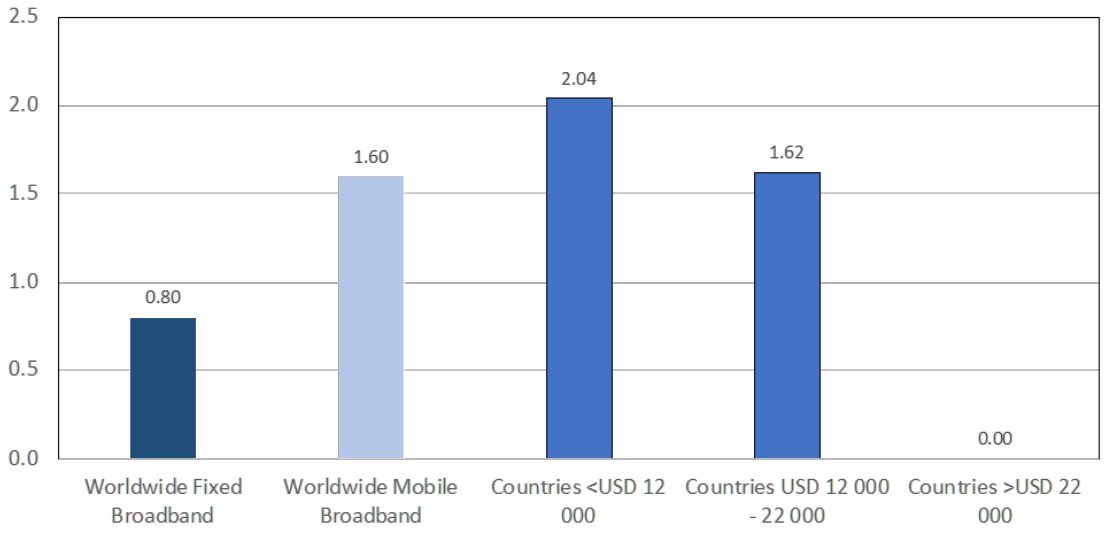
4 Mobile broadband and its impact on the economy through 2023

The 2021 study, run with data between 2010 and 2020, concluded that in countries that have low fixed broadband penetration (those that have low GDP per capita), it is mobile broadband technology that is the pre-eminent technology driving economic growth. The purpose of this chapter is to compare those results with the results of similar models based on datasets extended through the end of 2023. As mentioned above, the purpose is to determine whether the externalities of ICT noted during the pandemic remain.

4.1 Mobile broadband and its impact on the economy until 2020

The prior studies of the impact of mobile broadband were based on structural models like those used to measure the contribution of fixed broadband. The models were run for 129 countries between 2010 and 2020, for the global sample, for groups differentiated by level of development, and for the different regions. The results of the study indicated that the economic contribution of mobile broadband was higher than that of fixed broadband, although the impact decreased with a country's level of economic development (see Figure 12).

Figure 12: GDP growth impact of a 10 per cent increase in mobile-broadband penetration (2021 study: by economic development)



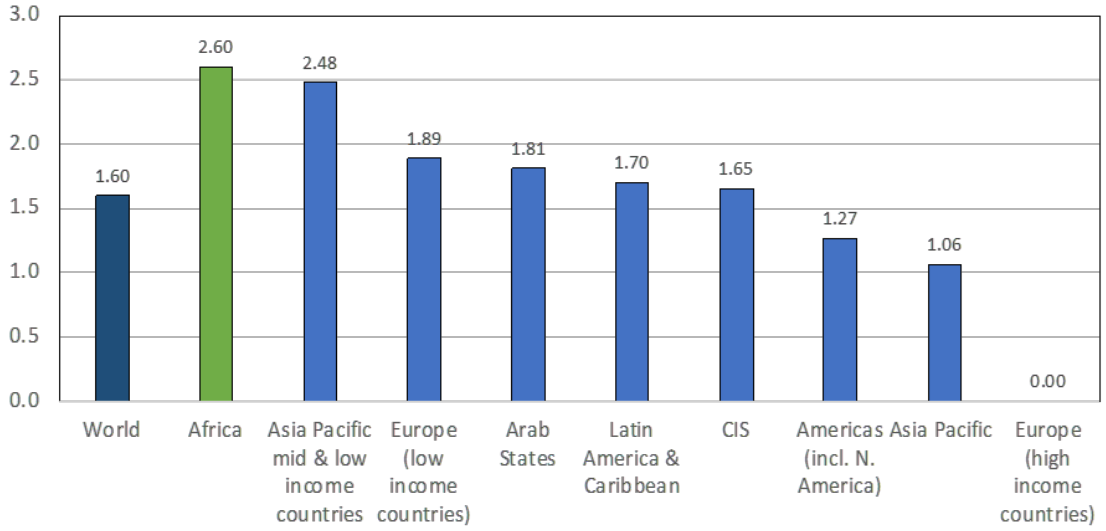
Source: ITU. The economic impact of broadband and digitization through the COVID-19 pandemic: Econometric modelling. June 2021

The models were also run to measure the impact by region:

- Africa (34 countries)
- Americas (18 countries)
- Arab States (14 countries)
- Asia and the Pacific (18 countries)
- CIS (8 countries)
- Europe (38 countries)

The results indicated that developing countries benefitted from mobile broadband more than advanced economies (see Figure 13).

Figure 13: GDP growth impact of a 10 per cent increase in mobile-broadband penetration (2021 study: by economic development)



Source: International Telecommunication Union. The economic impact of broadband and digitization through the COVID-19 pandemic: Econometric modelling. June 2021

The impact of mobile broadband was then calculated using the same models with datasets between 2010 and the end of 2023.

4.2 Mobile broadband and its impact on the economy through 2023

The models, run with the totality of the database (124 countries[14]) with data between 2010 and 2023, yielded statistically significant results, confirming the results published in 2021 with data through 2020 (see Table 9).

[14] To avoid imputations in GDP data, the five countries without data were excluded from the sample.

Table 9: 2021 and 2023 studies: economic impact of mobile broadband

Variables of mobile broadband model	2021 study	2023 study
GDP per capita (PPP)		
Mobile broadband subscriber penetration	0.160***	0.2286***
Gross fixed capital formation	0.137***	0.0340***
Years of education	0.048***	0.0142***
Mobile broadband subscriber penetration		
Mobile penetration	1.694***	0.6746***
Rural population	-0.052***	0.1519***
GDP per capita	0.046***	-0.0617
Mobile broadband ARPU	-0.012	0.0397***
HHI mobile broadband	-0.331***	0.0050
Mobile broadband revenue		
GDP per capita	0.517***	4.3311***
Mobile broadband ARPU	0.129***	1.0128***
HHI mobile broadband	-1.547***	-0.1272***
Mobile broadband adoption growth		
Mobile broadband revenue	-0.008***	-0.2749***
Observations	5 227	6 063
Number of countries	129	124
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010-2020	2010-2023
R-Squared	0.993	0.995

***, **, * significant at 1%, 5% and 10% critical value respectively
Note: all variables are expressed in logarithms
Source: ITU; analysis by the authors.

In the context of an increase in mobile-broadband penetration and a generalized decline in service prices, the results for 2010-2023 indicate that the impact of the mobile infrastructure on the world economy has increased since 2021. With the dataset extended through the end of 2023, an increase of 1 per cent in mobile-broadband penetration yielded an increase of 0.23 per cent in GDP (compared to a coefficient of 0.16 in the 2021 study). This increase can be explained by two main factors. In the first place, as in the case of fixed broadband, it suggests that some of the patterns generated in society during the pandemic continue to persist, as digitization remains a more important factor in economic growth than previously. Second, the growth of 5G has made wireless technologies more attractive to industry (for IoT, M2M, and so on), and

thus more relevant for economic activity. Moreover, the structural model provides estimates for other important parameters of the economy. The importance of fixed capital formation as a catalyst of GDP growth has receded, its coefficient declining from 0.14 per cent to 0.03 per cent, which could be partly a consequence of the COVID-induced recession.[15] Additionally, the educational level of the labour force continues to have a positive and statistically significant impact on economic growth, underscoring the importance of human capital development in sustaining long-term economic performance.

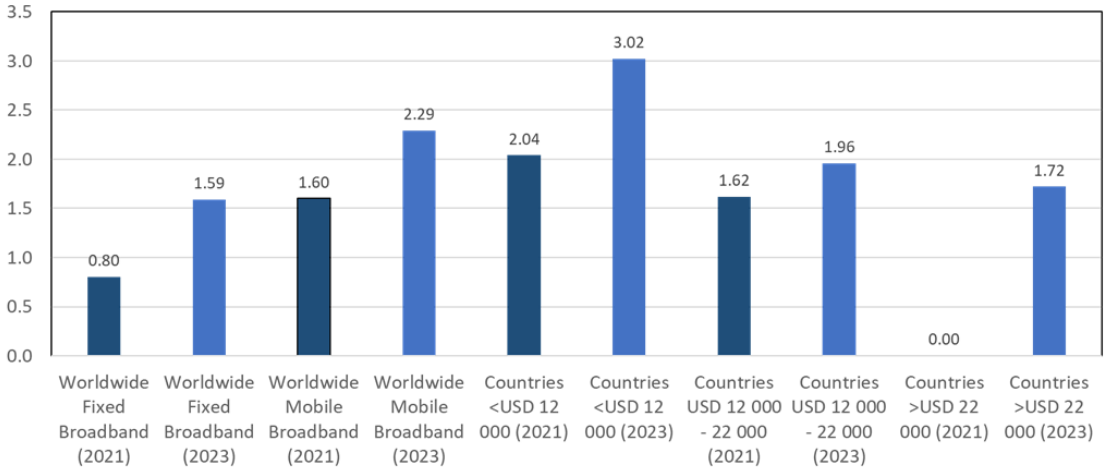
In terms of the demand equation, considering the effect of the pandemic, a change in the sign of the effect of the rural population and GDP on adoption can also be observed. Within a rural context or low GDP per capita, fixed broadband coverage is low, so the population relied on mobile technology to remain connected. It should also be noted that, for mobile broadband, ARPU is positively associated with penetration. While this might be counter-intuitive, ARPU is a more comprehensive variable than simply price (as used in fixed broadband) since it encompasses non-standardized parameters such as type of service plan, technology purchased (5G vs 3G), and revenues that are not directly associated with users, such as those from wholesale activity.

The structural model was also run with 2010-2023 data to test whether mobile broadband economic impact was affected by an increasing return to scale effect. As in the prior studies, the database was split in three groups of countries as measured by their GDP per capita as follows:

- GDP per capita higher than USD 22 000 (53 countries)
- GDP per capita between USD 12 000 and USD 22 000 (28 countries)
- GDP per capita lower than USD 12 000 (43 countries)

Similar structural models were run for each set of countries, yielding the following results (see Figure 14).

Figure 14: GDP growth impact of a 10 per cent increase in mobile-broadband penetration (2021 vs 2023 studies)



Source: ITU; analysis by the authors.

[15] Gross Fixed Capital Formation, a measure of net investment, is generally subject to a decline under recessions.

The results obtained by running the models with data through the end of 2023 confirmed the effects identified in the earlier study.

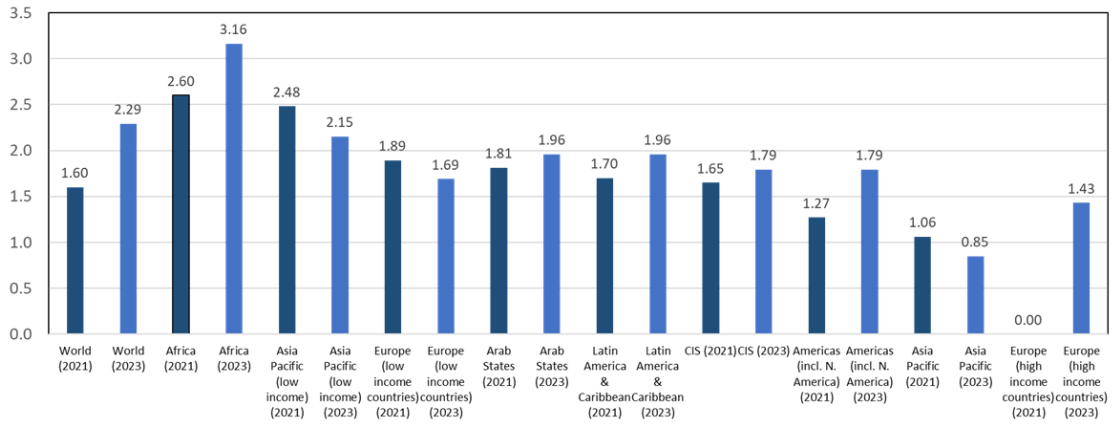
First, they showed that the impact on GDP per capita remains higher for mobile broadband than for fixed broadband.

Second, they confirmed the positive effect for countries with low and middle income.

Third, they confirmed the diminishing returns effect for highly developed countries, but now the coefficient of economic impact for countries with GDP per capita higher than USD 22 000 (higher income countries) is statistically significant.

Fourth, the results of the later 2023 study are consistent with those of the earlier one, although given the advance of 5G in high-income economies, mobile broadband was found to have a statistically significant impact in these regions as well. These findings provide an insight that could be validated by running the model for the whole-world sample (see Figure 15).

Figure 15: Regional GDP growth impact of a 10 per cent increase in mobile-broadband penetration (2021 vs 2023 studies)



Source: ITU; analysis by the authors.

Econometric modelling was thus applied to all the world's regions with 2010-2023 dataset, assuming an increase of 10 per cent in mobile-broadband penetration to calculate the effect on GDP per capita. The models suggested the following changes with respect to the 2021 study:

- Europe (high-income countries): consistent with the "diminishing returns" effect due to saturation, the impact on GDP per capita derived from mobile broadband is positive but low (only 1.43 per cent). However, the notable increase in the coefficient with respect to the previous study can be associated with the increasing economic importance of 5G.
- Europe (low-income countries): the coefficient of economic impact decreased marginally from 1.89 per cent to 1.69, well within the 90 per cent confidence interval.
- Americas: driven by the increasing returns to scale resulting from increasing penetration in Latin America, the Americas region shows that GDP would increase by 1.79 per cent (rather than 1.27 per cent in 2021). When isolated from the rest of the Americas region, the coefficient of impact on GDP per capita for Latin America increases from 1.70 per cent to 1.96. Again, the development of 5G networks, particularly in North America, may lie behind these effects.
- Asia-Pacific: a 10 per cent increase in mobile penetration would cause GDP per capita in the region to increase by 0.85 per cent, down from 1.06 in the 2021 study. The coefficient of GDP impact for Asia and the Pacific (low- and medium-income countries) decreased,

albeit at a lower rate and, again, consistently within the 90 per cent confidence interval: from 2.48 per cent to 2.15 per cent.

- Africa: as in the prior study, most countries in the region would enjoy a significant increase in GDP per capita if mobile penetration were to increase by 10 per cent: the calculated coefficient of 3.16 per cent is an increase from the 2.60 per cent in the 2021 study, suggesting an incremental return to additional mobile-broadband penetration.
- Arab States: the coefficient calculated for this group would increase from 1.81 per cent in the 2021 study to 1.96 with data through 2023.
- CIS: the countries in this region would see increase in the coefficient to 1.79 per cent, up from 1.65 per cent in the 2021 study, although again that result is within the 90 per cent confidence interval.

A comparison between the new results of the structural model and those obtained with the 2010-2020 broadband datasets thus leads to the following conclusions.

- First, in the context of an increase in mobile-broadband penetration, and a partial decline in service prices, the calculated coefficient for the economic impact of mobile broadband has increased. Some regions (Africa, CIS, the Americas, and high-income Europe) have undergone an increase in the economic impact of mobile broadband.
- Second, the reduction in the economic impact coefficient in Europe (low-income countries) and in the Asia and the Pacific region suggests that a "diminishing returns" effect may be kicking in as mobile-broadband penetration in those regions approaches saturation.
- Third, given the advance of 5G in high-income economies, mobile broadband was found to have a statistically significant impact in these regions as well.

5 Global analysis of fixed and mobile broadband and its impact on the economy through 2023

In summary, running the structural models for the dataset ending in 2023 for fixed and mobile broadband suggests the following:

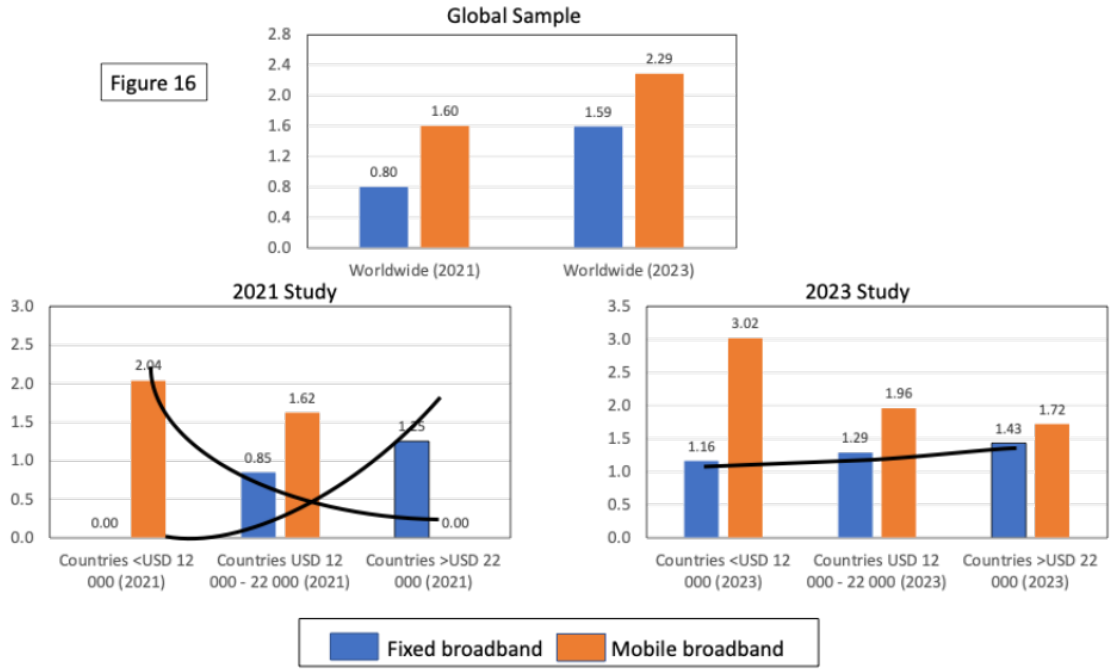
- The changes that took place in the broadband ecosystem in many countries during and after the pandemic (continuing capital spending on broadband expansion, increased penetration, and more affordable pricing, especially for mobile) have not substantially altered the conclusions drawn in the 2021 study.
- However, the calculated increase in per capita GDP resulting from a 10 per cent increase in broadband penetration in the global sample has increased for both fixed and mobile broadband, indicating continued increasing returns to scale.
- The contribution of fixed broadband continues to be greater in developed than in developing countries.
- The economic dividend of mobile broadband continues to be greater in countries with lower levels of economic development, diminishing in countries and regions with higher levels of penetration and development.

Repeating the modelling using the dataset extending to the end of 2023 and comparing the results with those obtained in the 2021 study has identified a higher economic contribution of mobile broadband in low-income developed countries and of fixed broadband in middle-income developed countries.

Figure 16 presents a comparison between the findings of the 2021 and 2023 studies regarding the economic impact of a hypothetical 10 per cent increase in broadband penetration. The top figure indicates that, on a global scale, the calculated economic contribution of such an increase in penetration has increased for both fixed and mobile broadband. This confirms the existence of increasing returns to scale, which establishes that the economic impact of the technology increases with the adoption of the technology. In other words, if the objective is to maximize the economic contribution of the technologies, it is important to accelerate their adoption.

The two bottom figures also compare the economic impact of fixed and mobile broadband in countries with different levels of development for the two studies. The comparison confirms and shows that while the contribution of fixed broadband continues to be greater in developed than in developing countries (1.43 per cent in high-income economies versus 1.16 per cent in low-income ones), the economic dividend of mobile broadband continues to be greater in countries with lower levels of economic development than in regions with higher levels of penetration and development (3.02 per cent in countries where GDP per capita is under USD 12 000 versus 1.72 per cent in countries where it is above USD 22 000).

Figure 16: GDP growth impact of a 10 per cent increase in broadband penetration (2021 vs 2023 studies)



Source: ITU; analysis by the authors.

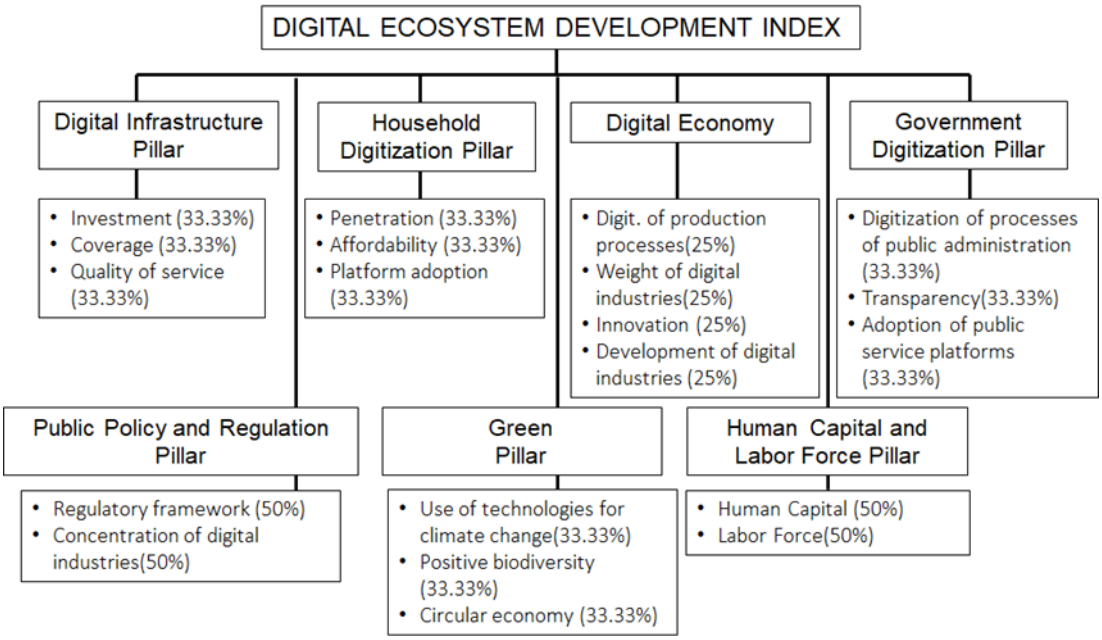
6 Digitization and its impact on the economy through 2022[16]

Digitization is the transformation of the techno-economic environment and socio-institutional operations of a nation through the deployment and use of digital technologies and applications. The 2018 and 2020 study introduced a digitization index that measured the cumulative economic effect of adoption and usage of multiple information and communication technologies across individual users and enterprises, the development of digital industries, and the factors of production of the digital economy, among other factors. This chapter compares econometric models to estimate the impact of digitization on GDP and productivity through 2022.

6.1 A new measurement of digitization

Since the 2021 study, a new index has been developed aiming to capture better the new dimensions of the digital economy. The new index, developed in 2022, is based on seven pillars and 158 indicators (see Figure 17).

Figure 17: Digital ecosystem development index structure

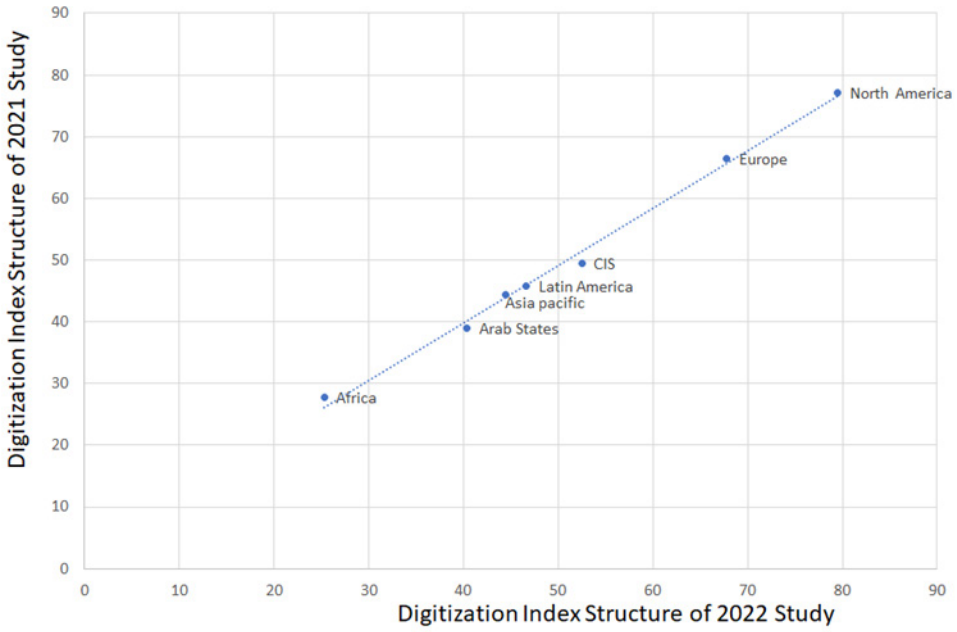


Source: CAF Latin America development Bank

A comparison of the prior and new indicates a high level of consistency (see Figure 18).

[16] The analysis extends up to 2022, as this is the latest available data point for the Digitalization Index.

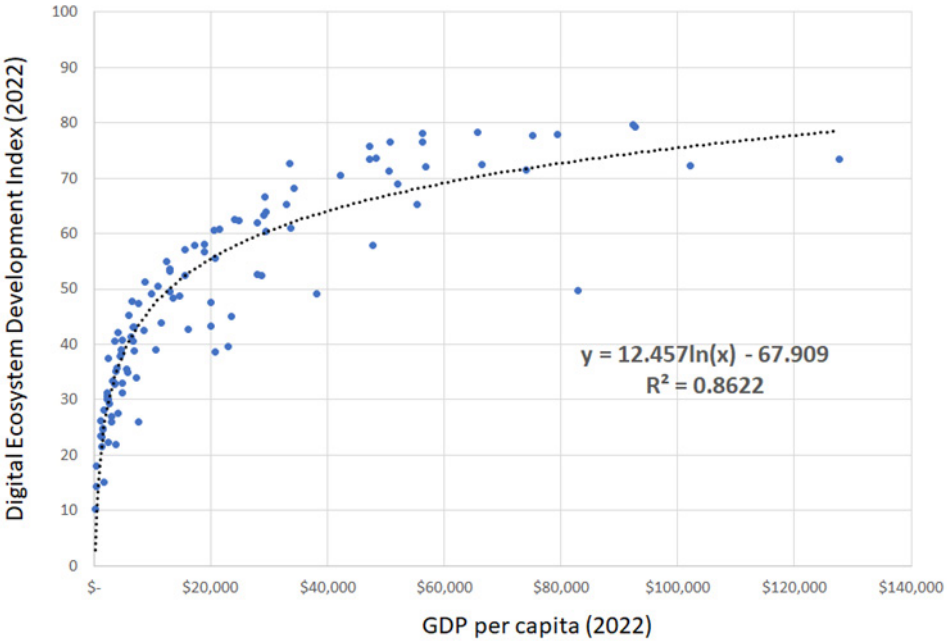
Figure 18: Correlation between both indices of the digital ecosystem (last data available for each index)



Source: CAF; analysis by the authors.

As in the 2021 version, the newly developed digital ecosystem index correlates with economic development (see Figure 19).

Figure 19: Correlation between GDP per capita and digital ecosystem development index, 2022



Sources: CAF; International Monetary Fund (IMF); analysis by the authors

6.2 Digitization and its impact on the economy until 2021

The economic impact of digitization in the 2021 study was tested through two econometric models run on data for 73 countries.[17] An endogenous growth model was used to test the impact of digitization on GDP growth, based on the Cobb-Douglas production function:

$$\log(GDP_{it}) = \alpha_0 + \alpha_1 \log(Capital_{it}) + \alpha_2 \log(Human\ Capital_{it}) + \alpha_3 \log(Digitization\ Index_{it}) + \alpha_4 \log(GDP_{it-1}) + \varepsilon_{it}$$

In addition, two models to test the impact of digitization on productivity were based on the following models:

$$\log(GDP_{it}/L_{it}) = \log(\mu_{it}) + \Upsilon \log(Digitization\ Index_{it}) + \alpha \log(k)$$

$$\log(Total\ Factor\ Productivity(A)_{it}) = \log(\mu_{it}) + \Upsilon \log(Digitization\ Index_{it})$$

The results of the models run on the prior version (2021) of the index indicated the following:

- On a global scale, digitization has a larger economic contribution than fixed broadband, on a par with that of mobile broadband: a hypothetical 10 per cent increase in the digitization index is associated with a 1.35 per cent increase in GDP per capita.
- The impact of digitization on advanced economies is higher than in emerging countries, confirming the increasing returns to scale effect: a 10 per cent increase in the digitization index yields an increase of 1.54 per cent of GDP per capita in OECD countries and 1.00 per cent in non-OECD countries.
- Digitization boosts labour productivity: a 10 per cent increase in the digitization index yields an increase of 2.50 per cent in labour productivity.
- Finally, a 10 per cent increase in the digitization index is associated with a 1.9 per cent increase in total factor productivity.

6.3 Digitization and its impact on the economy through 2022

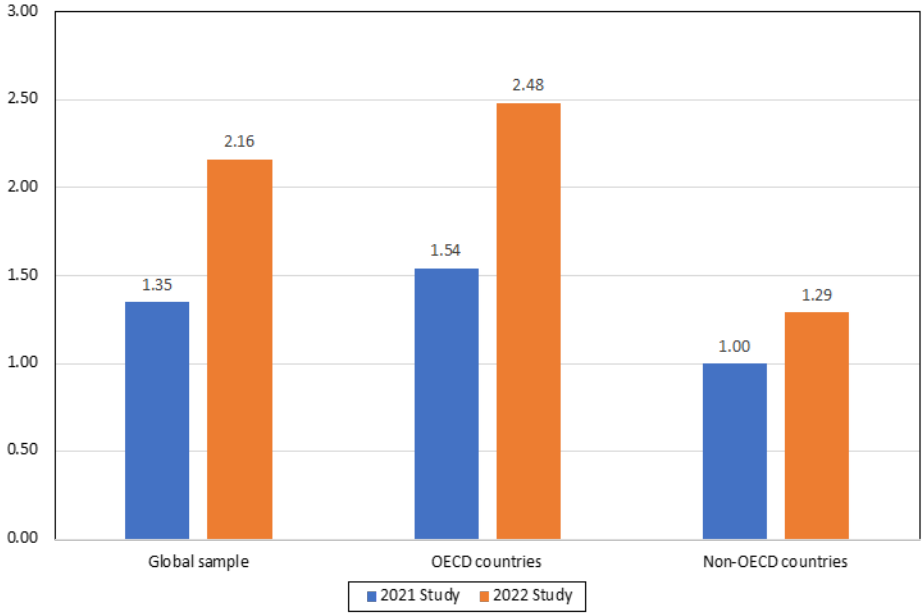
Using the same model, the economic impact of digitization through 2022 was then estimated for two variables: GDP growth and productivity.

Digitization and GDP growth

The impact on GDP growth was tested through a generalized method of moments (GMM) dynamic panel data model run for 101 countries with data between 2004 and 2022, once for the global sample and once for OECD and non-OECD countries separately (in the latter case, the series started in 2005). Figure 20 compares the results of this analysis with those generated in the 2021 study.

[17] The economies included: Argentina, Australia, Austria, Azerbaijan, Barbados, Belarus, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Côte d'Ivoire, Czech Republic, Denmark, Dominican Republic, 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, Latvia, Lebanon, Luxembourg, Malaysia, Mexico, Netherlands, New Zealand, Nicaragua, Norway, Panama, Paraguay, Peru, Poland, Portugal, Republic of Korea, Romania, Russian Federation, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Trinidad and Tobago, Türkiye, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela. Not all countries are included in the regression in every year due to a lack of control data in some cases.

Figure 20: Impact on GDP of a 10 per cent increase in the digital ecosystem development index



Sources: ITU; analysis by the authors.

As indicated in Figure 20, the results of the current study models are higher for 2022 than those for the previous year, as digitization aided in countering the GDP decline due to the pandemic. On the global scale, the impact of the digital ecosystem index increased from 1.35 per cent to 2.16 per cent. Second, as in the earlier study, the impact of the digital index on developed nations is higher than in developing countries (2.48 per cent vs 1.29 per cent), confirming the returns to scale effect. Again, this confirms the increasing relevance of digitization for economic activity since the pandemic.

Digitization and productivity

To measure the impact on labour productivity, the starting point was a Cobb-Douglas production function where GDP depends on physical capital stock (K) and labour (L):

$$GDP = AK^{\alpha}L^{\beta}$$

where the total factor productivity term (A) depends on the degree of digitization of each country: .

By assuming constant returns to scale on capital and labour, the function was converted to state that labour productivity depends on digitization and on physical capital stock per worker (lower-case letters *y* and *k* denote output and capital in worker terms). By applying logarithms for linearization, the following model was defined:

$$\log(GDP_{it}/L_{it}) = \log(\mu_{it}) + \Upsilon \log(Digitization\ Index_{it}) + \alpha \log(k)$$

Where is a fixed effect assumed to be specific for each country. The linear regression estimate was performed for a sample of 99 countries for the period 2009-2022.

Table 10: Fixed effects regression of labour productivity on capital per worker and digitization

Dependent variable:	Coefficient
log(*Digitization Index*)	0.2758***
	(0.0920)
log(*k*)	0.5688***
	(0.0774)
Country fixed effects	Yes
Year fixed effects	Yes
R-squared (within)	0.808
Observations	1 385

Note: *** p<1%. Robust standard errors in brackets.
Source: The Conference Board; analysis by the authors.

The coefficient of 0.2758 with high statistical significance in Table 10 indicates that a 10 per cent increase in the digitization index is associated with a 2.8 per cent increase in labour productivity. This result is not markedly different from the one calculated for 2020, where the coefficient was 2.5.

Alternatively, as stated initially, the total factor productivity term depends on the digitization level of each country, plus an individual fixed effect for each economy. By applying logarithms, this can be expressed as:

$$\log(Total\ Factor\ Productivity(A)_{it}) = \log(\mu_{it}) + \Upsilon\log\left(Digitization\ Index_{it}\right)$$

The corresponding regression yields the following results for a sample of 100 countries for the period 2004-2022:

Table 11: Fixed effects regression of total factor productivity on digitization

Dependent variable:	Coefficient
log(*digitization index*)	0.3136**
	(0.1313)
Country fixed effects	Yes
Year fixed effects	Yes
R-squared (within)	0.134
Observations	1 900

Note: ** p<5%. Robust standard errors in brackets.
Source: The Conference Board; analysis by the authors.

This means that, with the data through 2022, a 10 per cent increase in the digitization index is associated with a 3.1 per cent increase in total factor productivity. In the study published in 2021, that coefficient was 1.9 per cent.

The increase in the impact between the 2021 and 2023 studies reinforces the need for countries to build an agenda focused on development of the digital economy. That should comprise five areas of policy intervention[18]:

- Development of digital infrastructure, which consists of ICT capital spending, increased connectivity, and affordability. This should be achieved by providing the necessary incentives through enhanced universal service funding, balancing fiscal policies, reforming the management of spectrum, and taking innovative approaches to infrastructure sharing.
- Digital human capital, which entails the development of digital skills to match the changing needs of economies undergoing digital transformation. This should include educational and training programmes for skilling and reskilling, both in the general population and in the labour force.
- Digital innovation relating to the scale of research and development and the fostering of incubation ecosystems, by enhancing additional fiscal and financial incentives to support research and development.
- Digital adoption, which comprises the adoption of ICT services, devices and digital platforms by individuals, enterprises and governments. This should include lowering barriers to accessing digital devices and equipment by reducing import duties and bringing down local manufacturing costs.
- Development of a domestic digital sector, which entails the incubation of local sectors offering digital products and services both for local consumption and exporting.

[18] See ITU (2023). *Best Practice Guidelines: Regulatory and economic incentives for an inclusive sustainable digital future*. ITU Global Symposium for Regulators (GSR) 2023.

7 Conclusions and policy implications

This research has provided evidence that the ICT ecosystem has continued to grow in the time since the 2021 study. The following particularly notable trends were identified in the 2023 study. The expansion of broadband service coverage that began in 2020 in response to the COVID-19 pandemic, while slowing down, continues, thanks to increasing affordability and service coverage. Worldwide, fixed-broadband connectivity has grown to 71 per cent of households in 2023, although the rate of growth has diminished, possibly indicating that the pandemic-induced connectivity needs have been largely met (in other words, a diminished need for digital service has driven a decrease in the rate of growth of fixed broadband). The ongoing increase in broadband adoption was enabled by lower service prices. In the context of increasing income per capita in the post-COVID world, fixed-broadband prices[19] as a percentage of GNI per capita declined worldwide by 6.29 per cent the last year. Except for Africa, the digital divide is driven by non-economic factors (low digital literacy, lack of culturally relevant of content, and poor network coverage). Worldwide, fixed broadband (as a percentage of households) by 2023 was reaching an estimated average of 76 per cent of the population. The figure was above 90 per cent in North America, Europe, the CIS, and Latin America and the Caribbean and the Arab States. Coverage is lower in Asia and the Pacific and in Africa (75 per cent and 30 per cent respectively). While FTTH and 5G coverage is increasing, the gap between advanced economies and the developing countries remains significant.

Despite the increase in adoption presented above (with the consequent growth in traffic), worldwide telecommunication CAPEX per capita measured in current terms has increased at low rates. While the rate at which worldwide CAPEX per capita is increasing has slowed somewhat, from 0.62 per cent in 2021 to 2.37 per cent in 2022 and 0.27 per cent in 2023, it should be noted that, given a global inflation rate of 4.3 per cent[20], capital spending per capita in real terms is diminishing, hampering the continued growth of network coverage and consequently adoption of broadband, especially in rural areas.

These trends notwithstanding, the changes that took place in the ICT ecosystem at the end of the pandemic have not substantially altered the importance of ICT as a driver of economic growth:

- A hypothetical increase of 10 per cent in fixed-broadband penetration is associated with a 1.59 per cent increase in GDP per capita.
- An increase of 10 per cent in mobile-broadband penetration is associated with a 2.29 per cent increase in GDP per capita.
- Digitization also drives increases in GDP, labour productivity, and total factor productivity.

The confirmation of the economic contribution of ICT through 2023 provides support for policy measures aimed at bridging the digital divide. Policymakers and regulators in developing countries need to evaluate initiatives to reverse the decline in capital spending and stimulate investment in telecommunications to ensure continuous roll-out of networks. The modernization of the telecommunication regulatory framework should include, among other initiatives: granting convergent licences; making sufficient radio spectrum available at reasonable prices; allowing this resource to be traded in the secondary market with the acquiescence of the regulator, and to *be refarmed*; and defining significant market power based on criteria that go beyond simple

[19] The ITU surveys prices of the least expensive plan from the operator with the largest market share.
[20] IMF. Inflation rate, average consumer prices 2023. Retrieved in: https://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/ADVEC/WEOWORLD

market share. Of these elements, radio spectrum availability is particularly noteworthy, first, due to the lack of assigned amounts of this resource, and second, due to excessive pricing.

In addition, governments should emphasize initiatives to promote digital literacy among the vulnerable and disadvantaged. Programmes are needed to foster digital literacy in formal education, embedding ICT training in primary and secondary school curricula, complemented with targeted programmes focused on teachers. Digital literacy programmes in the formal educational system should be, by definition, large-scale and centrally driven, generally hosted within the ministries of education.

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APPENDICES

A.1 Fixed broadband models: global sample

	Global model	Low income	Middle-income	High income
Log(GDP per capita)				
Log(gross fixed capital formation)	0.0508***	0.1147***	0.1287***	0.0515***
	(0.0042)	(0.0092)	(0.0176)	(0.0091)
Log(education)	0.0439***	0.1243***	0.1943***	-0.0207**
	(0.0085)	(0.0193)	(0.0161)	(0.0092)
Log(fixed broadband penetration)	0.1586***	0.1156***	0.1292***	0.1428***
	(0.0182)	(0.0128)	(0.0068)	(0.0259)
Log(fixed broadband penetration)				
Log(mobile penetration)	0.2028***	0.4072***	-0.0689***	0.0595**
	(0.0304)	(0.0541)	(0.0149)	(0.0237)
Log(fixed telephone penetration)	0.0021	0.0254***	-0.0012	0.1094***
	(0.0032)	(0.0087)	(0.0016)	(0.0134)
Log(rural population)	-0.3548***	-0.6290***	0.0621	-0.5774***
	(0.0461)	(0.0365)	(0.0463)	(0.0526)
Log(GDP per capita)	2.9146***	0.7167***	-0.2499	1.8228***
	(0.0597)	(0.0479)	(0.1887)	(0.0544)
Log(fixed broadband price)	-0.0720***	-0.3776***	-0.1057***	-0.0316***
	(0.0104)	(0.0230)	(0.0233)	(0.0077)
Log(HHI fixed broadband)	-0.0474***	0.0329	0.0337	-0.1968***
	(0.0117)	(0.0241)	(0.0221)	(0.0199)
Log(fixed broadband revenue)				
Log(GDP per capita)	0.7966***	1.9414***	-0.4313**	0.7674***
	(0.0322)	(0.0869)	(0.2101)	(0.0812)
Log(fixed broadband price)	0.5765***	0.8658***	0.8947***	1.0494***
	(0.0361)	(0.0216)	(0.0258)	(0.0547)
Log(HHI fixed broadband)	-0.6692***	-0.0709	0.0506**	-0.9953***
	(0.0373)	(0.0493)	(0.0246)	(0.0506)
Fixed broadband adoption growth				
Log(fixed broadband revenue)	-0.4264***	-1.3786***	2.5424***	-0.2087***
	(0.0297)	(0.4610)	(0.4757)	(0.0206)
Observations	5 107	960	1 203	2 897
Country fixed effects	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes

(continued)

	Global model	Low income	Middle-in-come	High income
R-squared first model	0.991	0.958	0.881	0.978
Period	2010-2023	2010-2023	2010-2023	2010-2023

A.2 Fixed broadband models: regional models

	Africa	Europe (low income)	CIS	Arab States	Latin America and the Caribbean	Asia and the Pacific	Americas (including North America)	Europe (high income)
Log(GDP per capita)								
Log(gross fixed capital formation)	0.1591***	-0.1636***	-0.0291*	0.0713***	0.1985***	0.1221***	0.0434***	0.1031***
	(0.0149)	(0.0178)	(0.0163)	(0.0119)	(0.0198)	(0.0195)	(0.0114)	(0.0120)
Log(Education)	-0.0516*	0.0565***	-0.0479***	0.1948***	0.1129***	0.1513***	0.0175	0.0155
	(0.0264)	(0.0138)	(0.0134)	(0.0290)	(0.0243)	(0.0112)	(0.0138)	(0.0097)
Log(fixed broadband penetration)	0.1247***	0.1049***	0.1611***	0.0965**	0.1355***	0.1843***	0.2098***	0.3088***
	(0.0302)	(0.0074)	(0.0144)	(0.0479)	(0.0080)	(0.0111)	(0.0054)	(0.0329)
Log(Fixed broadband penetration)								
Log(fixed telephone penetration)	0.0275	-0.0234***	0.3431***	-0.0081	-0.2873***	0.2033***	-0.1307***	0.1035***
	(0.0183)	(0.0075)	(0.0446)	(0.0115)	(0.0262)	(0.0241)	(0.0378)	(0.0094)
Log(mobile penetration)	0.0934	-0.3683***	0.4415***	-0.1729**	-0.0859*	1.0198***	-0.2510***	-0.1118***
	(0.1351)	(0.0711)	(0.1532)	(0.0818)	(0.0444)	(0.0770)	(0.0625)	(0.0322)
Log(rural population)	0.5483***	-0.1898	2.0528***	0.2904***	-0.1218	0.0993***	-1.3932***	-0.0870***
	(0.0778)	(0.2078)	(0.2847)	(0.0117)	(0.2349)	(0.0088)	(0.3504)	(0.0079)
Log(GDP per capita)	0.7587***	0.0322	4.2393***	0.9098***	-0.4524	0.9308***	-1.8228***	0.3704***
	(0.0568)	(0.1832)	(0.1434)	(0.0473)	(0.3744)	(0.0418)	(0.5536)	(0.0193)
Log(fixed broadband price)	-0.3529***	-0.1125***	-0.3950***	0.3162***	-0.0701***	-0.1893***	-0.1870***	-0.0123
	(0.0526)	(0.0217)	(0.0311)	(0.0381)	(0.0190)	(0.0244)	(0.0237)	(0.0138)
Log(HHI fixed broadband)	0.2888***	0.1057***	0.2029***	-0.2152***	0.2979***	-0.5881***	0.2246***	-0.0633***
	(0.0774)	(0.0229)	(0.0219)	(0.0521)	(0.0308)	(0.0358)	(0.0457)	(0.0129)
Log(fixed broadband revenue)								
Log(GDP per capita)	-0.2032***	3.2292***	1.5631***	0.8292***	1.0333***	2.7269***	4.8656***	1.3181***
	(0.0484)	(0.2692)	(0.0694)	(0.0936)	(0.1023)	(0.0666)	(0.1118)	(0.0323)
Log(fixed broadband price)	0.3115***	0.3208***	-0.8350***	0.4125***	0.8215***	0.9876***	1.0582***	0.9733***
	(0.0680)	(0.0888)	(0.0891)	(0.0992)	(0.1385)	(0.0166)	(0.0193)	(0.0083)
Log(HHI fixed broadband)	-2.4242***	0.2768***	-0.3017***	0.8714***	-1.3818***	-0.3122***	-0.0711***	-0.1761***
	(0.1054)	(0.0817)	(0.0406)	(0.1506)	(0.0861)	(0.0529)	(0.0263)	(0.0186)
Fixed broadband adoption growth								
Log(fixed broadband revenue)	-0.3027	-0.4174***	-9.6887***	1.0758***	-0.3904***	-0.5056***	-0.3681***	-0.0721***
	(0.3510)	(0.0801)	(0.9170)	(0.1279)	(0.0508)	(0.0619)	(0.0360)	(0.0158)
Observations	395	1 269	380	628	821	816	933	1 731
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared first model	0.996	0.221	0.992	0.991	0.985	0.997	0.990	0.977

A.3 Mobile broadband models: global sample

	Global	Low-income countries	Middle-income countries	High-income countries
Log(GDP per capita)				
Log(gross fixed capital formation)	0.0340***	0.0152***	-0.1176***	0.0532***
	(0.0034)	(0.0054)	(0.0184)	(0.0065)
Log(education)	0.0142***	0.0064	-0.0009	0.0055
	(0.0035)	(0.0075)	(0.0147)	(0.0069)
Log(mobile broadband penetration)	0.2286***	0.3019***	0.1962***	0.1716***
	(0.0093)	(0.0204)	(0.0149)	(0.0149)
Log(mobile broadband penetration)				
Log(mobile penetration)	0.6746***	0.2799***	0.0400**	0.1387***
	(0.0249)	(0.0318)	(0.0186)	(0.0167)
Log(rural population)	0.1519***	-1.2605***	0.3158***	-0.1395***
	(0.0494)	(0.0726)	(0.0518)	(0.0271)
Log(GDP per capita)	-0.0617	3.0030***	-0.7191***	3.5157***
	(0.0686)	(0.0565)	(0.1166)	(0.0615)
Log(mobile ARPU)	0.0397***	0.0156	0.0634**	-0.0179
	(0.0087)	(0.0136)	(0.0255)	(0.0135)
Log(HHI mobile broadband)	0.0050	-0.0675***	0.1970***	-0.2697***
	(0.0128)	(0.0179)	(0.0295)	(0.0259)
Log(mobile broadband revenue)				
Log(GDP per capita)	4.3311***	4.0630***	-0.8892***	4.0468***
	(0.0567)	(0.0911)	(0.1307)	(0.0793)
Log(mobile broadband price)	1.0128***	1.0294***	1.0696***	1.0062***
	(0.0103)	(0.0230)	(0.0286)	(0.0156)
Log(HHI mobile broadband)	-0.1272***	-0.2186***	0.1439***	-0.2150***
	(0.0136)	(0.0294)	(0.0330)	(0.0308)
Mobile broadband adoption growth				
Log(mobile broadband revenue)	-0.2749***	-0.2627***	-0.6570	-0.2925***
	(0.0318)	(0.0898)	(0.5131)	(0.0457)
Observations	6 063	1 889	1 224	2 901
Country fixed effects	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes
R-squared first model	0.995	0.974	0.175	0.975

A.4 Mobile broadband models: regional models

	Africa	Europe (low income)	CIS	Arab States	Latin America & Caribbean	Asia and the Pacific	Americas (incl. N. America)	Europe (high income)	Asia and the Pacific (low & medium-income)
Log(GDP per capita)									
Log(gross fixed capital formation)	0.0384***	0.1849***	-0.8183***	0.0898***	-0.0088	0.2456***	0.0163	0.1700***	0.3337***
	(0.0102)	(0.0202)	(0.1214)	(0.0082)	(0.0174)	(0.0203)	(0.0149)	(0.0158)	(0.0166)
Log (education)	-0.0153	0.0880***	0.5145***	0.1255***	-0.0317	0.2580***	-0.0037	-0.1072***	0.1647***
	(0.0124)	(0.0138)	(0.0409)	(0.0162)	(0.0204)	(0.0144)	(0.0135)	(0.0161)	(0.0146)
Log(mobile broadband penetration)	0.3159***	0.1689***	0.1787***	0.1959***	0.1962***	0.0852***	0.1787***	0.1430***	0.2151***
	(0.0403)	(0.0323)	(0.0636)	(0.0290)	(0.0290)	(0.0188)	(0.0270)	(0.0493)	(0.0245)
Log(mobile broadband penetration)									
Log(mobile penetration)	0.4353***	0.6062***	0.9742***	1.3494***	-0.0077	1.3959***	-0.0820*	0.6784***	0.1469***
	(0.0448)	(0.0702)	(0.1836)	(0.0921)	(0.0273)	(0.0516)	(0.0441)	(0.0415)	(0.0200)
Log(rural population)	1.6543***	-0.8667***	7.3756***	1.0487***	-0.2477***	0.0280***	0.0367	-0.1131*	0.2502***
	(0.2165)	(0.1995)	(2.5376)	(0.1453)	(0.0625)	(0.0043)	(0.1385)	(0.0579)	(0.0595)
Log(GDP per capita)	-0.9227***	2.2006***	-2.9380**	-0.0983	4.7438***	0.2599***	2.9983***	-0.0152	-0.3767***
	(0.1495)	(0.1337)	(1.3972)	(0.1756)	(0.1351)	(0.0208)	(0.2573)	(0.0995)	(0.0997)
Log(mobile ARPU)	0.0077	0.1767***	0.0377	0.1803***	0.0574*	-0.0777***	-0.0946***	0.0751***	0.0620***
	(0.0172)	(0.0353)	(0.0627)	(0.0310)	(0.0315)	(0.0146)	(0.0231)	(0.0162)	(0.0234)
Log(HHI mobile broadband)	0.1578***	-0.3064***	0.3756**	-0.2810***	-0.3699***	0.0987***	-0.1205***	0.0273	0.1907***
	(0.0230)	(0.0317)	(0.1525)	(0.0367)	(0.0348)	(0.0313)	(0.0210)	(0.0182)	(0.0241)
Log(mobile broadband revenue)									
Log(GDP per capita)	4.7298***	1.2926***	0.8944***	0.4129***	5.5080***	-0.1778*	5.7003***	0.9946***	-0.4049***
	(0.2176)	(0.2440)	(0.0764)	(0.0743)	(0.1540)	(0.1042)	(0.1451)	(0.1055)	(0.1142)
Log(mobile broadband price)	1.1295***	0.8774***	0.5528***	0.2539***	1.0955***	0.9729***	1.0813***	0.1510**	1.0103***
	(0.0337)	(0.0910)	(0.0962)	(0.0578)	(0.0402)	(0.0874)	(0.0374)	(0.0649)	(0.0264)

(continued)

	Africa	Europe (low income)	CIS	Arab States	Latin America & Caribbean	Asia and the Pacific	Americas (incl. N. America)	Europe (high income)	Asia and the Pacific (low & medium-income)
Log(HHI mobile broadband)	-0.3124***	-2.4746***	-2.6725***	-1.7272***	-0.3478***	-0.6951***	-0.3646***	-2.7861***	0.2030***
	(0.0480)	(0.1991)	(0.1981)	(0.1410)	(0.0456)	(0.1901)	(0.0426)	(0.1439)	(0.0274)
Mobile broadband adoption growth									
Log(mobile broadband revenue)	-0.2689**	-0.3533***	-0.8287***	-0.6296***	-4.8600***	-0.3379***	-4.8463***	-0.2247***	-0.5491
	(0.1067)	(0.0716)	(0.1775)	(0.1735)	(0.3682)	(0.0631)	(0.3362)	(0.0526)	(0.4708)
Observations	1 242	1 224	410	650	819	891	929	1 724	1 540
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared first model	0.987	0.873	0.413	0.995	0.981	0.998	0.990	0.978	0.977

A.5 Digitization models

	Global model	OECD model	non-OECD model
Log(GDP per capita) t-1	0.6689***	0.7314***	0.6646***
	(0.0212)	(0.0307)	(0.0253)
Log(gross fixed capital formation)	0.1352***	0.1076***	0.1155***
	(0.0199)	(0.0264)	(0.0252)
Log(human capital)	0.0325*	-0.0662**	0.0485**
	(0.0184)	(0.0303)	(0.0216)
Log(digitization index)	0.2155***	0.2482***	0.1286*
	(0.0526)	(0.0961)	(0.0782)
Year fixed effects	Yes	Yes	Yes
Observations	1 715	646	1 069
Number of countries	101	38	63
Period	2004-2022	2004-2022	2005-2022

B.1 Methodology - Countries analysed

Countries analysed for economic impact of fixed broadband

• Albania	• Gabon	• Pakistan
• Algeria	• Georgia	• Panama
• Argentina	• Germany	• Paraguay
• Armenia	• Greece	• Peru
• Australia	• Hong Kong, China	• Philippines
• Austria	• Hungary	• Poland
• Azerbaijan	• Iceland	• Portugal
• Bahrain	• India	• Romania
• Bangladesh	• Indonesia	• Russia
• Belarus	• Iraq	• Saudi Arabia
• Belgium	• Ireland	• Senegal
• Bosnia and Herzegovina	• Israel	• Serbia
• Botswana	• Italy	• Singapore
• Brazil	• Jamaica	• Slovakia
• Bulgaria	• Japan	• Slovenia
• Cambodia	• Jordan	• South Africa
• Cameroon	• Kazakhstan	• Spain
• Canada	• Kenya	• Sri Lanka
• Chile	• Korea (Rep. of)	• Sweden
• China	• Kuwait	• Switzerland
• Colombia	• Kyrgyzstan	• Tanzania
• Congo	• Lebanon	• Thailand
• Costa Rica	• Lithuania	• Togo
• Cote d'Ivoire	• Macedonia	• Trinidad and Tobago
• Croatia	• Malaysia	• Tunisia
• Cyprus	• Mali	• Türkiye
• Czech Republic	• Mauritius	• Ukraine
• Denmark	• Mexico	• United Arab Emirates
• Djibouti	• Moldova	• United Kingdom

(continued)

• Dominican Republic	• Morocco	• Uruguay
• Ecuador	• Namibia	• United States
• Egypt	• Nepal	• Uzbekistan
• El Salvador	• Netherlands	• Viet Nam
• Estonia	• New Zealand	• Yemen
• Finland	• Nicaragua	• Zimbabwe
• France	• Norway	

Countries analysed for economic impact of mobile broadband

• Afghanistan	• France	• Nicaragua
• Albania	• Gabon	• Niger
• Algeria	• Gambia	• Norway
• Angola	• Georgia	• Pakistan
• Argentina	• Germany	• Panama
• Armenia	• Ghana	• Paraguay
• Australia	• Greece	• Peru
• Austria	• Guinea	• Philippines
• Azerbaijan	• Guinea-Bissau	• Poland
• Bahrain	• Hong Kong, China	• Portugal
• Bangladesh	• Hungary	• Romania
• Belarus	• Iceland	• Russia
• Belgium	• India	• Rwanda
• Benin	• Indonesia	• Saudi Arabia
• Bosnia and Herzegovina	• Iraq	• Senegal
• Botswana	• Ireland	• Serbia
• Brazil	• Israel	• Singapore
• Bulgaria	• Italy	• Slovakia
• Burkina Faso	• Jamaica	• Slovenia
• Cambodia	• Japan	• South Africa
• Cameroon	• Jordan	• Spain
• Canada	• Kazakhstan	• Sri Lanka
• Chad	• Kenya	• Sweden
• Chile	• Korea (Rep. of)	• Switzerland
• China	• Kuwait	• Tanzania
• Colombia	• Lebanon	• Thailand
• Congo	• Kyrgyzstan	• Togo
• Costa Rica	• Lesotho	• Trinidad and Tobago
• Cote d'Ivoire	• Lithuania	• Tunisia

(continued)

• Croatia	• Macedonia	• Türkiye
• Cyprus	• Malaysia	• Uganda
• Czech Republic	• Mali	• Ukraine
• Dem. Republic of the Congo	• Mauritania	• United Arab Emirates
• Denmark	• Mauritius	• United Kingdom
• Djibouti	• Mexico	• Uruguay
• Dominican Republic	• Moldova	• United States
• Ecuador	• Morocco	• Uzbekistan
• Egypt	• Namibia	• Viet Nam
• El Salvador	• Nepal	• Yemen
• Estonia	• Netherlands	• Zambia
• Ethiopia	• New Zealand	• Zimbabwe
• Finland		

B.2 Methodology - Data sources for models testing the economic impact of fixed and mobile broadband

Indicator	Source[21]
GDP per capita	IMF, World Economic Outlook Database, October 2024
Fixed broadband subscriber penetration	ITU Data Hub
Capital - Gross fixed capital formation (% of GDP)	World Development Indicators
Education- Skilled labour force	World Development Indicators
Fixed telephone subscribers	ITU Data Hub
Rural population (% of total population)	World Development Indicators
Fixed broadband price	ITU
HHI fixed broadband	OVUM & Author´s analysis
Fixed broadband revenue	ITU - OVUM
Mobile broadband subscriber penetration	GSMA
Mobile broadband ARPU	GSMA
HHI mobile broadband	GSMA
Mobile broadband revenue	GSMA

[21] Latest data available in February of 2025

B.3 Indicators included in the Digital Ecosystem Development Index and data sources

Pillar	Sub-pillar	Indicator	Source
Digital Infrastructure	Investment in Digital Infrastructure	Investment in Telecommunications (USD per capita at current prices. 5-year average)	ITU WTI Database & GSMA Intelligence
Digital Infrastructure	Investment in Digital Infrastructure	Investment in Big Data (Index)	Huawei - Oxford Economics
Digital Infrastructure	Investment in Digital Infrastructure	Investment in Data Centers (Index)	Huawei - Oxford Economics
Digital Infrastructure	Investment in Digital Infrastructure	Investment in Cloud (Index)	Huawei - Oxford Economics
Digital Infrastructure	Investment in Digital Infrastructure	Investment in IoT (Index)	Huawei - Oxford Economics
Digital Infrastructure	Network Coverage	2G Network Coverage (% of population)	ITU WTI Database
Digital Infrastructure	Network Coverage	3G Network Coverage (% of population)	GSMA Intelligence
Digital Infrastructure	Network Coverage	4G Network Coverage (% of population)	GSMA Intelligence
Digital Infrastructure	Network Coverage	5G Network Coverage (% of population)	GSMA Intelligence
Digital Infrastructure	Network Coverage	Fixed Broadband Coverage (% of households)	TAS Survey based on regulator data and company financial statements
Digital Infrastructure	Network Coverage	Electricity Coverage (% of population)	World Bank
Digital Infrastructure	Network Coverage	FTTH Coverage (% of households)	IDATE; OECD; TAS Survey
Digital Infrastructure	Service Quality	Average Download Speed of Fixed Broadband (Kbps)	Ookla/ Speedtest
Digital Infrastructure	Service Quality	Median Download Speed of Fixed Broadband (Kbps)	Ookla/ Speedtest
Digital Infrastructure	Service Quality	Median Latency of Fixed Broadband (Ms)	Ookla/ Speedtest

(continued)

Pillar	Sub-pillar	Indicator	Source
Digital Infrastructure	Service Quality	Average Download Speed of Mobile Broadband (Kbps)	Ookla/ Speedtest
Digital Infrastructure	Service Quality	Median Download Speed of Mobile Broadband (Kbps)	Ookla/ Speedtest
Digital Infrastructure	Service Quality	Median Latency of Mobile Broadband (Ms)	Ookla/ Speedtest
Digital Infrastructure	Service Quality	International Bandwidth per capita (bit/s)	ITU WTI Database
Digital Infrastructure	Service Quality	Internet Exchange Points per 1,000,000 inhabitants	Packet Clearing House - UNCTAD
Digital Infrastructure	Service Quality	Secure Internet Servers per 1,000,000 inhabitants	World Development Indicators (World Bank)
Digital Infrastructure	Service Quality	Free Hotspots per 1,000,000 inhabitants	https://www.wifimap.io/
Digital Infrastructure	Service Quality	Number of Satellites in Orbit per 1,000,000 inhabitants	NYO
Public Policy and Regulation	Regulatory Framework	Regulatory Agency Authority (Index from 0 to 100 developed by ITU)	ITU
Public Policy and Regulation	Regulatory Framework	Regulatory Agency Mandate (Index from 0 to 100 developed by ITU)	ITU
Public Policy and Regulation	Regulatory Framework	Regulatory Regime and Framework Index (Index from 0 to 100 developed by ITU)	ITU
Public Policy and Regulation	Regulatory Framework	Competition Model Index (Index from 0 to 100 developed by ITU)	ITU
Public Policy and Regulation	Regulatory Framework	Interministerial Collaborative Governance Index (Index from 0 to 100)	ITU
Public Policy and Regulation	Regulatory Framework	Regulatory Fee (%)	GSMA; Telecommunications Operators
Public Policy and Regulation	Regulatory Framework	Import Tariffs on Equipment (%)	WTO

(continued)

Pillar	Sub-pillar	Indicator	Source
Public Policy and Regulation	Regulatory Framework	Percentage of Licensed Software (Percentage of total software)	BSA
Public Policy and Regulation	Regulatory Framework	Global Cybersecurity Index (Index from 0 to 100 developed by ITU)	ITU
Public Policy and Regulation	Concentration of Digital Industries	Fixed Broadband HHI Index	Ovum, TAS Survey
Public Policy and Regulation	Concentration of Digital Industries	Pay TV HHI Index	TAS Survey based on data from Convergencia Research, OVUM, and Regulators
Public Policy and Regulation	Concentration of Digital Industries	Mobile Broadband HHI Index	GSMA Intelligence
Public Policy and Regulation	Concentration of Digital Industries	Mobile Telephony HHI Index	GSMA Intelligence
Public Policy and Regulation	Concentration of Digital Industries	Streaming HHI Index	TAS Survey based on data from OWLOO, App Annie, and Statista
Public Policy and Regulation	Concentration of Digital Industries	Social Media HHI Index	Stat Counter
Household Digitalization	Digital Technology Penetration	Fixed Broadband Penetration (connections per 100 households)	ITU WTI Database & Omdia
Household Digitalization	Digital Technology Penetration	FTTH Adoption (connections per 100 households)	IDATE; OECD; TAS Survey
Household Digitalization	Digital Technology Penetration	Mobile Broadband Penetration (connections per 100 inhabitants)	GSMA Intelligence
Household Digitalization	Digital Technology Penetration	Mobile Telephony Penetration (connections per 100 inhabitants)	GSMA Intelligence
Household Digitalization	Digital Technology Penetration	Unique Mobile Broadband Users (% of population)	GSMA Intelligence

(continued)

Pillar	Sub-pillar	Indicator	Source
Household Digitalization	Digital Technology Penetration	Pay TV Penetration (% of households)	TAS Survey based on data from ITU, Convergencia Research, B.B., and operator and regulator websites
Household Digitalization	Digital Technology Penetration	Internet Adoption (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Internet Adoption in Rural Areas (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Internet Adoption in Urban Areas (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Internet Adoption among Men (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Internet Adoption among Women (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Mobile Data ARPU as a Percentage of Total Mobile ARPU (%)	GSMA Intelligence
Household Digitalization	Digital Technology Penetration	App Spending per capita (USD per capita)	App Annie
Household Digitalization	Digital Technology Penetration	Computer Penetration (% of households)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Individuals Using a Computer in Rural Areas (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Individuals Using a Computer in Urban Areas (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Individuals Using a Computer among Men (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Individuals Using a Computer among Women (% of population)	ITU WTI Database
Household Digitalization	Digital Technology Penetration	Smartphone Adoption per 100 inhabitants	GSMA Intelligence
Household Digitalization	Affordability of Digital Services	Fixed Broadband Affordability (% of average income)	ITU

(continued)

Pillar	Sub-pillar	Indicator	Source
Household Digitalization	Affordability of Digital Services	Pay TV Affordability (% of average income)	TAS Survey based on data from Convergencia Research and operator websites
Household Digitalization	Affordability of Digital Services	Mobile Broadband Affordability for Smartphone (% of average income)	ITU
Household Digitalization	Affordability of Digital Services	Mobile Broadband Affordability for PC (% of average income)	ITU
Household Digitalization	Affordability of Digital Services	Percentage of Postpaid Mobile Users as a Proxy for Accessibility at the Base of the Pyramid	GSMA Intelligence
Household Digitalization	Affordability of Digital Services	Mobile Telephony Affordability (% of average income)	ITU
Household Digitalization	Adoption of Digital Platforms	App Downloads per capita (average number of downloads per inhabitant)	App Annie
Household Digitalization	Adoption of Digital Platforms	Social Media Adoption (average number of downloads per inhabitant)	App Annie
Household Digitalization	Adoption of Digital Platforms	Teleworking Capacity (% of jobs that can be done from home)	GTAP & ECLAC & Chicago Booth
Household Digitalization	Adoption of Digital Platforms	E-commerce (e-commerce revenue as a percentage of total retail revenue)	Euromonitor
Household Digitalization	Adoption of Digital Platforms	Percentage of Population Using the Internet to Pay Bills or Purchase Something Online (%)	Findex
Digital Economy	Digitalization of Production Processes and Related Services	Internet Usage (% of companies)	UNCTAD, OECD, Eurostat, local statistical institutes
Digital Economy	Digitalization of Production Processes and Related Services	Website Ownership (% of companies)	UNCTAD
Digital Economy	Digitalization of Production Processes and Related Services	Online Purchase of Supplies (% of companies)	UNCTAD, OECD, Eurostat, local statistical institutes

(continued)

Pillar	Sub-pillar	Indicator	Source
Digital Economy	Digitalization of Production Processes and Related Services	Percentage of Employees Using the Internet (% of employees)	UNCTAD, OECD, Eurostat, local statistical institutes
Digital Economy	Digitalization of Production Processes and Related Services	Software Spending per capita (USD)	BSA
Digital Economy	Digitalization of Production Processes and Related Services	Percentage of Employees Using a Computer (% of employees)	UNCTAD, OECD, Eurostat, local statistical institutes
Digital Economy	Digitalization of Production Processes and Related Services	Online Banking Usage (% of companies)	UNCTAD, OECD, Eurostat, local statistical institutes
Digital Economy	Digitalization of Production Processes and Related Services	E-commerce (% of companies)	UNCTAD, OECD, Eurostat, local statistical institutes
Digital Economy	Digitalization of Production Processes and Related Services	Data Center Equipment (Index)	Huawei - Oxford Economics
Digital Economy	Digitalization of Production Processes and Related Services	Installed Base of IoT (Index)	Huawei - Oxford Economics
Digital Economy	Digitalization of Production Processes and Related Services	AI Companies per 1,000,000 inhabitants	Crunchbase
Digital Economy	Digitalization of Production Processes and Related Services	Big Data Analytics Companies per 1,000,000 inhabitants	Crunchbase
Digital Economy	Digitalization of Production Processes and Related Services	Cloud Companies per 1,000,000 inhabitants	Crunchbase

(continued)

Pillar	Sub-pillar	Indicator	Source
Digital Economy	Digitalization of Production Processes and Related Services	IoT Companies per 1,000,000 inhabitants	Crunchbase
Digital Economy	Digitalization of Production Processes and Related Services	Fintech Companies per 1,000,000 inhabitants	Crunchbase
Digital Economy	Weight of Digital Industries	Fixed and Mobile Telecommunications Spending per capita (USD per capita)	ITU WTI Database & GSMA Intelligence
Digital Economy	Weight of Digital Industries	Digital Products Manufacturing (% of GDP)	GTAP
Digital Economy	Weight of Digital Industries	Digital Media Spending (USD per capita)	Global Entertainment & Media Outlook 2019 - 2023 & 2020 - 2024
Digital Economy	Weight of Digital Industries	Electronic Publications Spending (USD per capita)	Global Entertainment & Media Outlook 2019 - 2023 & 2020 - 2024
Digital Economy	Weight of Digital Industries	Digital Advertising Spending (USD per capita)	Global Entertainment & Media Outlook 2019 - 2023 & 2020 - 2024
Digital Economy	Weight of Digital Industries	Video Game Spending (USD per capita)	Global Entertainment & Media Outlook 2019 - 2023 & 2020 - 2024
Digital Economy	Innovation	USPTO Patents per 1,000,000 inhabitants	USPTO
Digital Economy	Innovation	Charges for Intellectual Property Use (USD per capita)	World Bank
Digital Economy	Innovation	Public R&D Spending (% of GDP)	UNESCO
Digital Economy	Innovation	R&D Personnel per million inhabitants	UNESCO

(continued)

Pillar	Sub-pillar	Indicator	Source
Digital Economy	Innovation	Ease of Access to Loans (Index)	World Bank
Digital Economy	Innovation	Total Startup Funding (USD per capita)	CB Insight
Digital Economy	Innovation	Private R&D Spending (% of GDP)	UNESCO
Digital Economy	Innovation	Angel Investments in High-Tech (% of GDP)	OECD
Digital Economy	Development of Digital Industries	Fintech (Average Amount of Digital Payments per Inhabitant, USD)	Statista
Digital Economy	Development of Digital Industries	Percentage of Local Websites among the Top 25 Most Visited (%)	Alexa
Digital Economy	Development of Digital Industries	ICT Goods Exports (USD per capita)	World Bank
Digital Economy	Development of Digital Industries	ICT Services Exports (USD per capita)	World Bank
State Digitalization	Government Digital Services and Procedures	Aggregate Insolvency Indicator (Years to Resolution)	World Bank
State Digitalization	Government Digital Services and Procedures	Property Registration (Index of ease for an LLC to acquire real estate)	World Bank
State Digitalization	Government Digital Services and Procedures	Paying Taxes (Index)	World Bank
State Digitalization	Government Digital Services and Procedures	Ease of Starting a Business (Days Required)	World Bank
State Digitalization	Government Digital Services and Procedures	Customs Processing Time (Index)	World Bank
State Digitalization	Government Digital Services and Procedures	Cross-Border Trade (Index)	World Bank
State Digitalization	Government Digital Services and Procedures	Frequency with Which Shipments Arrive at Their Destination Within the Scheduled or Expected Delivery Times (Index)	World Bank
State Digitalization	Government Transparency and Public Integrity	Open Budget (Index)	International Budget.com

(continued)

Pillar	Sub-pillar	Indicator	Source
State Digitalization	Government Transparency and Public Integrity	OURdata (Index)	OECD
State Digitalization	Government Transparency and Public Integrity	Open Data (Index)	Open Data Barometer
State Digitalization	Government Transparency and Public Integrity	Corruption Perception Index by Transparency International (Index)	Transparency.org
State Digitalization	Government Digital Platforms	Online Service Component of E-government Development Index (Index)	UNDESA
State Digitalization	Government Digital Platforms	Government Websites Quality Index (Index)	UNDESA
State Digitalization	Government Digital Platforms	Medical App Downloads (average downloads per inhabitant)	App Annie
State Digitalization	Government Digital Platforms	National Telemedicine Plan (Binary Variable)	WHO
State Digitalization	Government Digital Platforms	Ratio of Students to Computers Index (Index)	UNESCO
State Digitalization	Government Digital Platforms	Schools with Internet (% of schools)	UNESCO
State Digitalization	Government Digital Platforms	Educational App Downloads (average downloads per inhabitant)	App Annie
Human Capital and Workforce	Human Capital	PISA Results (Score)	OECD
Human Capital and Workforce	Human Capital	Digital Workforce Training (% of companies)	UNCTAD, OECD, Eurostat, local statistical institutes
Human Capital and Workforce	Human Capital	Expected Years of Education (Years)	UNESCO
Human Capital and Workforce	Human Capital	Tertiary Education Enrollment Rate (% of inhabitants in the age range)	UNESCO
Human Capital and Workforce	Human Capital	Graduates in Mathematics, Engineering, and Hard Sciences (per 1,000,000 inhabitants)	UNESCO
Human Capital and Workforce	Workforce	ICT-intensive Jobs (per 1,000 inhabitants)	Going Digital OECD

(continued)

Pillar	Sub-pillar	Indicator	Source
Human Capital and Workforce	Workforce	IT Workforce (Index)	Huawei - Oxford Economics
Human Capital and Workforce	Workforce	Employees in the Telecommunications Sector (per 1,000,000 inhabitants)	ITU WTI Database
Human Capital and Workforce	Workforce	Employment in Digital Industries (% of population)	Going Digital OECD
Human Capital and Workforce	Workforce	Telecom Sector Employment Income (% of total payroll)	GTAP
Human Capital and Workforce	Workforce	Population with Digital Skills (% of population)	ITU
Human Capital and Workforce	Workforce	Digital Skills Index (Index)	WEF
Human Capital and Workforce	Workforce	Software Developers Quantity Index (Index)	Huawei - Oxford Economics
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Domestic Product Emissions in Current Production, Mt CO2 per USD 1 billion of GDP	GTAP
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Import Emissions in Current Production, Mt CO2 per USD 1 billion of GDP	GTAP
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Private Consumption Emissions of Domestic Product, Mt CO2 per USD 1 billion of GDP	GTAP
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Private Consumption Emissions of Imported Product, Mt CO2 per USD 1 billion of GDP	GTAP
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Greenhouse Gas Emissions in the Energy Sector, Mt CO2 per USD 1 billion of GDP	Climate Watch
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Greenhouse Gas Emissions in Industrial Processes, Mt CO2 per USD 1 billion of GDP	Climate Watch

(continued)

Pillar	Sub-pillar	Indicator	Source
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Greenhouse Gas Emissions in Agriculture, Mt CO2 per USD 1 billion of GDP	Climate Watch
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Greenhouse Gas Emissions in Waste, Mt CO2 per USD 1 billion of GDP	Climate Watch
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	Adjusted Savings: Damage by CO2 Emissions (% of GNI)	World Bank
Green Digital Economy	Use of Technologies for Climate Change Mitigation and Adaptation	E-waste Generated per Capita (Kg per USD 1 billion of GDP)	Global Waste.org
Green Digital Economy	Positive Biodiversity	Percentage of Primary Energy from Renewable Sources (%)	Our World in Data
Green Digital Economy	Positive Biodiversity	Proportion of Controlled Solid Waste (%)	EPI
Green Digital Economy	Positive Biodiversity	Wastewater Treatment (% of total)	EPI
Green Digital Economy	Positive Biodiversity	Reduction in Forest Coverage in Forested Areas (Index)	EPI
Green Digital Economy	Circular Economy	Presence of E-waste Regulation Laws (Binary)	Global Waste.org
Green Digital Economy	Circular Economy	Coordination Mechanism for Sustainable Consumption and Production (Number of Laws)	United Nations
Green Digital Economy	Circular Economy	Digital Cities Index (Index)	IMD Business School
Green Digital Economy	Circular Economy	M2M Penetration (per 100 inhabitants)	GSMA Intelligence

B.4 Econometric methodology

Economic contribution of fixed and mobile broadband

The econometric models currently in use in the study consist of four equations: an aggregate production function modelling the economy and, subsequently, three functions: demand, supply and output. In the case of mobile broadband telecommunications, for example, the last three functions model the mobile market operation and, controlling for the reverse effects, the actual impact of the infrastructure, as follows:

- In the production function, GDP is linked to the fixed stock of capital, labour and the mobile infrastructure proxied by mobile broadband penetration.
- The demand function links mobile broadband 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, the mobile penetration and the level of competitive intensity in the mobile market measured by the HHI (Herfindahl Hirschman) index.
- The supply function links aggregate mobile revenues to mobile price levels proxied by ARPU, the industry concentration index of the mobile market (HHI), and GDP per capita.
- The output equation links annual change in mobile penetration to mobile revenues, used as a proxy of the capital invested in a country in the same year. The econometric specification of the model is:

Aggregate Production function: (1)

$$GDP_{it} = a_1K_{it} + a_2L_{it} + a_3MBB\_Pen_{it} + e_{it}$$

Demand function: (2)

$$MBB\_Pen_{it} = b_1Rural_{it} + b_2Mob\_Price_{it} + b_3GDPC_{it} + b_4HHI_{it} + b_5Mob\_Pen_{it} + e_{it}$$

Supply function: (3)

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

Output function: (4)

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

In order to test the current economic impact of telecommunication technology, two models were constructed (one for fixed broadband and another one for mobile broadband) and specified for two cross-sectional samples of countries. This methodology would allow the hypotheses

to be tested while controlling for endogeneity effects.[22] Also, the models include country and year fixed effects, to capture the particular characteristics of each country and year related with unobservable indicators (like policy controls and interventions).

Economic impact of digitization

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

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

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

where

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

K corresponds to the fixed capital formation, and

L to the labour force.

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

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

To assess the existence and strength of the causal link between digital ecosystem development and economic development, an endogenous growth model based on the Cobb-Douglas production function was specified linking the stock of fixed capital, labour force, and the CAF Digital Ecosystem Development Index (See Appendix B-3). Where the total factor productivity term (A) depends on the degree of digitization of each country:

$$A = \mu DIGITIZATION^{\Upsilon}.$$

[22] 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."

By assuming constant returns to scale on capital and labour, the function was converted to state that labour productivity depends on digitization and on physical capital stock per worker (we use lower case letters y and k to denote output and capital in worker terms). By applying logarithms for linearization, the following model was defined:

$$\log(GDP_{it}/L_{it}) = \log(\mu_{it}) + \Upsilon \log(Digitization\ Index_{it}) + \alpha \log(k)$$

Alternatively, as stated initially, the total factor productivity term depends on the digitization level of each country, plus an individual fixed effect for each economy. By applying logarithms, this can be expressed as:

$$\log(Total\ Factor\ Productivity(A)_{it}) = \log(\mu_{it}) + \Upsilon \log(Digitization\ Index_{it})$$

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