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Digitalisation

An opportunity for Europe

February 2021

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Contents

Executive summary

The role of digitalisation as a driver for economic outcomes is at the forefront of policymakers' strategy considerations across the globe. Digital has the potential to increase growth in a more sustainable and equitable way, with innovations enhancing the welfare of citizens and supporting economic resiliency. This has been made especially evident in the wake of the COVID-19 pandemic, with its impact on everyday activities and economic interactions.

In this context, the European Union is focusing a significant portion of its €1.8 trillion 2021-2027 Multiannual Financial Framework on digital and sustainable modernisation.[1] As such, it is crucial that appropriate consideration is given to how best to measure and monitor the progress and impact of digitalisation. This study outlines the potential impact on broad-based European economic growth and convergence across Member States by focusing on investments in digital ecosystems. It builds on existing evidence and measures developed by the EU to assess the potential impact of investing in comprehensive digitalisation and ecosystem development on economic growth and productivity in EU Member States. Answering the following key questions, the study outlines:

What is the role of digitalisation in driving economic growth and productivity?

Digitalisation can impact the economy both directly, through new products, and indirectly, through reshaping all economic activities. This is because a developed digital ecosystem offers the opportunity for greater innovation and improves the efficiency and effectiveness of labour and capital across industries. Altogether, a more developed digital ecosystem can contribute to sustainable economic growth through greater output from new products and more productivity, as well as knock-on benefits such as enhanced quality of living, health, and personal safety for citizens, a more resilient society and economy, and a more a more equitable society.

What are the gaps in existing evidence for the impact of digitalisation on economic growth?

A number of studies have found broadly positive links between digitalisation and economic indicators, using various measures of digitalisation. However, these have mostly focused on the impact of discrete digital indicators, such as measures of connectivity, and therefore may ignore the important role of changes to the wider digital ecosystem. It is therefore key to measure digital progress in countries using more comprehensive measures, such as the EU's Digital Economy and Society Index (DESI),[2] to account for the potential additive impacts of wider digital ecosystem development. In addition, technology is rapidly evolving, and therefore it is crucial that the impact of digitalisation is assessed against the most recent data.

What is the impact of greater digitalisation and digital ecosystem development?

Using the EU's DESI and data from 27 EU countries and the United Kingdom across 2014-2019, it is estimated that a 10% increase in the DESI score is associated with a 0.65% higher GDP per capita, holding factors such as labour, capital, government consumption and investment in the economy constant. This means that the relative impact is greater for countries starting from a lower digital development base, and that digital growth may play a role in driving convergence. This impact on GDP per capita is driven by the productivity and efficiency gains afforded by digital technologies.

> A 10% increase in the DESI score is associated with a 0.65% higher GDP per capita

> The relative impact is greater for countries starting from a lower digital development base, and this digital growth may play a role in driving convergence.

1. See European Commission (2020), "Recovery plan for Europe".
2. See European Commission (2020), "The Digital Economy and Society Index".

Executive summary *(Cont'd)*

What does this imply for Europe?

By focusing investment in the stimulus on digital convergence, the EU can support its objective of European economic convergence. If investment was to drive all EU Member States to a DESI score of 90 by 2027 (the end of the Multiannual Financial Framework), GDP per capita across the EU would be 7.2% higher at the end of the period, with countries at lower GDP per capita in 2019 standing to be the biggest beneficiaries . This suggests that, under the right conditions, a comprehensive, digital ecosystem-focused investment plan over the next seven years can create the foundation for a converging and growing Europe that maximises economic benefits for all its citizens.

> If investment was to drive all EU Member States to a DESI score of 90 by 2027, GDP per capita across the EU would be 7.2% higher

What is the impact of focusing EU investment on the digitalisation of Europe?

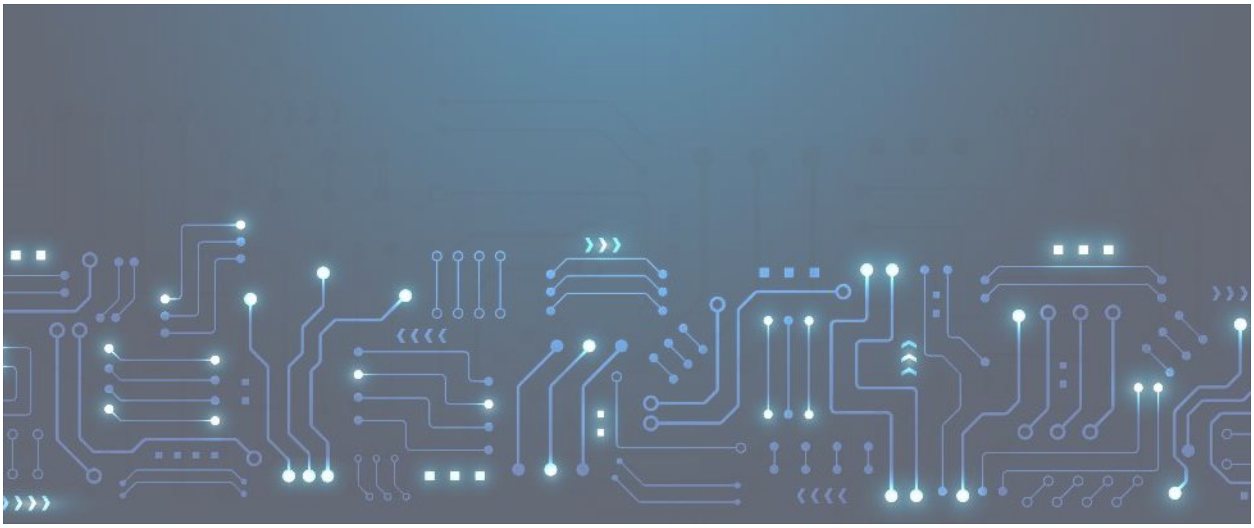
In the wake of COVID-19, the way people work, socialise, and buy goods and services in the EU has been transformed, with a fundamentally more digital experience in many everyday activities. At the same time, the pandemic and its associated restrictions has had reverberating impacts through the EU economy. In particular, it has demonstrated how important connectivity, digital skills, and digital technologies and services have become for the resilience of economic activity and, in combination with wider conditions, economic growth.

In this context, the EU is focusing a significant portion of its €1.8 trillion 2021-2027 Multiannual Financial Framework on digital and sustainable modernisation.[3] This offers a significant opportunity for the EU to invest in and progress its long-running objectives of a digital Europe. Paired with a wider pro-growth policy and strategy, it can support the development of open and sustainable digital societies that work for EU citizens and promote the ability of digital-focused businesses to compete both within the Single Market and abroad.[4] By harnessing the funding power of the EU's stimulus package, policymakers can create the foundation for inclusive, long-run economic growth and convergence across Member States.

Given the scale of investment, Europe needs to be able to measure how digitalisation is advancing and monitor the impact of investment on digitalisation. In this context, this study outlines the potential impact on broad-based European economic growth and convergence across Member States by focusing on investments in digital ecosystems. It builds on existing evidence and measures developed by the EU to assess the potential impact of investing in comprehensive digitalisation and ecosystem development on economic growth and productivity in EU Member States.

How does digitalisation impact the economy?

A digital-focused growth strategy can impact the economy through multiple channels. Initially, it can directly contribute to economic output by creating new products and services derived entirely from digital technologies, with associated new employment to create these products and services. However, its impact through the wider ecosystem created can be even greater. Digitalisation reshapes how existing goods and services are produced and delivered across all industries. From e-commerce, to data generation and use, to outsourcing of business processes, digital technologies can change the ways in which firms do business. These help to improve efficiency and effectiveness of production inputs, encouraging more sustainable resource use.



3. See European Commission (2020), "Recovery plan for Europe".
4. See European Commission (2020), "The European Digital Strategy".

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Under the right conditions, digitalisation can deliver economic benefits to businesses. Digitalisation can then also have knock-on impacts that further improve the wider, long-term wellbeing of citizens.

Sustainable economic growth

Digitalisation supports the delivery of a green and sustainable future for Europe. Digital technologies will be essential to decoupling economic growth from resource consumption, and through greater use can facilitate many environmental benefits. These range from reduction in paper use to reduction of fossil fuel consumption through the use of smart logistics and smart cities to reduce traffic flows.[7]

Enhanced quality of living, health, and personal safety

Innovations in areas such as eHealth are expected to improve the healthy life years of European citizens, and smart city technologies can improve citizens' welfare and safety with knock-on impacts to health through lower emissions and mortality.[8] All this can support longer term economic output for Europe as people remain healthy and economically active for longer periods of their lives.[9]

Increase business potential

Digitalisation can widen the potential output of businesses by allowing greater geographical reach and access to new customers outside of the EU particularly through e-commerce as well as new services and products that would not otherwise be available.[5]

Increase productivity

Digitalisation can increase productivity through greater access to information for people and businesses and more efficiency through services such as collaboration tools and cloud services.[6]

A more resilient society and economy

The COVID-19 pandemic has illustrated the importance of digital technologies in economic resilience. This has ranged from ensuring the continuation of economic activity through remote data access via the cloud; to helping people and businesses communicate with each other; to enabling governments to use data to provide better services and engage with their constituents. A digital economy and society are more resilient, allowing European citizens and businesses to deal with unexpected shocks and keep economically active.[10]

A more equitable society

The digital ecosystem has enabled the inclusivity of more members of society, driven by the opportunities offered for both individuals and businesses. Opportunities through investment in digital skills and tools allows the benefits of digitalisation to be shared more equitably. The COVID-19 pandemic has particularly highlighted some of the inequities and divisions within Europe, with key disparities in the way that different citizens from different parts of society have been impacted. Digitalisation therefore has the potential to foster greater inclusivity, by allowing more access to opportunities for young people, women, and underrepresented people to participate in the wider economy.[11]

Measuring digitalisation and its impact

Existing literature have used various measures of digitalisation to look at the aggregate impact it can have on economies. These have broadly found positive links between rises in digital indicators and economic growth and productivity. However, most studies have focused on the impact of discrete digital indicators, such as measures of connectivity, potentially ignoring the impacts of wider digital ecosystem changes that may be captured by more comprehensive measures.

Examples of the latter include the EU's own measure of the overall level of digitalisation in its economies, namely the Digital Economy and Society Index (DESI).[12] This is a composite index, calculated for each Member State, that aims to capture the main elements of digitalisation and digital ecosystems by tracking digital performance across five themes covering 37 indicators of digital progress.

5. See Lin (2014), "Estimating the effect of the Internet on international trade".
6. See Ollo-Lopez and Aramendia-Muneta (2012), "ICT impact on competitiveness, innovation and environment".
7. See Vodafone (2020), "Smart.cities".
8. See European Commission (2020), "Healthy life years statistic".
9. See Vodafone (2020), "eHealth".
10. Pierri and Timmer (2020), "IT Shields: Technology Adoption and Economic Resilience during the COVID-19 Pandemic"
11. OECD (2017). Enhancing the Contributions of SMEs in a Global and Digitalised Economy. Available at: https://www.oecd.org/industry/C-MIN-2017-8-EN.pdf.
12. See European Commission (2020), "The Digital Economy and Society Index".

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 1 illustrates the spectrum of indicators that contribute to the DESI. By accounting for a broad range of themes within digitalisation, from connectivity to human capital, the index aims to capture elements of the entire digital ecosystem. Figure 2 illustrates the change in DESI scores over time for the EU27 countries.

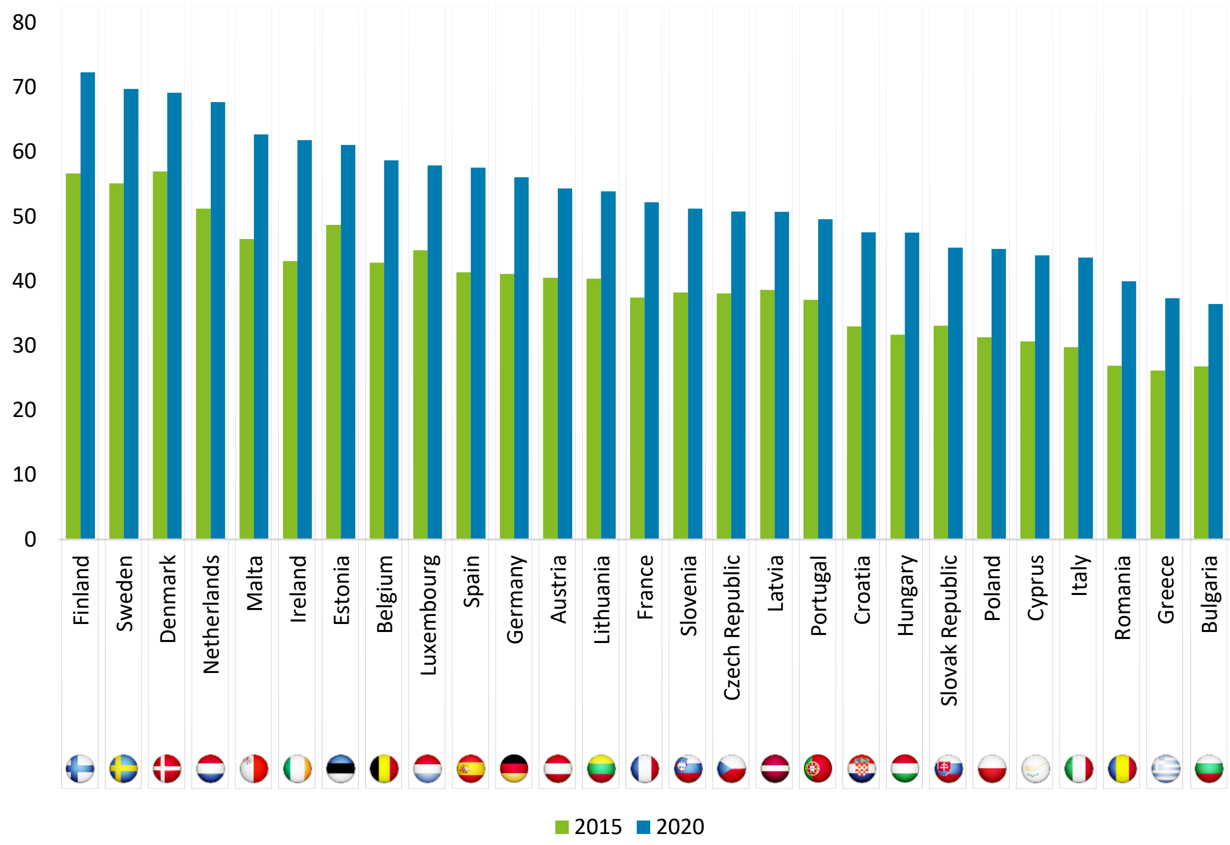
Figure 1: Components of DESI

CONNECTIVITY	**Fixed Broadband Take-Up:** as measured by overall fixed broadband take-up and take-up of fixed broadband over 100 mbps **Fixed Broadband Coverage:** as measured by fast broadband (NGA) and Fixed Very High-Capacity Network (VHCN) coverage **Mobile Broadband:** as measured by 4G coverage, mobile broadband take-up and 5G readiness **Broadband Price Index:** as measured by a broadband price index
HUMAN CAPITAL	**Internet User Skills:** as measured by the number of individuals with basic and above basic digital and software skills **Advanced Skills and Development:** as measured by the number of total and female ICT specialist employed as a proportion of the labour force and the number of ICT graduates
USE OF INTERNET SERVICES	**Internet Use:** as measured by the proportion of regular internet users and people who have never used the internet **Activities Online:** type of internet usage, as measured by the proportion of individuals using the internet for news, social networking, video calls, online courses, and streaming a variety of multimedia **Transactions:** as measured by individuals using the internet for online banking, shopping and selling online
INTEGRATION OF DIGITAL TECHNOLOGY	**Business Digitalisation:** as measured by electronic information sharing, social media, big data and cloud usage by businesses **E-commerce:** SME trade, as measured by SMEs selling online, cross-border and online turnover
DIGITAL PUBLIC SERVICES	**E-government:** as measured by e-government users, pre-filled forms data, online service completion, digital public services for businesses and a composite index of open data

Source: European Commission

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 2: DESI scores for EU27 countries over time.



Source: European Commission

This coverage across different themes is crucial to measuring the impact of digitalisation on the economy. This is because, although improvements in any single indicator may bring benefits, it is the combination of wider factors, such as collaboration between public and private sectors or improvements in the digital skills of individuals, that enable digitalisation to deliver greater productivity and economic growth. On a practical level, European citizens and businesses are unlikely to feel the benefits of more connectivity if the services they are looking to use (such as goods from other businesses or government services) are analogue, or if they do not possess the skills to use these digital services. By using measures of improvements in the digital ecosystem as a whole, this therefore allows a better understanding of the impact of a more digital society on economic indicators and overall wellbeing.

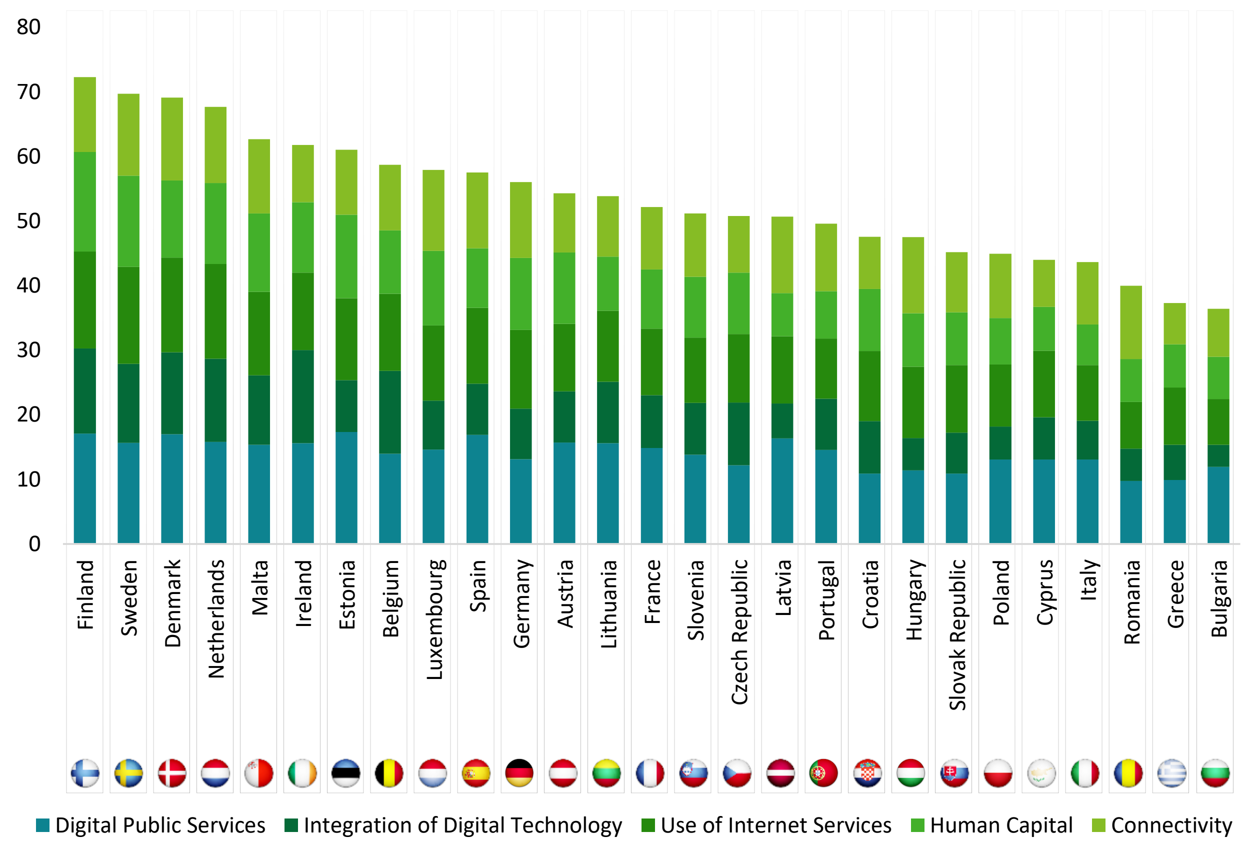
Digitalisation – an opportunity for Europe?

There is a clear opportunity for the EU to use the funding available to achieve sustainable growth and welfare improvements for its citizens by making digital a key feature of its strategic policy. At the same time, the least digitalised are also expected to gain the most from greater digitalisation. This means that, with different Member States at varying stages of development and digitalisation (see Figure 3), there is an opportunity to use digital convergence as measured by DESI to support the EU's longer-term goal of economic convergence. By working toward this digital convergence, Europe can lay the foundations to become a global digital leader and help its economy compete more effectively with international counterparts.

Source: European Commission

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 3: DESI Scores by country for 2020



Source: European Commission

This study therefore builds on the existing evidence from literature to estimate the economic impact of a more developed digital ecosystem on European economies, and to analyse the types of investments driving this impact. Using econometric techniques to establish the link between DESI and economic growth and productivity, this study illustrates the potential from focusing EU investment as part of its COVID-19 recovery on digital convergence, estimating the impact on economic growth across Member States.

The rest of this report is organised as follows:

Section 1

Summarises the existing literature surrounding digitalisation and economic output.

Section 2

Outlines the analysis performed to estimate the relationships between DESI score and economic growth and productivity.

Section 3

Illustrates the impact investment could have for the EU by highlighting examples in Europe and Asia of successful pro-growth digital strategies and developing an illustrative scenario using analysis results of the economic impact of a digital convergence scenario by the end of the 2021-2027 financial framework period.

The analysis in this study is also supported by two case studies highlighting economies that have successfully used digital technologies to drive growth.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

1. Digitalisation and its link with economic growth and productivity

A number of studies have investigated the link between different digital indicators and economic output, with many of these focusing particularly on measures of connectivity. For example, Katz & Callorda (2018) investigated the link between broadband penetration and GDP per capita. They found *an increase of 1 percent in mobile broadband penetration (defined as number of unique mobile broadband subscribers) yielded an increase in 0.15 percent in per capita growth.* Similarly, Toader et al (2018), explored the impact of mobile phones, and found that *a 1 percent increase in the number of mobile subscriptions resulted in a 0.4 per cent growth in GDP per capita.*

Others have looked more broadly at internet usage. *Myovella et al. (2020) found that a 1 percent increase in the number of people using the internet yielded a 0.07 percent growth in GDP per capita.* Others, including Qu et al (2017), and Koutroumpis (2018), have performed similar analyses over the link between connectivity and economic growth and found consistent positive relationships.

In contrast, only a few studies have attempted to analyse how more comprehensive measures of digitalisation link to economic growth, accounting for the additive effect of improving the digital ecosystem as a whole. Katz & Callorda (2018) constructed their own digital index, similar in spirit to the DESI, consisting of indicators representing general connectivity and wider themes such as infrastructure reliability and affordability. They found that *an increase of 1 per cent in their digital ecosystem development index resulted in a 0.13 per cent growth in GDP per capita.* Similarly, Solomon and Klyton (2020) assessed the impact of various elements of digitalisation on economic growth in Africa using the Networked Readiness Index, a composite measure of digitalisation.

However, the scarcity of such studies, likely due to data availability means that *other themes that are covered more directly in composite indices like DESI, such as ICT skills and digital public services, are relatively underrepresented in the literature.* Figure 4, shows the range of associations found in the literature between types of digital infrastructure and economic growth across different geographies. It should be noted that these studies take a variety of approaches to account for data and estimation issues.[13]

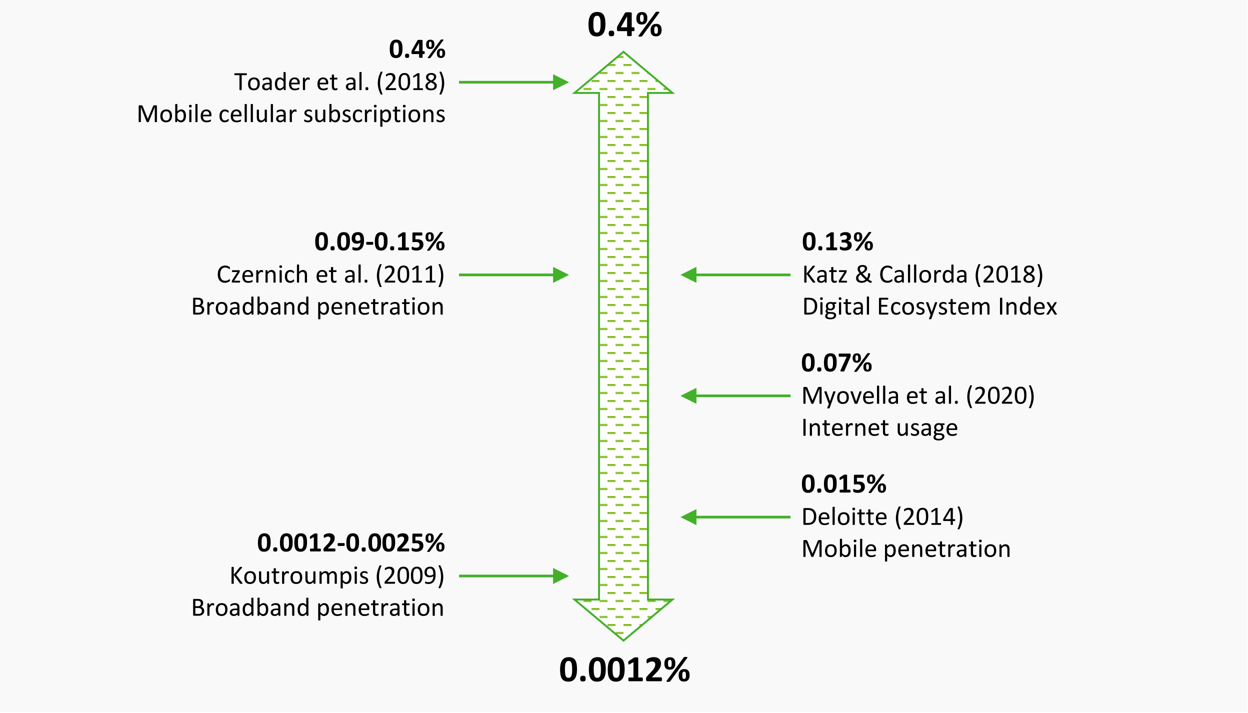
Table 1: Summary of key literature analysing link between digital connectivity and economic growth

Indicator	Selected examples
Broadband penetration	Katz & Callorda (2018) Banerjee et al. (2020) Koutroumpis (2018) Czernich et al. (2011)
Digital ecosystem index	Katz & Callorda (2018) Solomon and Klyton (2020)
Mobile telephony	Toader et al. (2018) Qu et al. (2017) Deloitte (2012)
Internet use	Myovella et al. (2020) Choi & Hoon (2009)

13. For example, studies account to different degrees for the potential for endogeneity.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 4: Existing research finds that a 1% increase in different indicators is correlated with an increase GDP per capita by between:



In addition to estimating the overall impact of greater digitalisation, other studies have looked to investigate the indirect impact of greater digitalisation in particular through productivity increases. This is because the relationship between digitalisation and economic growth is partly attributable to improvements in firm-level efficiencies, for example more efficient use of infrastructure and greater productivity from existing data assets through cloud technologies.[14] These improvements increase a firm's productivity more broadly, aggregating across firms into overall macroeconomic productivity boosts and greater economic output.

Studies that have looked at the impact of different technologies on productivity on a firm level have broadly found positive impacts. Empirical studies suggest that firms that use data to a significant extent can achieve productivity gains of 5%-13%, all else equal.[15] Similarly, the adoption of improved online communication tools has reduced the costs of interacting as well as increasing productivity.[16] These digital tools and others therefore have the potential to greatly increase the efficiency of production inputs (labour and capital) for individual firms, in aggregate increasing overall economic productivity.

> Studies suggest that firms that use data to a significant extent can achieve productivity gains of 5%-13%

A stream of literature has sought to investigate the impact of digitalisation on overall economic productivity (across all production inputs such as capital and labour) and on labour market outcomes. For example, research by Chou et al (2014) estimate that a *$1 million increase in IT capital is associated with a 0.6% growth in total factor productivity (i.e. productivity across all inputs to production).*[17] Others have found a found a positive relationship between the adoption of high-speed broadband, and the subsequent diffusion of other digital technologies, highlighting the wider impacts of digitalisation on productivity.[18]

14. See Brohi and Bamiah (2011), "Challenges and Benefits for Adopting the Paradigm of Cloud Computing".
15. See Deloitte (2017), "The Data Landscape".
16. See McKinsey (2012), "The social economy: Unlocking value and productivity through social technologies".
17. See Chou et al. (2014), "The Impacts of Information Technology on Total Factor Productivity: A Look at Externalities and Innovations".
18. See Andrews et al. (2018), "Going digital: What determines technology diffusion among firms?".

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Table 2: Summary of key literature analysing link between digital adoption and productivity related outcomes

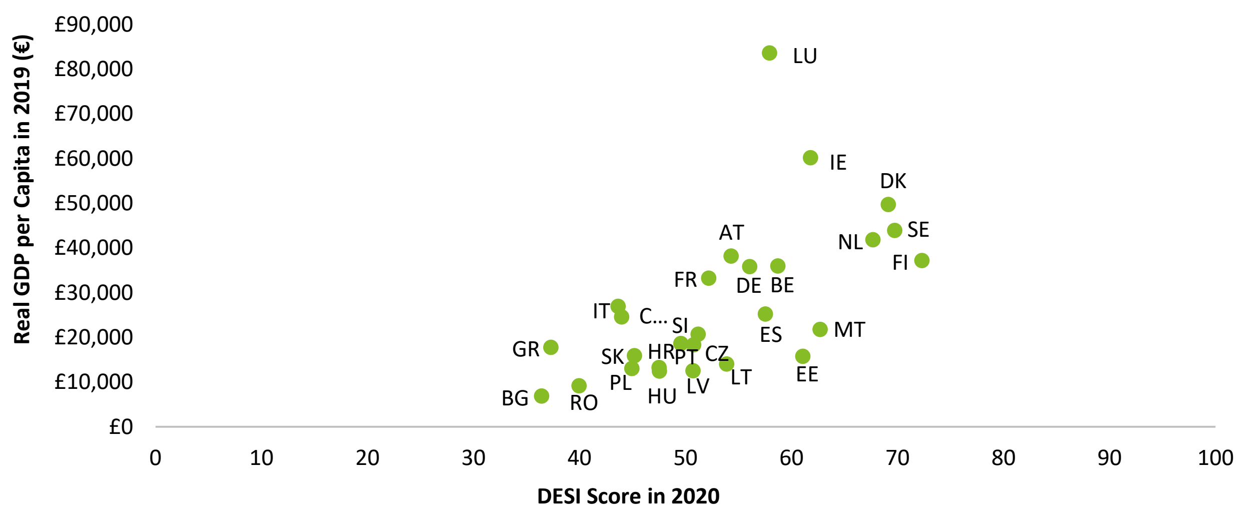
Topic	Selected examples
Factor productivity	[Chou et al. (2014)](#) [Fuente-Mella et al. (2019)](#) [Hawash and Lang (2020)](#) [Zaballos and López-Rivas (2012)](#) [Grimes et al. (2009)](#)
Innovation & Technology Adoption	[Andrews et al. (2018)](#)
Employment	[Michaels et al. (2014)](#) [Katza et al. (2010)](#)

2. Analysing the impact of digital ecosystem on economic growth and productivity

The digital ecosystem and economic growth

To better understand the impact of the digital ecosystem as a whole on economic growth, analysis was conducted on a sample of 27 EU countries and the United Kingdom using data from the World Bank, Eurostat, and DESI scores for Member States for the period 2014-2019. As observed in Figure 5, *there exists a strong correlation between DESI scores and GDP per capita, highlighting the strong relationship between digitalisation and the average economic wellbeing across countries.* Therefore, econometric analysis was used to estimate the direct, and causal, link between DESI scores and economic growth, as measured by GDP per capita (further details on the approach, the limitations, and the results in full can be found in Annex A2).

Figure 5: The cross-sectional relationship between real GDP per capita (€, 2010) in 2019 and 2020 DESI Scores amongst EU nations



Source: Eurostat, European Commission

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Results of the analysis provide *evidence of a causal impact of an increase in digitalisation, as measured by DESI, and per capita GDP growth*. This study finds that *a 10% increase in DESI is associated with a 0.65% higher GDP per capita*, holding factors such as labour, capital, government consumption and investment in the economy constant.

This means that the impact of a point increase in DESI on economic growth will vary depending on the starting point of a country, with countries at a lower DESI score able to achieve higher growth rates from the same change in DESI as countries with lower DESI scores.

A Driver of Convergence

The impact of a point increase in DESI on economic growth will vary depending on the starting point of a country. If a country's DESI score is 30, for example, the 10% increase in DESI to deliver 0.65% higher GDP per capita amounts to only 3 points on the overall DESI score. Comparatively, for a country already at a DESI score of 60, to achieve the same 0.65% increase in GDP per capita they would need a 6-point increase in the DESI score. This highlights the potential role of digitalisation in driving economic convergence across the EU.

Accordingly, using these estimates, Figure 6 illustrates the representative impact of a 5-point increase on GDP per capita across the EU27. This compares to an average increase of 2.77 points per year for each country over the period 2015-2020, as previously shown by Figure 2.

This estimate suggests that a 5-point increase in the 2019 DESI score for:[19]

0.64%

Germany (from 51.2 to 56.2) would have been associated with a 0.64% increase in real GDP per capita, from €35,840 to €36,069.

0.70%

Portugal (from 47.0 to 52.0) would have been associated with a 0.70% increase in real GDP per capita, from €18,590 to €18,719.

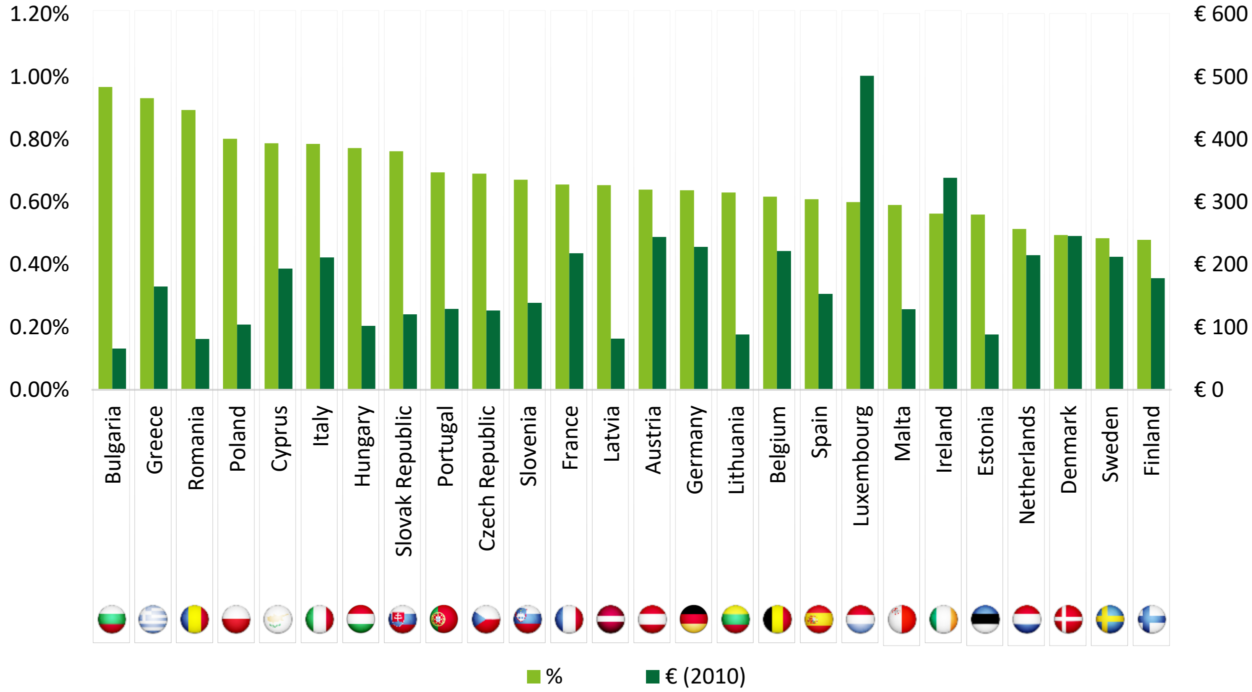
0.77%

Hungary (from 42.3 to 47.3) would have been associated with a 0.77% increase in real GDP per capita, from €13,260 to €13,363.

19. At the time of writing, national income data was only available from 2019 and earlier, therefore estimates were made using real GDP data (€, 2010) from 2019 for countries in the EU-27. Data on GDP per capita was sourced from Eurostat.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 6: The estimated impact of increasing the DESI by 5-points across the EU27 from 2019 scores



Source: Deloitte analysis, Eurostat, European Commission

To investigate the policy areas likely to be driving the impact of DESI, supplementary analysis was developed for the relationship between proxies of the five DESI sub-themes, highlighted in Figure 1, and GDP per capita (see Annex A3 for results and details). Chosen based on the correlation to the DESI sub-themes, this analysis expanded the dataset to cover OECD countries in addition to EU countries and the period 2012-2019.

While direct comparability is not possible, the results are broadly in line with the wider DESI's positive association with GDP per capita. However, they do show that *certain indicators have a stronger positive link to economic growth, namely the indicators for the 'Connectivity', 'Use of Internet Services' and 'Integration of Digital Technologies' sub-themes of DESI.* This suggests that these sub-themes may play a relatively larger role in improvements to economic outcomes, although this does not mean that others do not impact economic outcomes positively because:

- There is limited variation and sample sizes for certain indicators and countries respectively, meaning that coefficients are not directly comparable. For example, no statistically significant relationship was identified for indicators such as IT specialists, despite displaying a strong correlation with GDP per capita.
- As with the wider literature, missing the potential additive effect of improvements across sub-themes and the wider digital ecosystem, although indicators estimated separately may pick up some of the overall impact given they are all positively correlated (e.g. a country with better performance in one area is likely to have better performance in other areas).
- The inability to capture the nuances in sub-themes. For example, similar to other studies, the indicator for connectivity accounts only for access, and not for quality of networks or broadband prices that can also influence the degree of benefits from network improvements.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

The digital ecosystem and productivity growth

Looking to the link between digitalisation and productivity, the indirect impact of a more developed digital ecosystem is also estimated. This impact on productivity can be investigated by considering total factor productivity, a measure of economic productivity that measures an economy's long-term technological dynamism. This is done by estimating a 'stochastic frontier', allowing the assessment of economies against their maximum potential efficiency. Under this method, digitalisation is understood as a way to reduce economic inefficiency, boosting productivity in the economy to help it achieve a greater economic output with the same production inputs, capital and labour (Further details on this approach are outlined in Appendix A5).

Using this framework, and data consistent with above, it is estimated that *a 5-point increase in the DESI score is associated with a 2.5% increase in total factor productivity on average*. This is higher than the overall link with economic growth estimated above due to the long-term nature of efficiency gains. Productivity does not increase quickly, even if other inputs change year on year. Therefore, gains from productivity are felt over time.[20]

The increase in productivity also varies between countries depending on the level of efficiency, as reflected in Figure 7. This is because an increase in the DESI score will have a greater impact in those countries that start off at a lower level of digital development. As countries become more digitally developed, the gains from digitalisation decrease for the same level of improvement (as measured by DESI scores), suggesting a large role in driving convergence.

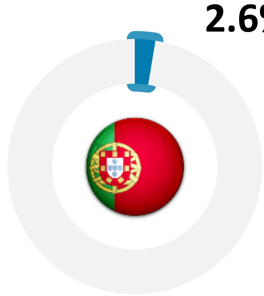
> An increase in the DESI score will have a greater impact in those countries that start off at a lower level of digital development

Estimates suggest that a 5-point increase in the 2019 DESI score in:

2.2%

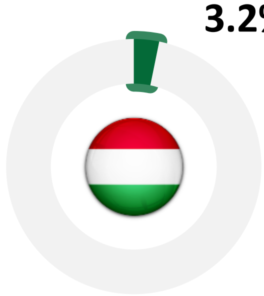
Germany (from 51.2 to 56.2) would have been associated with a 2.2% rise in productivity.

2.6%



Portugal (from 47.0 to 52.0) would have been associated with a 2.6% rise in productivity.

3.2%

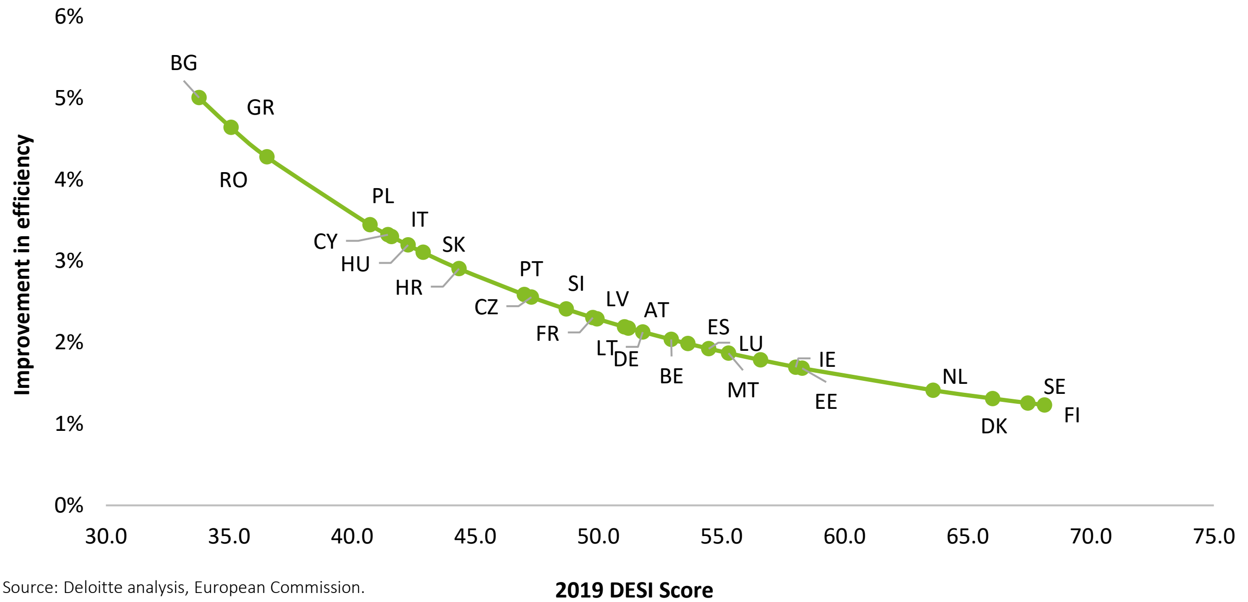


Hungary (from 42.3 to 47.3) would have been associated with a 3.2% rise in productivity.

20. The difference between the estimates for the relationship between DESI score and productivity and for the association between DESI score and economic output may also partly be due to the endogeneity between economic output and digitalisation which the panel analysis used above accounts for in its specification. In addition, the small sample may affect the accuracy of the coefficients. See Technical Annex for further information.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 7: Effect of a 5-point increase in DESI score on productivity in each Member State



Source: Deloitte analysis, European Commission.

3. Implications of investment in the digitalisation of Europe

The existing evidence on the impact of digitalisation, and the positive link found between DESI and economic growth and productivity, suggest that the EU can make significant contributions to its long-run economic potential through investment in digitalisation in Member States, such as improved infrastructure and upskilling. This is not to say that improving digital infrastructure, skills, and adoption alone would be sufficient to drive growth. Rather, as part of a wider pro-growth strategy demonstrated in Member States, such as Estonia, and in other regions, such as Asia, they can help deliver benefits to citizen wellbeing in the form of more and better products and services. At the same time, they offer a more sustainable channel for growth and would support the resiliency of European economies, ensuring they adapt and continue to function in the face of unexpected shocks.

> The evidence suggests that the EU can make significant contributions to its long-run economic potential through investment in digitalisation

C2 General

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Estonia – a pro-growth, digital-focused strategy

Recently named 'the most advanced digital society in the world', Estonia has been a keen adopter of digitalisation. Having committed to a digital governance model in the early 2000s, 99% of its state services are accessed online.[21] The key driver for this digitalisation has been a focus on a decentralised digital infrastructure and allowing citizens to utilize a digital ID to store personal data. Residents of Estonia can use this ID to access all state e-services, as well a large number of private e-services.

However, this has not been in isolation, and Estonia has paired its digital government initiatives with a number of policies to promote digital investment and a wider pro-growth agenda. This includes its e-Residency program, which allows individuals to start businesses in the country without living there. The program serves as an entry way for companies to start doing business in the European Union, encouraging investment from overseas and increased tax revenues. At the same time, Estonia has focused on enhancing research and development activities in the digital space, increasing the capacity of the state to act as a client for innovative solutions and fostering entrepreneurship through specific support for start-ups.[22]

All this has had significant benefits for Estonian citizens and businesses. *Its digital government policies have been estimated to deliver 2% of GDP in taxpayer savings as well as time saved*.[23] At the same time, Estonia has been ranked first in Europe in both start-up friendliness and entrepreneurial activity.[24] The country is home to more tech unicorns, (private companies valued at more than $1 billion) per capita than any other small country in the world encouraging growth through a digitally focused strategy.[25]

21. See e-Estonia (2020), "We have built a digital society and we can show you how".
22. See Estonian Ministry of Economic Affairs and Communications, (2013), "Estonian Entrepreneurship Growth Strategy 2014-2020".
23. See European Economic and Social Committee (2017), "Advantages of digital society".
24. See Tallinn (2018), "Estonia is the best country in the world for start-up companies" and World Economic Forum (2017), "Entrepreneurial Employee Activity and Competitiveness in Europe".
25. See CNBC (2019), "How a tiny country bordering Russia became one of the most tech-savvy societies in the world".

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Digitalisation in Asia – a route to economic inclusion and growth

Many East and Southeast Asian countries have used digitalisation as a key foundation on which to improve economic wellbeing. This has provided their citizens with a great variety of digital goods and services, in some cases leapfrogging traditional substitutes with better quality, and more affordable and accessible, products for customers. In order to bring these benefits to the whole population, many Asian policy-makers have focused on expanding connectivity, developing fixed and mobile broadband infrastructure to cover both urban and rural areas.[26] Others have provided dedicated training programmes to improve the level of digital skills across the population.[27]

The results of these policies can be seen in Asian countries' position as global leaders in take-up of e-commerce and fintech solutions, growing rapidly from small bases. In China, e-commerce grew from 1% of global e-commerce retail value in 2008 to over 40% in 2018 and exceeds the US in e-commerce as a percentage of domestic retail (15% vs 10%), with 40% of these sales representing new consumption rather than cannibalisation of existing retail.[28] In fintech, companies such as Tencent, Alibaba, Go-Jek, and Grab have used their respective digital platforms as accelerants of digital and financial development and inclusion with China's e-retailing market valued at $2 trillion.[29] This has allowed individuals and small businesses affordable access to modern payment services that side-step the need for traditional financial infrastructure.

This digital leadership is also demonstrated in innovation levels. Asian countries took the top-five spots in a ranking of the share of total ICT patents in 2018, and, in productivity, *the IMF estimates that Asian firms participating in e-commerce have had a 30% boost to total factor productivity and 50% boost to exports*.[30]

Digitalisation has also been a key aspect of economic resiliency in the face of COVID-19, with digital tools a key part of the response for many Asian countries. For example, in South Korea public health bodies were able to benefit from a government-run application to enable pharmacies to report face mask inventories, helping to manage crowds for limited stocks.[31] Similarly, authorities shared information with the public through apps that, using contact tracing data, granularly highlighted areas of high infection so people could avoid them.

26. See China Copyright and Media (2016), "Outline of the National Informatization Development Strategy".
27. See OpenGov (2019), "Government launches ICT training programme for elderly".
28. See International Monetary Fund (2018), "Asia's Digital Revolution".
29. See The Economist (2020), "Why retailers everywhere should look to China"
30. See International Monetary Fund (2018), "E-commerce as a Potential New Engine for Growth in Asia".
31. See McKinsey (2020), "How technology is safeguarding health and livelihoods in Asia".

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

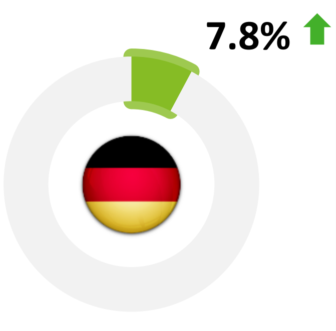
The estimates in this study on the impact of DESI on economic growth can be used to illustrate the potential to the EU of focusing investment on developing Europe's digital ecosystems, as measured by DESI. Building on these estimates, an illustrative analysis demonstrates the difference in economic outcomes by 2027 (the end of the 2021-2027 Multiannual Financial Framework) in:

An **'as-is'** scenario, with DESI and other economic variables growing at historical rates to drive GDP per capita growth; and

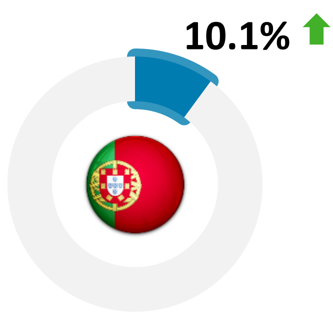
A '**digital convergence**' scenario, where DESI is growing at a faster rate for most countries to reach a score of 90 across all countries.[32] Given past growth in DESI, this suggests an aspirational goal for Europe driven by the significance of the investment and focusing on digital convergence.

See Annex A7 for further details on the approach for estimating these scenarios and impacts.[33]

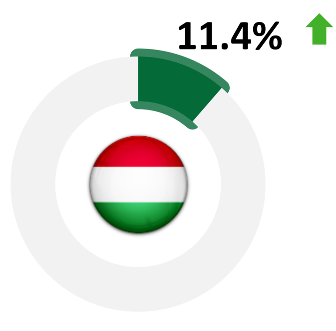
In a 'digital convergence' scenario, where digital investment drives all Member States to a DESI score of 90 by 2027, GDP per capita across the EU27 would be 7.2% percentage points higher by 2027 than an 'as is' scenario. This translates to:



A 7.8% higher GDP per capita in Germany by 2027, compared to the base case scenario



A 10.1% higher GDP per capita in Portugal by 2027, compared to the base case scenario

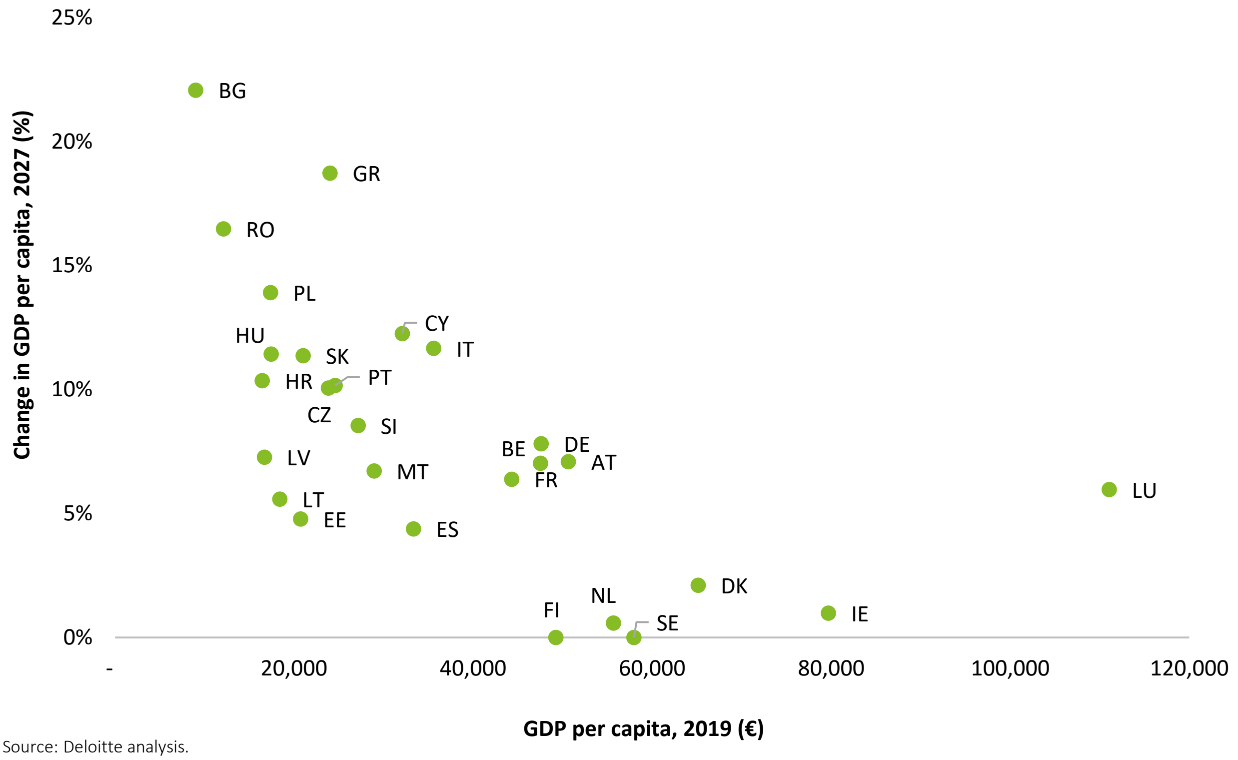


A 11.4% higher GDP per capita in Hungary by 2027, compared to the base case scenario

32. The only exception is Sweden, which would reach a DESI score of 90 by 2027 based on historical trends.
33. The scenarios in this analysis are purely illustrative and do not take into account other external factors that may impact future GDP figures, such as the COVID-19 pandemic.

What is the impact of focusing EU investment on the digitalisation of Europe? *(Cont'd)*

Figure 8: Difference in GDP per capita as of 2027 in percentage points between 'digital convergence' scenario and 'as is' scenario plotted against 2019 GDP per capita, by country



Source: Deloitte analysis.

While illustrative only, this shows the opportunity to Europe from focusing on investments that enhance the wider digital ecosystem. At the same time, the illustrative analysis demonstrates the potential for digitalisation to support EU convergence. For a given increase in DESI, countries that are less digitally developed, and therefore with lower DESI scores, would gain even more from marginal increases in digitalisation. This means that by aiming for a DESI score of 90 across Member States, the EU could help to bring less developed and more developed countries to a more converged and higher level of economic output.

> By aiming for a DESI score of 90 across Member States, the EU could help to bring less developed and more developed countries to a more converged and higher level of economic output.

Overall, the evidence in this study highlights the significant potential benefits of greater digitalisation for the European Union. A digitally focused strategy could bring improvements to both productivity and economic output, as well as many welfare enhancing benefits related to an improved digital ecosystem. Through the sheer scale of the investment and a focus on digital convergence, it could support Europe in its goal of economic convergence. As per Deloitte's report with Vodafone, '*Digital for Europe: Collaboration. Innovation. Transformation.*', *it will be essential for EU and national policymakers to foster the broader environment and maximise the efficacy of digital investment, bringing together partnerships, a focus on digital skills, and a complementary policy framework*. If done right, this study shows that a comprehensive, ecosystem-focused investment plan over the next seven years can create the foundation for a converging and growing Europe with a more digital, economical beneficial future for its citizens.

Technical annex

The EU long-term budget 2021-2027 together with temporary instruments designed to boost the recovery from the COVID-19 crisis, form the largest stimulus package ever financed through the EU budget, of €1.8 trillion. A significant portion of this has been committed to digitalisation in an effort to build a digitally focused growth strategy. This growth will be achieved through investment in all areas of the digital ecosystem. It is therefore important that the effects of improvements to this wider digital ecosystem are properly understood and the following section details the econometric analysis undertaken in order to study the economic impacts of digitalisation, as measured by the DESI.

The DESI is a composite index for EU member states that has been used since 2014. As such, there are certain limitations surrounding the size of the panel available. Therefore, to supplement our analysis of the DESI, analyses are presented utilising five indicators, representing each dimension of the DESI. These indicators are available in a larger panel, enabling the confirmation of the existence of a robust association, while also helping to understand the underlying digital drivers of growth.

This annex sets out, in more detail, the datasets used, and the approaches taken for the analysis performed. It is organised as follows:

- **A1** A detailed outline of the datasets used.
- **A2** A description of the dynamic panel analysis approach used to estimate the relationship between digitalisation and economic growth.
- **A3** Results of dynamic panel analysis.
- **A4** Dynamic panel analysis postestimation.
- **A5** A description of the stochastic frontier analysis approach used to estimate the relationship between digitalisation and productivity.
- **A6** Results of the stochastic frontier analysis.
- **A7** Detailed outline of the approach to estimating long-term macroeconomic scenarios for the EU Member States.

A1. Dataset

The dataset employed for analysis of DESI consists of the EU27 countries plus the United Kingdom. Data is available for the index for the period covering 2014 – 2019.[34] Due to the relatively short range of this data, additional data for individual sub-indicators of the DESI has also been used, covering 2012 – 2019 as well as more countries. These sub-indicators have been chosen to represent, and correlate closely with, the five themes of the DESI. Data for these indicators has been sourced from Eurostat and the OECD and are summarised in Table 3. Macroeconomic data such as GDP, labour force size, gross fixed capital formation and government final consumption expenditure have been sourced from the World Bank.

34. DESI Scores primarily correspond to indicators measured in the year before, i.e. 2020 DESI scores relate to 2019 measurements. As such, DESI scores in the analysis were reconciled with the prior year.

Technical annex *(Cont'd)*

Table 3: Summary of data used for analysis variables of interest

Variable	Time period covered	Number of countries	Geography covered	Source
DESI score	2014 – 2019	28	EU27 plus United Kingdom	European Commission
Households with Internet Access (%)	2012 – 2019	41	EU27 plus selected others	Eurostat, OECD
Employed IT Specialists (% employment)	2012 – 2019	27	EU27	Eurostat
Individuals Using the Internet for Internet Banking (%)	2012 – 2019	42	EU27 plus selected others	Eurostat, OECD
Enterprises with E-commerce sales (%)	2012 – 2019	37	EU27 plus selected others	Eurostat, OECD
Individuals using the Internet to Interact with Public Authorities	2012 – 2019	37	EU27 plus selected others	Eurostat, OECD

A2. Approach – Dynamic Panel Analysis

In order to estimate the impact of digitalisation on economic growth, empirical analysis focuses on examining the relationship between the DESI and per capita economic growth within the EU.

In this analysis, the model and estimation approach follow the applications of Toader et al (2018), Andrianaivo and Kpodar (2011) and Waverman et al (2005) examining the impact of ICT and other digital infrastructure on growth.[35] These studies overcome the limitations of standard panel data approaches and address the endogeneity of digital indicators by utilising a Generalised Method of Moments (GMM) estimation of a dynamic panel data model.

35. See Toader et al. (2018), "Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries"; Andrianaivo and Kpodar (2011), "ICT, Financial Inclusion, and Growth: Evidence from African Countries" and, Waverman et al. (2005), "The Impact of Telecoms on Economic Growth in Developing Countries".

Technical annex *(Cont'd)*

Model and Estimation:

Following the standard empirical growth economics literature, a standard endogenous growth model of the following form is adapted:

$$lnY_{i,t} - lnY_{i,t-1} = alnY_{i,t-1} + \beta lnD_{i,t} + \delta lnX_{i,t} + \tau_t + \epsilon_{i,t} \qquad \textbf{(1)}$$

As the model is linear and expressed in logarithms, this is equivalent to the model that is estimated:

$$lnY_{i,t} = \gamma lnY_{i,t-1} + \beta lnD_{i,t} + \delta lnX_{i,t} + \tau_t + \epsilon_{i,t} \qquad \textbf{(2)}$$

Where $\gamma = (1+a)$, and:

- $lnY_{i,t}$ is the log of GDP per capita;
- $lnY_{i,t-1}$ represents the log of lagged GDP per capita;
- $D_{i,t}$ represents the digital indicator, with β the coefficient of interest;
- $lnX_{i,t}$ represents a vector of macroeconomic control variables, containing typical growth determinants in measures of government consumption, trade openness, gross fixed capital formation (each as a percentage of GDP) and labour force size;
- τ_t is a time-varying trend, consistent across countries;
- $\epsilon_{i,t}$ is the error term comprising of an unobserved time-invariant, country-specific fixed effect (unobserved heterogeneity) and an idiosyncratic component $(\epsilon_{i,t} = \eta_i + v_{i,t})$; and
- i,t denotes a given country i in year t

When estimating this model, standard panel data approaches may face limitations. Pooled OLS regressions are likely to be biased and inconsistent if the unobserved heterogeneity (η_i) is correlated with endogenous variables (such as $\ln Y_{i,t-1}$). Similarly, when taking differences or applying the fixed-effects estimator, aiming to remove such unobserved fixed effects, the transformed error term is likely to correlate with transformed endogenous variables, creating a dynamic panel data bias.[36]

Therefore, to estimate the parameters of **(2)**, the following analysis utilises a system GMM estimator in line with Blundell and Bond (1998).[37] This approach attempts to address endogeneity using internal instruments, instrumenting pre-determined or endogenous variables with their past values uncorrelated with error term components. The system-GMM approach was adopted since if the instrumented variables are highly persistent, difference-GMM is likely to perform poorly.[38, 39] Furthermore, the use of the system-GMM facilitates estimation on unbalanced panel data structures, useful where data missingness is more prevalent.

Analysis of the DESI was performed covering the 27 present members of the EU and the United Kingdom for the period of 2014-2019, the largest sample possible.[40] For the subsequent analysis using digital indicators, in order to gain more robust estimates of whether there is an association between economic growth and the indicators, the maximum panel size of EU and OECD countries was used for the period covering 2012-2019. This means that the sample changes between different models, limiting direct comparison of coefficients. In both sets of regressions, lagged GDP is modelled as pre-determined, the digital indicators as endogenous and macroeconomic controls as exogenous.[41] In addition, lag limits were set and collapsed where appropriate to limit the number of instruments with respect to the panel size.[42] For the digital indicators, multiple specifications of lag limits were tested for each variable and the preferred sets are presented. Time trends were also included in each specification to remove additional sources of autocorrelation.

36. See Nickell (1981), "Biases in Dynamic Models with Fixed Effects".
37. See Blundell and Bond (1998), "Initial conditions and moment restrictions in dynamic panel data models".
38. See Bond et al. (2001), "GMM Estimation of Empirical Growth Models" and Roodman, (2009), "How to do xtabond2: An introduction to difference and system GMM in Stata".
39. This was further validated by performing the Dickey-Fuller unit root test on GDP per capita in a selection of EU countries. Moreover, fixed effects and pooled OLS regressions of equation (**2**) were estimated to understand the upper- and lower-bounds for the coefficient of lagged GDP compared to results for the difference-GMM estimator which fell below the lower-bound, indicating weak instruments and a significant downward bias in this approach..
40. The sample size, in particular the small number of countries, presents limitations for estimating accurate coefficients. For further discussion, see Soto (2009), "System GMM estimation with a small Sample"
41. Coefficients relating to digital indicators were of a similar magnitude and significance when modelling the macroeconomic controls as predetermined and instrumenting with lagged values, however, the instrument count was too large relative to the small panel size.
42. Instrument counts can proliferate with longer time-series and, as an excessive number of instruments over and above the number of panel units, risks overfitting endogenous variables, it is recommended to limit lags and collapse instruments where necessary. For further discussion, see Roodman, (2009), "A Note on the Theme of Too Many Instruments".

Technical annex *(Cont'd)*

Data:

In addition to conducting analysis on the DESI, five indicators were chosen for supporting analysis representative of the five DESI sub-themes. This analysis is undertaken to understand potential drivers of growth that comprise the digital ecosystem. The corresponding correlations of each digital indicator with the respective DESI dimension is in bold, presented within the correlation matrix in Table 4. Correlations are produced covering the period of 2014-2019, for the 27 EU member states and the United Kingdom, except for IT Specialists which was only available for the EU-27.

Each digital indicator is correlated with the DESI and the respective sub-themes, with correlation coefficients ranging from 0.61 to 0.90. Indicators for the proportion of IT specialists employed, individuals using the internet for online banking, and enterprises engaging in e-commerce are highly correlated with the DESI sub-dimensions of Human Capital, Use of the Internet and Integration of Digital Public Services scores, respectively. The variable indicating households' access to the internet is a useful proxy to gauge access and use of the internet, but is slightly less correlated to Connectivity, as it does not consider other aspects of connectivity such as the quality of networks or broadband prices.

Table 4: Correlation matrix of digital indicators against the DESI and dimensions

Variables	Households with Internet Access (%)	IT Specialists (% Employment)	Individuals using Online Banking (%)	Enterprises engaging in E-commerce (%)	Individuals Interacting with Public Authorities Online (%)
DESI Score	0.83	0.83	0.88	0.72	0.80
DESI Connectivity Score	**0.65**	0.50	0.57	0.30	0.49
DESI Human Capital Score	0.79	**0.90**	0.85	0.67	0.81
DESI Use of Internet Services Score	0.84	0.81	**0.90**	0.64	0.86
DESI Integration of Digital Technology	0.63	0.70	0.69	**0.89**	0.60
DESI Digital Public Services Score	0.58	0.58	0.69	0.49	**0.61**
Households with Internet Access	1.00	0.78	0.82	0.59	0.75
IT Specialists (% Employment)	-	1.00	0.80	0.62	0.75
Individuals using Online Banking (%)	-	-	1.00	0.65	0.90
Enterprises engaging in E-commerce (%)	-	-	-	1.00	0.56
Individuals Interacting with Public Authorities Online (%)	-	-	-	-	1.00

Technical annex *(Cont'd)*

A3. Results – Dynamic Panel Analysis

Table 5: System-GMM Estimation of the relationship between the DESI and GDP per capita

VARIABLES	(1)
Log of Lagged GDP per Capita	0.974***
	(0.006)
Log of DESI	0.065***
	(0.023)
Log of Government Consumption, % GDP	-0.078**
	(0.036)
Log of Gross Fixed Capital Formation, % GDP	-0.005
	(0.013)
Log of Trade, % GDP	0.014***
	(0.004)
Log of Labour Force	0.005**
	(0.002)
Observations	168
Number of Countries	28
Arellano Bond test for second order autocorrelation, p-value	0.848
Hansen test for overidentifying restrictions, p-value	0.136
Instruments	24

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Results are shown for a single-step system GMM estimation using the Log of GDP per capita as the dependent variable.

In the main GMM estimation, outlined in Table 5, a highly significant and positive association was found between the DESI and economic growth, significant at the 1% level of confidence. The results indicate that a 10% increase in a countries DESI score is associated with a 0.65% increase in GDP per capita.

The coefficient on DESI is smaller than the correlation between GDP per capita and the DESI, indicating that the bi-directional relationship is likely to be substantial. Nonetheless, the highly significant positive coefficient provides evidence of a positive and causal association between DESI and economic growth.

When looking at the macroeconomic controls, government consumption is significant and negative, as is commonly found in analyses of EU countries or other developed nations.[43] Similarly, trade openness and labour force are found to be significantly and positively correlated with growth, similar to existing literature. Conversely, gross fixed capital formation as a percentage of GDP, otherwise investment, does not appear to be significantly different from zero.[44]

43. See Kutasi and Marton (2020), "The long-term impact of public expenditures on GDP-growth".
44. When excluding DESI from the specification, gross fixed capital is positive and significant. This may indicate potential importance of digital investments, as well as potential collinearity between these variables.

Technical annex *(Cont’d)*

Table 6: System-GMM estimation of Digital Indicators and GDP per capita

VARIABLES	(1)	(2)	(3)	(4)	(5)
Log of Lagged GDP per Capita	0.980***	0.981***	0.982***	0.983***	0.976***
	(0.006)	(0.022)	(0.006)	(0.007)	(0.005)
Log of Households with Internet Access	0.063**				
	(0.025)				
Log of IT Specialists (% Employment)		0.013			
		(0.035)			
Log of Individuals Using Online Banking (%)			0.015**		
			(0.007)		
Log of Enterprises Engaging in E-commerce (%)				0.026**	
				(0.011)	
Log of Individuals Interacting with Public Authorities Online (%)					0.005 (0.006)
Log of Government Consumption, % GDP	-0.036*	-0.043	-0.043*	-0.045*	-0.003
	(0.020)	(0.050)	(0.023)	(0.024)	(0.025)
Log of Gross Fixed Capital Formation, % GDP	0.023**	0.030	0.020**	0.015	0.026**
	(0.010)	(0.029)	(0.009)	(0.014)	(0.011)
Log of Trade, % GDP	0.004	0.012	0.005	0.014*	0.009
	(0.004)	(0.010)	(0.004)	(0.007)	(0.007)
Log of Labour Force	-0.001	0.002	-0.001	0.001	-0.002
	(0.001)	(0.004)	(0.001)	(0.002)	(0.002)
Observations	294	216	297	274	274
Number of Countries	41	27	42	37	37
Arellano Bond test for second order autocorrelation, p-value	0.100	0.117	0.112	0.055	0.212
Hansen test for overidentifying restrictions, p-value	0.136	0.079	0.189	0.220	0.108
Instruments	40	29	42	39	35

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Results are shown for two-step system GMM estimations using the Log of GDP per capita as the dependent variable.

Technical annex *(Cont'd)*

In the supplementary set of regressions, the five digital indicators were regressed against GDP per capita with results presented in Table 6. When digital indicators were combined into a single regression, all were found to be insignificant. This is expected as some digital indicators are highly collinear, as indicated by the correlational matrix Table 4 (this is also expected due to the number of instruments relative to the size of the panel dataset). For this reason, these results were excluded, and the five indicators were estimated separately.

Out of the five regressions, household access to the internet, individuals using the internet for online banking, and enterprises engaging in e-commerce were all positively and significantly associated with GDP per capita growth at the 5% level of confidence. Despite the correlation with GDP per capita, a positive but insignificant relationship is observed between IT specialists and economic growth. This might be because of the smaller sample size available and thus less variation.

There is no observable relationship between economic growth and the proportion of individuals interacting with public authorities online. This is largely expected as preliminary analysis confirmed that there was a weak correlation with GDP per capita. However, the correlation between this variable and digital public services was the lowest out of the five indicators at 0.61. Other elements of digital public services not accounted for in this analysis, such as open data policies, may still play a more important role as a determinant of growth.

All other variables are of the expected sign with both government consumption and gross-fixed capital formation as a proportion of GDP appearing significant in most well-fitting specifications. Trade openness was consistently found to be positive but insignificant in all models except one, and labour force was found to be insignificant in each specification. This may be a consequence of the higher standard errors introduced using instruments as well as the inclusion of time trends and highly stationary nature of the lagged GDP which may absorb variation attributable to these variables, especially if this variation is common across countries.[45]

A4. Model validation - Dynamic Panel Analysis

In order to test the validity of the instruments included in dynamic panel data models, two postestimation tests are commonly performed. The Arellano-Bond test for autocorrelation, tests the null hypothesis that there is no second-order serial correlation of the idiosyncratic error terms, a necessary condition for valid estimation. Secondly, the Hansen test for over-identifying restrictions is performed under the null hypothesis that instruments are uncorrelated with the error term, a condition required to justify the choice of instruments to retrieve consistent estimates.

For both test statistics, a p-value greater than 0.05 signals that the null hypothesis cannot be rejected at the 5% level of confidence, supporting the choice of instruments used in the estimation. The p-value of both test statistics are included within regression results.

Across specifications, the p-values for both tests consistently exceed 0.05, however, the regression concerning IT specialists displays a Hansen test statistic of 0.079 reiterating that the set of instruments included this regression may be a cause for concern.[46]

A5. Approach – Stochastic Frontier Analysis

While the direct link between digitalisation economic growth has been assessed through the dynamic panel estimation analysis, alternative approaches can estimate the indirect effects brought about by the wider digital ecosystem. The indirect impact that digitalisation exerts on GDP is due to wider access to digital technologies reducing transaction costs, promoting efficiency and allowing faster information flows. For this reason, the impact of digitalisation can be assessed by studying the link with Total Factor Productivity (TFP), a measure of productivity that often illustrates an economy's long-term technological dynamism. Increases in TFP lead to increases in GDP through better utilisation of traditional inputs such as labour and capital.

This is best examined through a stochastic frontier analysis (SFA). SFA assumes the existence of a theoretical production possibility frontier that each economy could achieve for a given level of inputs, and is an econometric technique designed to specifically compare productivity across a number of observations. The approach assumes that at most a country can lie on its theoretical efficient frontier or below. This is due to an assumed level of country-specific inefficiency as well as random shocks to GDP associated with the business cycle. SFA allows the separation of these two effects and enables analysis of those inputs that impact efficiency, in this case digitalisation.

45. In all specifications, multiple time dummies were found to be highly significant absorbing sources of potential serial correlation, but at a potential cost of insignificant macroeconomic controls.
46. A p-value below 0.1 for the Hansen test statistic may indicate an increased risk of invalid instruments. For further discussion, see Roodman, (2009), "A Note on the Theme of Too Many Instruments"

Technical annex *(Cont'd)*

Figure 9: Example of Stochastic Frontier Analysis

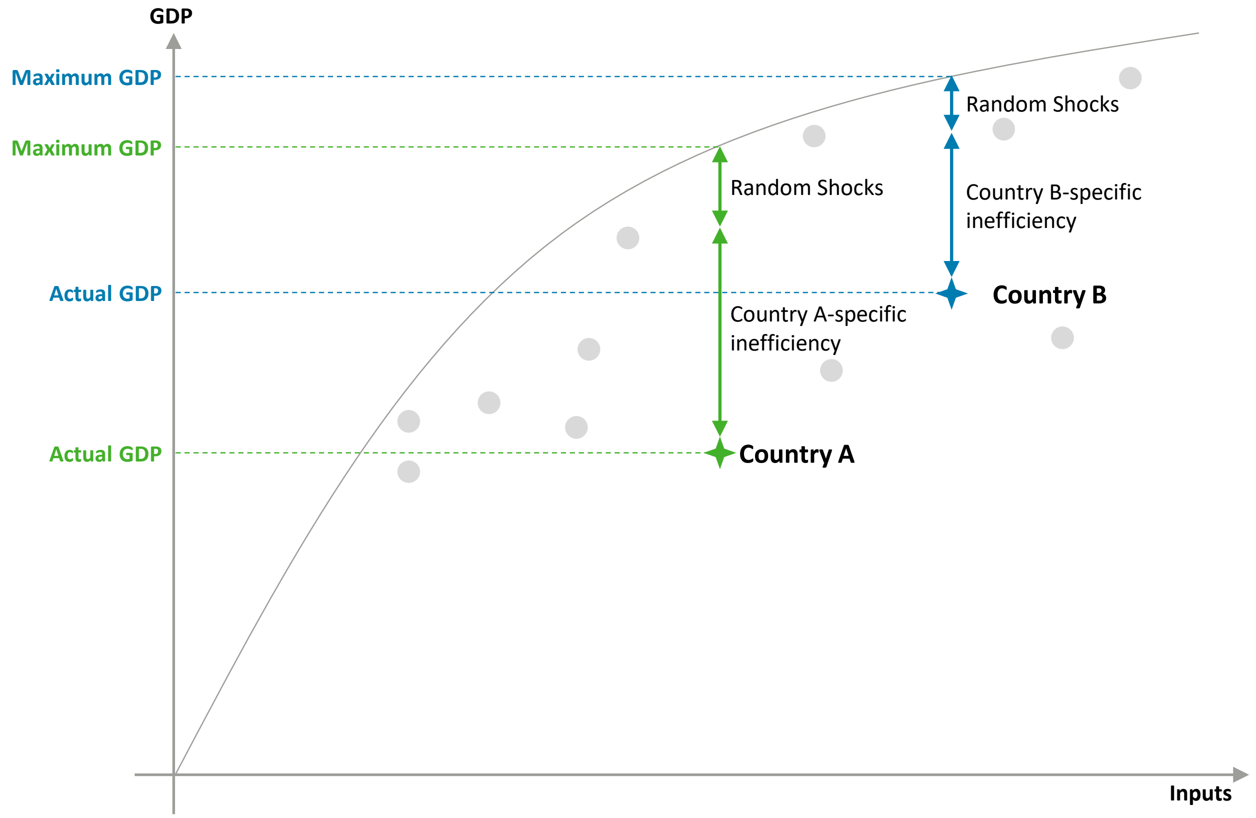


Figure 9 represents how two countries with differing levels of inputs can also have inefficiencies specific to each country. Here Country A is further away from its maximum level of output than Country B as a result of a greater level of inefficiency.

To examine the link between digitalisation and overall efficiency this theoretical frontier is first estimated as follows:

$$\boldsymbol{GDP_{i,t}} = \boldsymbol{f}(\boldsymbol{X}_{i,t}) \cdot \boldsymbol{TFP}_{i,t} \cdot \boldsymbol{e}^{v_{it}}$$

Where:

- $\boldsymbol{X_{i,t}}$ includes Capital, Labour, Education, Trade and Government Consumption;
- $\boldsymbol{f}(\boldsymbol{X}_{i,t})$ is Cobb-Douglas;
- $\boldsymbol{e}^{v_{it}} = \boldsymbol{v_{i,t}} - \boldsymbol{u_{i,t}}$;
- $\boldsymbol{v_{i,t}}$ represents a normally distributed disturbance and $\boldsymbol{u_{i,t}}$ represents inefficiency; and
- $\boldsymbol{TFP_{i,t}} = \boldsymbol{e}^{\alpha - u_{i,t}}$.

Here, α represents a constant term, u is a country specific inefficiency term and v us the usual idiosyncratic error term. From the estimation of these, the link between digitalisation and efficiency can then be estimated by regressing the error term $\boldsymbol{u_{i,t}}$ on the indicator for digitalisation as follows:

$$\boldsymbol{ln}\ (\boldsymbol{u_{i,t}}) = \delta - \Upsilon \boldsymbol{Z}_{i,t} + \boldsymbol{w}_{i,t}$$

Where:

$\boldsymbol{Z}_{i,t}$ represents the chosen indicator of interest; and

$\boldsymbol{w}_{i,t} \sim iidN(0, \sigma 2\mathrm{w})$.

A6. Results – Stochastic Frontier Analysis

The data used is consistent with that set out in Annex A2. We have obtained all macroeconomic indicators from World Bank in order to construct the stochastic frontier. As above, we have initially performed our analysis using DESI scores for the EU27 countries and, in order to increase sample size, have subsequently reperformed for specific sub-indicators for DESI using Eurostat data.

Table 7 presents the results of the stochastic frontier analysis. All coefficients are positive and significant with the exception of government expenditure. The results for the inefficiency regression for DESI and all other indicators of digitalisation are outlined in Table 8.

Table 7: Econometric results for Stocahstic Frontier regression

Input variable	Coefficient
Capital	0.155***
Labour	0.683***
Trade	0.057***
Government Consumption	-0.117***
Year	0.001*
Intercept	5.775
Observations	952

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Econometric results for inefficiency regression for all independent variables analysed

Independent variable	Coefficient	Observations
DESI Score	0.115***	140
Household internet access	0.077***	668
Number of IT specialists	0.109***	431
% using online banking	0.057***	618
Enterprises with e-commerce	0.070***	428
Public authority interactions	0.054***	514

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Technical annex *(Cont'd)*

All coefficients are of the expected sign and indicate that an increase in measure of digitalisation is associated with an increase in efficiency. In the analysis, the DESI score is allowed to have a non-linear relationship with total factor productivity. Therefore, the interpretation of a 10% increase in DESI score will depend on the DESI score in the specific country. In order to calculate this relationship, the following transformation must be applied to the coefficient of the DESI score:

$$\frac{d\,u}{d\,DESI} = 1000\ \frac{\Upsilon}{DESI}$$

For instance, given a DESI score of X, the effect on total factor productivity is:

$$\frac{d\,u}{d\,DESI} = 1000\ \frac{0.115}{X}$$

With the interpretation that, for a country with DESI score of X, a 10% increase in the DESI score would increase total factor productivity by $1000\ \frac{0.115}{X}$ percent.

A7. Results for macroeconomic scenarios by country

In order to better illustrate the relationship between digitalisation and economic growth, simple macroeconomic scenarios for each of the EU27 countries were constructed, comparing an 'as is' scenario as a base to a 'digital convergence' scenario.

'As is' scenario: All factor inputs, such as capital, labour and DESI scores for each economy were projected forward to 2027 based on a linear trend from the previous 10 years' data (for DESI this is based on the previous 5 years' data). GDP per capita was then estimated from this using the equation set out in our panel data analysis (see equation 1 in Annex A2).

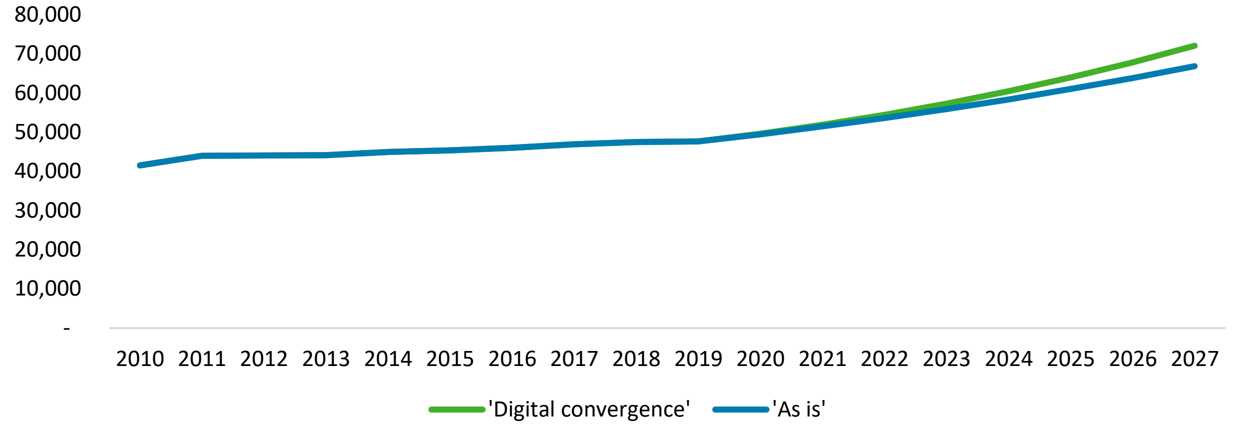
'Digital convergence' scenario: DESI scores for each country were projected forward to 2027 based on a linear trend to reach a score of 90 by 2027. GDP per capita in each year was then calculated as above, but with the modified DESI score. For Sweden, the projection is based on the historical linear trend and it is projected to reach a score of greater than 90 in 2027.

See below graphs illustrating the difference between the two scenarios for a sample of EU countries.

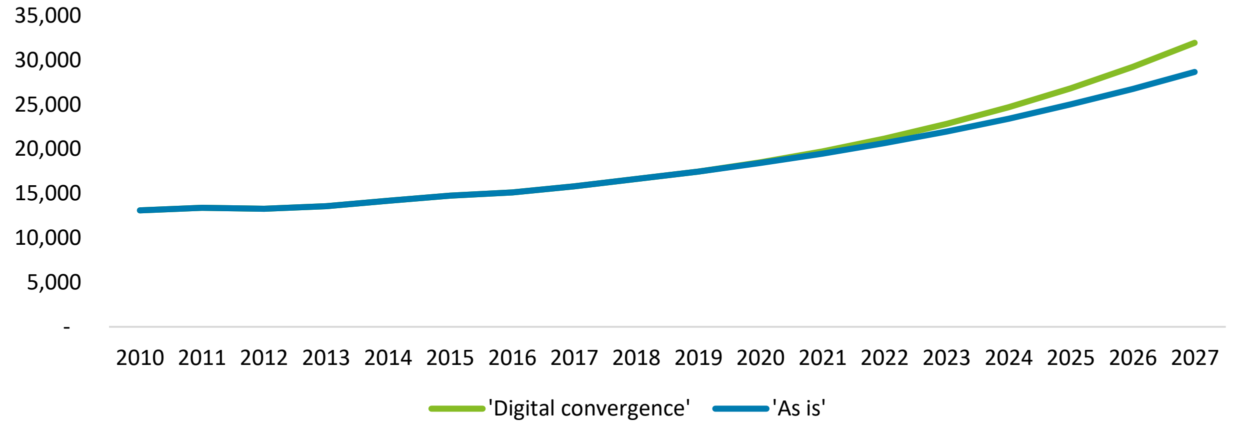
The impact of a 'digital convergence' was then calculated by taking the difference between these two scenarios for each Member State. The figure for the overall EU average was calculated by using total projected GDP for the EU divided by the overall population figure estimated on a linear basis for both scenarios. By constructing the estimates in this manner, the approach accounts for the non-linearity of the impact of an increase in DESI score on GDP per capita based on the pre-existing level of DESI. This is because countries at a lower DESI score will have higher percentage increases in DESI, and therefore higher annual impacts on GDP per capita.

Technical annex *(Cont'd)*

Germany



Hungary



Portugal