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The impact of the digital economy on economic growth: The case of OECD countries

O impacto da economia digital no crescimento econômico: O caso dos países da OCDE

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Abstract

Purpose: This longitudinal study analyzes the impact of the digital economy on economic growth in Organisation for Economic Co-operation and Development (OECD)'s countries, divided into groups by their level of development (transition and innovation countries).

Originality/value: Empirical studies on information and communications technology (ICT)'s impact on countries' economic growth have increased over the last few years. However, there are still no studies that analyze this problem for the group of OECD countries, let alone divide these countries according to their level of economic development to assess the differences between more developed countries and less developed. The study of this gap in the literature allows us to infer important implications for policymakers to implement the digital agenda more efficiently.

Design/methodology/approach: We used a panel data sample from the World Bank covering 36 OECD countries from 2000 to 2019. A statistical analysis of the variables was carried out separately for all OECD countries and the transition and innovation countries groups. We then performed a correlation analysis between the variables, and three models were estimated using the generalized moments panel method (GMM) using a fixed cross-section.

Findings: The impact of the digital economy as measured by the technology proxy – internet, mobile phone, and fixed-broadband – on the economic growth of OECD countries depends on their level of development and the measures of the technologies that capture the digital economy. ICTs positively influence the development of the economies of OECD countries and can be used as instruments by policymakers. These agents must implement policies that strengthen the physical and technological infrastructures of the ICTs, the digital empowerment of human capital, and more significant social equity in accessing the ICTs.

Keywords: mobile telephone, internet, fixed broadband, digital economy, economic growth

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Resumo

Objetivo: Este estudo longitudinal analisa o impacto da economia digital no crescimento econômico dos países da Organização para a Cooperação e Desenvolvimento Econômico (OCDE), que foram divididos em grupos de acordo com o seu nível de desenvolvimento (países em transição e em inovação).

Originalidade/valor: Estudos empíricos sobre o impacto das tecnologias da informação e comunicação (TIC) no crescimento econômico dos países vêm sendo desenvolvidos nos últimos anos. No entanto, ainda não existem estudos que analisem esse problema para o conjunto de países da OCDE, muito menos esses países estiveram divididos de acordo com seu nível de desenvolvimento econômico, permitindo avaliar as diferenças entre os mais desenvolvidos e os menos desenvolvidos. O estudo dessa lacuna existente na literatura permite inferir implicações importantes para os decisores políticos implementarem a agenda digital de forma mais eficiente.

Design/metodologia/abordagem: Utilizou-se uma amostra de dados em painel, recolhida pelo Banco Mundial, que abrange os 36 países da OCDE e o período de 2000 a 2019. Realizou-se uma análise estatística das variáveis para todos os países da OCDE e separadamente para países em transição e países em inovação. Em seguida, realizou-se uma análise de correlação entre as variáveis e foram estimados três modelos pelo método do painel de momentos generalizados (GMM) com as diferenças entre países fixas.

Resultados: O impacto da economia digital medida pela *proxy* de tecnologia – internet, telefone móvel e banda larga fixa – no crescimento econômico dos países da OCDE depende do seu nível de desenvolvimento e das medidas das tecnologias que capturam a economia digital. As TIC influenciam positivamente o desenvolvimento das economias dos países da OCDE e podem ser usadas como instrumentos pelos formuladores políticos. Esses agentes devem implementar políticas que fortaleçam as infraestruturas físicas e tecnológicas das TICs, o empoderamento digital do capital humano e a maior equidade social no acesso às TICs.

Palavras-chave: telefone móvel, internet, banda larga fixa, economia digital, crescimento econômico

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INTRODUCTION

In the past few decades, the digital economy has gained the attention of researchers, consultants, journalists, policymakers, and business managers as an area of high potential (Li et al., 2020; Tapscott, 1996). Countries' wealth is directly related to their capacity to produce. Consequently, the workers who are better paid are also those who make more, which leads them to have higher standards of living. Innovation is a factor that directly influences the production and socio-economic development of countries and their regions (Cardona et al., 2013; Lopes et al., 2021a).

Every country is looking for ways to create gradual and sustainable growth. The growth of the gross domestic product (GDP) *per capita* depends strongly on the technological progress that the country has. Countries that are more innovative and technological often manage to be more competitive and have better economic performances (Lopes et al., 2021b; Solow, 1957). From the analysis of the influence of information and communications technology (ICT) on innovation, several studies have shown that the use of ICTs, in particular the internet, allows the dissemination of tacit and codified knowledge, favors technological diffusion, the development of new products, processes, business, and cooperation between companies (Billon et al., 2017). Thus, ICTs stimulate and favor innovation opportunities by favoring information networks that allow the creation of knowledge spillovers (Bloom et al., 2013). In addition, they make it possible to identify new sources of innovation, develop the capacity for exploration and creativity and reduce the time to market (Osorio-Urzúa, 2008). ICTs enable strategic innovation by identifying new customer needs, new production and logistics methods, and new customer segments (Markides & Anderson, 2006).

The New Theory of Growth highlighted the reasons that led to technological changes. Thus, investment in knowledge, innovation, and human capital has a crucial impact on the growth of economies, which we currently call knowledge-based economies. To this end, policymakers must implement policies that stimulate education and support and encourage research and development (R&D). In this way, it can increase innovation and, consequently, countries' productivity (Cardona et al., 2013; Grossman & Helpman, 1991; Romer, 1990).

In this context, European countries have been changing their policies over the past three decades to improve their innovative performance. However, not all European Union economies have managed to achieve sustainable economic growth, have grown little, or even declined in their produc-

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tivity (Lopes et al., 2018; Pradhan et al., 2019). To make their economies more competitive and increase their economic growth, in 2014, the European Union implemented its new development policies for the regions called RIS3 (research and innovation strategies for smart specialization) (Foray, 2014; Lopes et al., 2019b). The policymakers of the different countries belonging to the European Union have significantly strengthened their investment to update and develop their ICTs infrastructures and consequently increase innovation (Paragi, 2021; Pradhan et al., 2019). However, the Digital Agenda for Europe was implemented in 2010, whose main objective is to develop Europe's economy, bringing sustainable socio-economic benefits to the single digital market (Szeles & Simionescu, 2020).

In this environment, digital technologies have had an increasing impact on economies. Digital technologies have been evolving and expanding across all economic activities and society. This new reality has made the economy more intelligent and data-driven (Hanna, 2016; Szeles & Simionescu, 2020). The World Economic Forum and the Group of Twenty define the digital economy as diverse economic activities that use digital knowledge and information as critical factors of production, information, and communication technology, along with modern information networks as a virtual space of activities to develop productivity growth (Li et al., 2020).

From this perspective, all countries in the European Union are aware of the digital economy. However, the biggest challenge is to ensure that development is equitable and broad enough to cover all member states. For that, investment and policies must be effective, as it is not enough to guarantee the widespread access and use of the internet by the various economic actors. The benefits of digitization are reduced if this is not done well. Thus, the strategy for developing a digital economy involves creating ecosystems for digital transformation (Hanna, 2012, 2016). In turn, digital transformation ecosystems must have standard interdependent components such as digital transformation applications, ICT infrastructure; ICT services sector; human capital; policies, and institutions (Szeles & Simionescu, 2020). In this way, the European Union intends to develop the digital single market.

Despite this, the digital single market still has several challenges to overcome. In some regions of the European Union, there are still some gaps, and significant differences, concerning the transition to a digital economy, such as 1. integration of digital technologies in digital public services and by companies; 2. low or even no broadband coverage; 3. widespread use of the internet; and 4. shortage of labor with ICT skills (Auby & Gregorio, 2015; Răileanu-Szeles, 2015; Szeles & Simionescu, 2020). The digital divide is a gap

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concerning ICT applications, whether between countries or within countries (at the regional level) (Ahmed, 2021; Al-Roubaie, 2018; Arkhipova & Sirotin, 2019).

Despite the increase in studies on the influence of ICTs on countries' economic growth in recent years, no study has yet used ICTs as a proxy for the three measures used in this study (internet, mobile phone, and fixed broadband). Additionally, this issue has not yet been studied for the Organisation for Economic Co-operation and Development (OECD) countries as a whole and the OECD countries divided by their degree of economic development. This is a critical gap to be further examined since the impact of ICTs on economic growth depends on the type of countries' economies (more developed or less developed), and, as such, digital decisions at the government and company level must be adopted, taking this assumption into account.

This longitudinal study aims to analyze the impact of the digital economy on economic growth in OECD countries, with these countries divided into groups based on their level of development (transition and innovation countries). Through the proxy for ICT, we intend to include mobile-cellular telephone subscriptions per 100 inhabitants, a percentage of individuals using the internet, and fixed-broadband subscriptions per 100 inhabitants. We will also assess the impact of these indicators on economic growth as measured by GDP *per capita* in OECD countries and individually in the transition and innovation countries groups. The data for this article were collected from the World Bank, which includes the 36 OECD countries from 2000 to 2019.

The results of this study demonstrate that the impact of the digital economy, measured by the technological proxy (internet, mobile phone, and fixed broadband), depends on the development of the countries' economies. The internet's positive impact on countries' GDP *per capita* was found, regardless of their degree of economic development. Regarding mobile phones, there is a positive impact on GDP *per capita* when considering the OECD countries as a whole and in the group of innovation countries. Finally, fixed broadband positively affects the economic growth of transition countries but negatively impacts OECD countries when considered as a whole and in the group of innovation countries.

This study's results help narrow the gap in the literature in terms of empirical studies on the still insufficient literature that justifies the different impacts that ICTs can have on countries' economic growth. We tried to demonstrate that these differences are related to the level of economic

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development of the economies and the type of ICTs considered under analysis. Thus, we intend to suggest measures that reduce the digital divide, increasing the use of digital technologies by families, companies, and governments. This empirical study contributes to improving the performance of digital economies, which are relevant to the operation of the digital agenda in Europe. The results suggest that the impact of the digital economy as measured by the technology proxy – internet, mobile phone, and fixed-broadband – on the economic growth of OECD countries depends on their level of development and the technologies' measures that capture the digital economy. Thus, policymakers must promote more significant investment in physical infrastructure to support ICT; provide social incentives for broadband internet access; regulate the prices of ICT services to enable widespread access; develop digital empowerment programs and develop regional strategies for digital growth with ICT innovation as a priority.

In the first section, we make the framework for the study and highlight the problem under analysis. In the second section, we elaborate on the digital economy and economic growth literature review. In the third section, we describe the data and the methodology. In section four, we present the results and compare them with the literature. The final section offers our conclusions.

LITERATURE REVIEW: DIGITAL ECONOMY AND ECONOMIC GROWTH

Several authors have highlighted the importance of the digital economy measured by ICT in countries' economic growth. The most classic theories of production factors, such as neo-Schumpeterian theories (Bahrini & Qaffas, 2019; Pyka & Andersen, 2012; Schumpeter & Backhaus, 2003) and the neoclassical growth theory (Solow, 1956), have already shown a positive impact on ICT; it translated into inputs on the economic supply side in the form of the capital production factor and boosted the production process, technological advances, the quality of the workforce and, consequently, economic growth. However, contrary to the more classic theories that considered technology an exogenous factor, recent empirical studies have shown an endogenous relationship between ICT. This is found not only through positive impacts on economic growth but also economic development in terms of average life expectancy, education, health, and reducing poverty rates (Grossman & Helpman, 1991). On the other hand, recent empirical studies

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show that some countries may have a positive relationship between ICT and economic growth. Still, there is evidence of a negative relationship, indicating that its impact depends on the level of economic development in the countries under analysis (Ward & Zheng, 2016) since more significant investments in ICT lead to more significant economic benefits in developed countries to the detriment of developing countries (Dewan & Kraemer, 2000; Thompson & Garbacz, 2011).

The positive impact of ICT on economic growth has been seen through the increase in business outputs, namely due to the reduction of transaction costs of companies with the use of digital technologies (Roller & Waverman, 2001) and/or the modernization of production techniques in the productive units (Pohjola, 2002), in greater productivity (Van Zon & Muysken, 2005), in the indirect growth caused in the non-ICT sectors, in the improvement of the market processes, the creation of employment opportunities, the creation of knowledge, and the reduction of price fluctuations, among others (Bahrini & Qaffas, 2019; Grimes et al., 2012; Haftu, 2019; Jorgenson & Stiroh, 1999; Lee et al., 2012; Pradhan et al., 2018; Vu, 2011). On the other hand, there is a consensus by international organizations, namely the United Nations and the European Commission, that in countries where ICT is used in different sectors ranging from industry, commerce, health, education, and transport, in the public and private sector's supply of goods and services, a better quality of life for the population and economic development is promoted.

In practical terms, the ICTs measured by fixed-line phones have a positive impact on countries' economic growth as found by Hardy (1980) for 60 countries in the period from 1968 to 1976; by Roller and Waverman (2001) for 21 OECD countries in the period from 1970 to 1990; by Madden and Savage (1998) for 27 countries in Central and Eastern Europe in the period 1975-1990. ICT measured by mobile phones, personal computers, and fixed-line telephone also have a positive impact on countries' economic growth, especially in more developed countries (Gruber & Koutroumpis, 2014; Inklaar et al., 2005; Koutroumpis, 2009; Sassi & Goaied, 2013; Vu, 2011). The poorest countries have lower levels of mobile penetration, as found in the studies of Ward and Zheng (2016), Albiman and Sulong (2016), Wamboye et al. (2015), Vu (2011), Gruber and Koutroumpis (2010).

Niebel (2018) analyzed the impact of ICT on economic growth in countries with different levels of development (developing, emerging, and developed countries), with no statistically significant differences found in the output of ICT elasticities between groups of countries, that is, emerging

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and non-developing countries, obtain more significant benefits in terms of economic growth by investing more in ICT than developed countries, a conclusion also shared by Haftu (2019) more specifically in terms of investments in mobile phones.

More recently, the measurement of ICT by broadband and the internet has also positively impacted these technologies on economic growth (Aghaei & Rezagholizadeh, 2017; Pradhan et al., 2018; Sepehrdoust, 2018). Bahrini and Qaffas (2019) concluded that ICT measured by broadband and internet usage are the principal drivers of economic growth for Africa's developing countries. David and Grobler (2020), in an empirical study on the impact of ICT on the economic development of African countries, concluded that the implementation of mobile telecommunications has grown faster than other ICT, with a positive effect on economic growth and, as such, recommend more significant investments in terms of fixed-line and internet infrastructures as found in studies of Salahuddin and Alam (2016) and Haftu (2019). However, the broadband penetration rate is slower in developing countries, contributing positively to economic growth (Alam et al., 2019; Mayer et al., 2020) but less intensively and more slowly (Habibi & Zabardast, 2020; Thompson & Garbacz, 2011). Myovella et al. (2020) studied 41 countries in Sub-Saharan Africa and 33 OECD countries from 2006 to 2016 and found a positive relationship between digitalization and economic growth. Thus, according to Bagheri and Rodrigues (2017), the impact of fixed-broadband subscriptions on GDP *per capita* depends on the countries' development level.

On the other hand, Habibi and Zabardast (2020) and Thompson and Garbacz (2011) found in more developed countries with the latest and most advanced technology, fixed-broadband's contribution to economic growth is less.

However, another group of empirical studies indicates that the relationship between ICT and economic growth is negative. This relationship is especially true in developing countries, with consequences on the labor market reflected in the increased unemployment of unskilled workers. With the more effective implementation of ICT, they remain without functions, and on the other hand, because the competitive role of developed country markets is reinforced where developing countries do not have competitive advantages (Aghion et al., 1998; Freeman & Soete, 1997). Other authors have also found hostile relations between ICT and economic growth in developing countries, such as Dewan and Kraemer (2000), whose study involved 36 countries from 1985 to 1993 and concluded that in developing

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countries, the low investment in technological infrastructures and the lack of regulation of the markets means that there are no additional benefits of ICT in the economic growth of these countries; Lee et al. (2012) found a positive impact of ICT on economic growth in developed Sub-Saharan Africa countries but a negative relationship in developing countries; Papaioannou and Dimelis (2007) and Yousefi (2011), in a data panel from 42 developed and developing countries, concluded that there is a positive impact of ICT only on the economic growth of developed countries, allowing trade liberalization, the improvement of human capital, and more favorable government policies.

Based on the results of the analyzed studies, we formulated the following hypotheses:

- Hypothesis 1 (H1): High levels of mobile-cellular telephone subscriptions are positively related to economic growth, regardless of the development of OECD countries. This hypothesis is supported by Bahrini and Qaffas (2019), Ward and Zheng (2016), Albiman and Sulong (2016), Wamboye et al. (2015), Vu (2011), and Gruber and Koutroumpis (2010).
- Hypothesis 2 (H2): Countries with higher rates of individuals using the internet have higher GDP growth rates *per capita*, regardless of the level of development of OECD countries. This hypothesis is supported by Bahrini and Qaffas (2019), Pradhan et al. (2018), Sassi and Goaied (2013), and Wamboye et al. (2015).
- Hypothesis 3a (H3a): High levels of fixed-broadband subscriptions are negatively related to the economic growth of more developed countries. This hypothesis is supported by Bagheri and Rodrigues (2017).
- Hypothesis 3b (H3b): High levels of fixed-broadband subscriptions are positively related to the economic growth of the least developed countries. This hypothesis is supported by Salahuddin and Alam (2016), Alam et al. (2019), and Mayer et al. (2020).
- Hypothesis 4 (H4): The effect of technology proxy measured by mobile-cellular telephone subscriptions, percentage of individuals using the internet, and fixed-broadband subscriptions on economic growth positively impacts transition countries. This hypothesis is supported by Koutroumpis (2019), Habibi and Zabardast (2020), and Thompson and Garbacz (2011).

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DATA ANALYSIS AND METHODOLOGY

The literature review carried out focused on the relationship between economic growth and the digital economy. There is still no consensus on the indicators that best measure the digital economy and the impact of each of these measures on economic growth. This leads to heterogeneity in econometric methods, results and conclusions, and different suggested policies.

This study considers a sample of the 36 countries of the OECD: Germany, Australia, Austria, Belgium, Canada, Chile, South Korea, Denmark, Slovakia, Slovenia, Spain, United States, Estonia, Finland, France, Greece, Hungary, Ireland, Iceland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Norway, New Zealand, Netherlands, Poland, Portugal, United Kingdom, Czech Republic, Sweden, Switzerland, and Turkey.

To achieve the main objective of analyzing the impact of the digital economy on economic growth, we carried out a comparative analysis of the OECD countries, having divided the countries into two groups according to their degree of development. For this division, the GDP *per capita* of each country in 2019 was used as a criterion, as suggested by Schwab (2018) and Stoica et al. (2020) in the global competitiveness report. The classification of countries according to their degree of development based on GDP *per capita* is as follows: < 2,000 USD for the factor-driven economies; between 2,000 USD and 2,999 USD for the economies in transition from stage 1 to stage 2; between 3,000 USD and 8,999 USD for the efficiency-driven economies; between 9,000 USD and 17,000 USD for the economies in transition from stage 2 to stage 3; and> 17,000 USD for innovation-driven economies.

All OECD countries have a GDP *per capita* of more than 9000 USD in 2019 and are therefore classified into two groups: 1. economies in transition from stage 2 to stage 3, i.e., economies in transition between efficiency and innovation, which will be called transition countries; and 2. innovation-driven economies which will be called innovation countries (Table 1). Economies in transition refer to countries that are more competitive than those classified as efficiency-driven economies and, as such, productivity is higher. Companies must develop more efficient production processes and increase product quality to promote higher wages. This group includes Chile, Latvia, Mexico, and Turkey. All other countries are classified as innovation-driven economies. Innovation countries are economies that pay higher wages and have higher standards of living. Maintaining higher wages and higher living standards is only possible if companies compete in the market through new products and/or more sophisticated and innovative production processes.

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Table 1

Classification of OECD countries according to their degree of development

Level of economic development					
Transition countries		Innovation countries			
GDP *per capita* (2019) $9000 – $17000		GDP *per capita* (2019) > $17000			
Chile	$ 15 091,45	Australia	$ 57 186,62	Israel	$ 35 278,92
Latvia	$ 16 722,10	Austria	$ 50 552,91	Italy	$ 35 680,16
Mexico	$ 10 267,50	Belgium	$ 47 618,30	Japan	$ 49 187,83
Turkey	$ 15 125,39	Canada	$ 51 588,76	Korea, Rep.	$ 28 675,03
		Czech Republic	$ 24 265,99	Lithuania	$ 18 609,72
		Germany	$ 47 446,73	Luxembourg	$ 111 062,34
		Denmark	$ 65 820,24	Netherlands	$ 55 488,97
		Spain	$ 33 392,53	Norway	$ 92 556,32
		Estonia	$ 20 856,02	New Zealand	$ 38 992,97
		Finland	$ 49 397,23	Poland	$ 17 406,55
		France	$ 44 317,39	Portugal	$ 24 658,50
		United Kingdom	$ 43 711,71	Slovak Republic	$ 20 999,13
		Greece	$ 24 024,23	Slovenia	$ 27 426,79
		Hungary	$ 17 572,31	Sweden	$ 58 012,96
		Iceland	$ 51 332,14	Switzerland	$ 79 406,66
		Ireland	$ 79 703,41	United States	$ 55 753,14

Source: Elaborated by the authors based on Schwab (2018) and Stoica et al. (2020).

As the method of assessing the impact of the digital economy on countries' economic growth, a set of indicators was collected in February 2021 for each OECD country at World Bank's world development indicators (WDI) that measured economic growth, the digital economy, and macroeconomic conditions. Economic growth is measured by GDP *per capita* at constant 2010 prices as the dependent variable. GDP *per capita* at constant prices is the most widely used indicator to measure economic growth (World Bank, 2021) being utilized in a logarithm as used by Myovella et al. (2020), Habibi and Zabardast (2020), Mayer et al. (2020), Mićić (2017), Koutroumpis

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(2009), Haftu (2019), Donou-Adonsou (2019), Adeleye and Eboagu (2019), Alam et al. (2019), Bahrini and Qaffas (2019), Ghosh (2017), among others.

As measures of the digital economy, a technology proxy was used that contemplates mobile-cellular telephone subscriptions per 100 inhabitants, a percentage of individuals using the internet, and fixed-broadband subscriptions per 100 inhabitants, which has implications for the economic growth of countries as found by empirical studies referenced above. These indicators are the independent variables, as used by Myovella et al. (2020), Habibi and Zabardast (2020), Haftu (2019), Donou-Adonsou (2019), Adeleye and Eboagu (2019), Alam et al. (2019), and Bahrini and Qaffas (2019).

Control variables were used to measure macroeconomic conditions (Bahrini & Qaffas, 2019; Myovella et al., 2020). According to the economic literature, some variables explain the economic growth of countries, such as gross capital formation (grosscap), public spending (govexp), population growth (pop), and economic openness (eopen). Table 2 shows the variables, their definition, and source, according to that presented by World Bank's WDI.

Table 2

Dependent, independent, and control variables

Variable	Definition	Source
Dependent variable		
GDP *per capita* (constant 2010 US$) (GDP_PC)	GDP *per capita* is GDP divided by the midyear population.	World Bank's WDI
Independent variables – digital economy measures (technology proxy)		
Mobile-cellular telephone subscriptions (per 100 inhabitants) (MOBILE)	During the past three months, cell phone subscriptions were used per 100 inhabitants.	World Bank's WDI
Individuals using the internet (%) (INTERNET)	During the past three months, the percentage of individuals using the internet.	World Bank's WDI
Fixed-broadband subscriptions (per 100 inhabitants) (FIXEDBROAD)	Fixed-broadband subscriptions (fixed subscriptions to high-speed access to the public internet) per 100 inhabitants.	World Bank's WDI
Control variables – measures of the macroeconomic condition		
Economic openness (% of GDP) (TRADEOPEN)	Total exports + imports of goods and services, divided by gross domestic product.	World Bank's WDI
Population Growth (annual, %) (POP)	Population growth rate (year t / year t-1).	World Bank's WDI

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Table 2 (conclusion)

Dependent, independent, and control variables

Variable	Definition	Source
Control variables – measures of the macroeconomic condition		
Gross fixed capital formation (% of GDP) (GROSSCAP)	Gross fixed capital formation includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including commercial and industrial buildings, hospitals, offices, schools, and private residential.	World Bank's WDI
General government final consumption expenditure (% of GDP) (GOVEXP)	Includes all current government expenditures for purchases of goods and services	World Bank's WDI

Source: Elaborated by the authors.

Taking into account the primary objective and the formulated hypotheses, we used a quantitative methodology, like Myovella et al. (2020), Habibi and Zabardast (2020), Haftu (2019), Donou-Adonsou (2019), Adeleye and Eboagu (2019), Alam et al. (2019), and Bahrini and Qaffas (2019). This methodology allows for establishing significant relationships between variables, application to different samples, and replicating the results to other databases. Thus, we performed a descriptive statistical analysis of the variables used (Table 3) for a sample of all OECD countries and groups of countries classified by their degree of development (Table 4) and correlation analysis (Table 5). Finally, we estimated econometric regressions to test the formulated hypotheses (tables 6 and 7). As a dynamic data panel, three models were estimated to test these four hypotheses. This was accomplished using the panel generalized method of moments (GMM) method using a fixed cross-section (Greene, 2018; Wooldridge, 2001) in the Eviews10 software. As the sample is composed of panel data, compared to the ordinary least squares or two-stage least squares methods, the GMM method is more efficient since it corrects problems of heteroscedasticity or autocorrelation, which are common in this type of sampling.

The GMM model is specified by that linear model: $y = xb + u$, fulfilling orthogonality condition $E[x'u] = 0$.

The vector of estimators of b can be considered the solution that solves the equation of moments: $E[x'(y-xb)]=0$, having as a solution $b = E(x' x)^{-1} E(x' y)$, whose sample correspondent is the OLS estimator - $b = (x' x)^{-1} x' y$.

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Instrumental variables (independent variables and the control variables) allow solving the equation of moments (b = E(z´x)-1 E(z' y)) and its sample equivalent is the instrumental variable estimator (bVI =(z'x)-1z'y). With fixed effects and constant variances, time-varying errors have zero means and zero correlations.

RESULTS AND DISCUSSION

Table 3 shows the descriptive statistics for the variables (dependent, independent, and control). There was a total of 703 observations over the years 2000 to 2019. The average value of the dependent variable – GDP *per capita* – is 37,486.17 USD. In the period analyzed, the countries of the OECD are innovation economies on average. The minimum value of this variable is 6,964.92 USD, registered in Lithuania in 2000, and the maximum value is 11,1968.30 USD, registered in Luxembourg in 2007. Using the logarithm of GDP *per capita*, the average value is 10.35, the maximum value is 11.63, and the minimum is 8.85.

Concerning the independent variables relating to the digital economy, the average percentage of internet users (internet) is 66.30%, with the maximum rate being 99.01% registered in Iceland in 2018 and 2019 and the minimum rate being 5.08% reported in Mexico in 2000; the average value of mobile-cellular telephone subscriptions per 100 inhabitants (mobile) is 104.61, with a minimum of 14.23 in Mexico in 2000 and a maximum value of 172.12 in Finland in 2012; finally, the average value of fixed broadband subscriptions per 100 inhabitants (fixed broadband) is 21.57, with a maximum value of 46.33 recorded in Switzerland in 2018 and the minimum value of .01 in Latvia in 2000. Variations in values presented by the statistics of the independent variables indicate that these variables will have different impacts on the country's economic growth. It has been confirmed that there are no lagged effects.

The control variables represent the macroeconomic condition of the countries. Government expenditures (govexp) had a maximum rate of 27.94% in Denmark in 2009 and an average rate of 19.07%. Gross fixed capital formation (grosscap) has a maximum rate of 43.44% in Ireland in 2019 and an average rate of 22.56%. Economic openness (tradeopen) has a maximum rate of 408.36% in Luxembourg in 2015, and an average rate of 95.29%; the average population growth rate (POP) is 0.56%, the maximum being 2.89% of the sample, registered in Ireland in 2007.

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Table 3

Descriptive statistics of the variables

	LOG (GDP *PER CAPITA*)	FIXED BROAD	INTER	MOBILE	GOVEXP	GROSSCAP	TRADE OPEN	POP
Mean	10.35	21.57	66.30	104.61	19.07	22.56	95.29	0.56
Median	10.55	23.96	72.16	108.60	19.22	22.30	78.63	0.51
Maximum	11.63	46.33	99.01	172.12	27.94	43.44	408.36	2.89
Minimum	8.85	.01	5.08	14.23	9.52	11.07	19.80	-2.26
Std. dev.	0.64	12.83	22.77	27.97	3.76	3.91	57.03	0.78
Obs (n)	703	703	703	703	703	703	703	703

Source: Elaborated by the authors.

Table 4 presents the average values of the variables by groups of OECD countries according to their level of development: transition countries and innovation countries. On average, in the most developed countries (innovation countries), the values of GDP *per capita*, the average percentage of internet users, mobile-cellular telephone subscriptions, fixed-broadband subscriptions, government expenditures, and economic openness are higher than in transition countries. However, the gross fixed capital formation variables and the population growth rate are, on average, higher in transition countries. This result is because the gross fixed capital formation is an essential source for the diffusion of new technology, skills management, and the acquisition of new knowledge in transition countries. The higher rate of population growth in these countries is due to the absence of birth control policies.

Table 4

Average of variables by group of countries

Variable	Transition	Innovation
LOG (GDP_PER_CAPITA)	9.3292	10.4752
FIXEDBROAD	10.2223	23.0050
INTERNET	44.6147	69.0440
MOBILE	83.7278	107.2553
GOVEXP	13.9794	19.7192

(continue)

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Table 4 (conclusion)

Average of variables by group of countries

Variable	Transition	Innovation
GROSSCAP	23.7250	22.4095
TRADEOPEN	71.3987	98.3155
POP	.6914	.5462

Source: Elaborated by the authors.

Table 5 shows the result of the correlation test performed, showing multicollinearity between the independent, dependent, and control variables. There is a positive and high correlation between independent variables such as internet and fixed broadband (.8824, for a r <.05), this being the highest correlation found between variables mobile with internet and fixed broadband (.6179 and .6367, respectively, for r <.05). There is also a negative correlation between grosscap and the independent variables internet, fixed broadband, and mobile.

Table 5

Variable correlation matrix

Probability	LOG (GDP *PER CAPITA*)	FIXED BROAD	INTER	MOBILE	GOVEXP	GROSSCAP	TRADE OPEN	POP
LOG (GDP PER_CAPITA)	1.0000							
FIXEDBROAD	.4728*	1.0000						
INTERNET	.5589*	.8824*	1.0000					
MOBILE	.2464*	.6367*	.6179*	1.0000				
GOVEXP	.3173*	.2881*	.2855*	.2191*	1.0000			
GROSSCAP	(.1325)*	(.1677)*	(.1205)*	(.1700)*	(.2237)*	1.0000		
TRADEOPEN	(.1523)*	.1747*	.2199*	.3103*	(.0040)	(.0190)	1.0000	
POP	.3906*	.0566	.086*	(.0884)*	(.1480)*	(.0851)*	.0052	1.0000

Source: Elaborated by the authors.

Note: *r < .05.

The results of the estimated regressions (Table 6) demonstrate that the digital economy measured by the technology proxy that contemplates

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mobile-cellular telephone subscriptions, individuals using the internet, and fixed-broadband subscriptions have a significant influence on the economic growth of OECD countries as measured by GDP *per capita*, its impact being different according to the level of development of the countries (transition or innovation countries).

Table 6

Regression analysis

	All	Innovation	Transition
	Model 1	Model 2	Model 3
C	9.8904* (.0658)	10.0224* (.0728)	9.4186* (.1660)
FIXEDBROAD	(.0027)* (.0006)	(.0019)* (.0006)	.0140* (.0032)
INTERNET	.0036* (.0004)	.0027** (.0004)	.,0044* (.0010)
MOBILE	.0024* (.0002)	.0024* (.0002)	(.0002) (.0005)
Control variables			
GOVEXP	(.0162)* (.0025)	(.0157)* (.0025)	(.0430)* (.0078)
GROSSCAP	.0086* (.0011)	.0087* (.0011)	.0115 * (.0026)
TRADEOPEN	.0013* (.0002)	.0014* (.0002)	(.0025)* (.0010)
POP	.0329* (.0080)	.0236* (.0079)	.1451* (.0324)
R2	.9901	.9881	.9359
Adjusted R2	.9895	.9873	.9264
Durbin-Watson Stat	.2215	.02260	.2898
Obs. (N)	703	624	79

Source: Elaborated by the authors.

Note: *$p < 0.01$; standard errors are shown in parentheses.

Then three models were estimated using the GMM method using a fixed cross-section. Model 1 represents the impact of the digital economy on GDP *per capita* in all OECD countries; model 2 represents the impact of the digital economy on the GDP *per capita* of the innovation countries. Model 3 illustrates the digital economy's effect on *per capita* the transition countries' GDP *per capita*.

According to the data obtained in the F statistics, all models are statistically significant. The adjusted R squared value in all models is greater

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than 90%. Thus the independent and the control variables explain more than 90% of the variation in economic growth in OECD countries as measured by GDP *per capita*.

Regarding the independent variables, mobile-cellular telephone subscriptions, Individuals using the internet, and fixed-broadband subscriptions are used as a proxy for technology. This represents the digital economy in model 1, where all OECD countries are listed, and in model 2, where the OECD innovation countries are having a different impact on economic growth: mobile-cellular telephone subscriptions and individuals using the internet have a positive effect, and fixed broadband subscriptions have a negative impact.

In model 3, referring to the OECD transition countries, fixed broadband subscription and the internet have a positive and significant impact (r = 0.000), but the variable mobile is not substantial. This independent variable is no longer explanatory of GDP *per capita*, the economic growth of the transition countries.

The results demonstrate that high levels of mobile-cellular telephone subscriptions (MOBILE) are positively related to economic growth; when we consider all OECD countries (model 1) and the group of innovation countries (model 2), a 2.4% increase in mobile-cellular telephone subscriptions have a 10% impact on GDP growth *per capita*. However, in the transition countries group (model 3), this variable is no longer significant in explaining GDP *per capita* and economic development. In transition countries, income levels are very different. ICT investments are lower and therefore have lower levels of mobile penetration. These results are consistent with Bahrini and Qaffas (2019), Ward and Zheng (2016), Albiman and Sulong (2016), Wamboye et al. (2015), Vu (2011), and Gruber and Koutroumpis (2010), among others. Thus, Hypothesis 1 of high levels of mobile-cellular telephone subscriptions is positively related to economic growth, regardless of the development of OECD countries.

Countries with higher rates of Individuals using the internet (internet) have higher rates of GDP growth *per capita*, regardless of the level of development of OECD countries, confirming hypothesis 2 (H2). The impacts of individuals using the internet on GDP *per capita* are more intense in transition countries (0.44%) than in innovation countries (0.27%) and when all OECD countries are considered (0.36%). These results are in line with the most recent empirical studies that concluded that high percentages of internet users have a positive and significant effect on countries' economic growth (Bahrini & Qaffas, 2019; Pradhan et al., 2018; Sassi & Goaied, 2013;

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Wamboye et al., 2015). However, the impact of the internet on economic growth depends on the countries' stage of development. The internet is the main engine for promoting communication in developing countries, and in more developed countries, it has a fundamental supporting role. Therefore, in all economic sectors, these countries depend more on internet use (Myovella et al., 2020). According to Haftu (2019), promoting ICT skills in internet users, especially in the least developed countries, is crucial for fostering economic growth and development.

High levels of fixed-broadband subscriptions harm economic growth when considering all OECD countries (model 1) and in the innovation countries group (model 2) but are positively related in the transition countries group (model 3). Thus, the impact of fixed-broadband subscriptions on GDP *per capita* depends on the level of development of countries (Bagheri & Rodrigues, 2017), with a negative effect in more developed countries (innovation countries) and a positive effect in less developed countries (transition countries), confirming hypotheses 3a and 3b.

The rapid growth of broadband infrastructures affects countries with low income more positively (Salahuddin & Alam, 2016), one of the main factors contributing to the economic growth of developing countries (Haftu, 2019). On the other hand, the broadband penetration rate is slower in developing countries, and the increasing and progressive penetration create prospects for economic prosperity in these countries (Alam et al., 2019; Mayer et al., 2020).

Habibi and Zabardast (2020) and Thompson and Garbacz (2011) found in more developed countries with the latest and most advanced technology. Fixed broadband' has a lower contribution to economic growth. Currently, 3G/4G services that improve mobile broadband penetration in more developed countries are valued instead of fixed broadband penetration policies. The effect of the latter services is three times greater in the countries' economic growth as they reduce broadband prices, allowing for more significant innovation and improvements in business performance. Thus, in more developed countries where broadband policies are defined, the penetration of fixed broadband may not influence economic growth (Ghosh, 2017), and there is decreasing economic returns (Koutroumpis, 2019).

The effect of the technology proxy measured by mobile-cellular telephone subscriptions, percentage of individuals using the internet, and fixed-broadband subscriptions on economic growth has a more positive impact on transition countries in general, despite the variable mobile-cellular telephone subscriptions cease to be significant to explain GDP *per capita*. This confirms Hypothesis 4 (H4).

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Regarding the control variables that reflect the macroeconomic condition, all variables are significant for r = 0.000. Regardless of the level of development of OECD countries, the effect of the impact of control variables on GDP *per capita* is the same in the three models (govexp has a negative impact, grosscap and pop have a positive impact on all models), except for tradeopen which, on models 1 and 2, have a positive impact on GDP *per capita*. It has a negative effect in model 3 of the transition countries. The result of the macroeconomic variable tradeopen on economic growth varies with the level of development of the countries; in the least developed countries, barriers to trade, dependence on the export of primary raw materials, weak infrastructures, and large distances between markets explain the negative impact of this variable on economic growth.

FINAL REMARKS

The digital economy is a challenge that countries have been working on to develop and accelerate the digital single market (Szeles & Simionescu, 2020). Thus, the present study sought to analyze the impact of the digital economy on economic growth in OECD countries. Five hypotheses were formulated:

- Hypothesis 1: High levels of mobile-cellular telephone subscriptions are positively related to economic growth, regardless of the level of development of OECD countries.
- Hypothesis 2 (H2): Countries with higher rates of individuals using the internet have higher rates of GDP growth *per capita*, regardless of the level of development of OECD countries.
- Hypothesis 3a (H3a): High levels of fixed-broadband subscriptions are negatively related to the economic growth of more developed countries.
- Hypothesis 3b (H3b): High levels of fixed-broadband subscriptions are positively associated with the economic growth of the least developed countries.
- Hypothesis 4 (H4): The effect of the technology proxy measured by mobile-cellular telephone subscriptions, percentage of individuals using the internet, and fixed-broadband subscriptions on economic growth have a more positive impact on transition countries.

We note that the impact of the digital economy measured by the technology proxy – internet, mobile phone, and fixed broadband – on the

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economic growth of OECD countries depends on their level of development and the technologies that capture the digital economy. We found a positive impact of the internet on the GDP *per capita* of all OECD countries, even when divided into transition and innovation countries. We note the mobile phone's positive impact on the economic growth of OECD countries when considered as a whole and in the group of innovation countries. However, it was found that there is a negative impact on the group of transition countries and the fixed broadband on the economic growth of OECD countries (transition countries and innovation countries). Thus, we can conclude that ICTs positively influence the development of the economies of the European Union.

After presenting the main results, we leave some suggestions for policymakers to reflect on, which can reduce the digital divide and increase the use of digital technologies by families, companies, and governments. Policymakers must ensure the physical infrastructures that allow ICTs access to society as a whole (Haller & Lyons, 2015). Our study confirms that internet use increases the return on GDP *per capita*. It seems relevant that all countries have access to broadband coverage, allowing everyone to use the internet. Policymakers can create social measures that enable internet access for everyone, as families and businesses still cannot pay for these services. With more internet users, the likelihood of consumption increases (online shopping) (Pilik et al., 2017; Weltevreden & Van Rietbergen, 2007). There are many countries in the European Union where prices for these services are excessive. High prices make it impossible for micro and small companies to fully exploit the strategic potential of ICTs (Cesaroni & Consoli, 2015).

On the other hand, policymakers can diversify or create training public policy programs, increasing investment in ICTs, which aim to exploit the potential of ICT and boost the economy (Fernandez-Portillo et al., 2020). To accelerate the development of the digital economy, the different regional actors (government, academia, and companies) must work to increase the levels of qualification in the higher education of the population, the development of R&D partnerships, and incentives. The development of patents must be reviewed and improved to increase the innovation performance of the regions (Farinha et al., 2020; Lopes et al., 2019a). The regional digital economy is positively affected by regional economic development (regional economic, social and demographic context), so it is imperative to emerge regional strategies for digital growth, with ICT innovation as a priority (Szeles & Simionescu, 2020).

The originality of this study is due to its assessment of the impact of the digital economy on GDP *per capita* in all OECD countries. It also divides

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groups of countries by their level of development (transition and innovation countries). We also suggest measures that reduce the digital divide, increase the use of digital technologies by families, higher education institutions, companies, and governments, and promote and stimulate ICT skills in internet users, especially in less developed countries. This empirical study contributes to clarifying the existing literature on the subject and leaving measures that can improve the performance of digital economies, which are relevant for the operation of the Digital Agenda in Europe.

We found some limitations during this study. The data collected is secondary and covers only the 36 OECD countries. When these data were collected, the available data were from 2000 to 2019. As future lines of investigation, we can cross the variables present in this study with those present in the Global Competitiveness Report, Global Entrepreneurship Monitor, or Regional Innovation Scoreboard. The database can be updated in the coming years, and the results can be compared with this study. This study can also be replicated in other regions of the globe, allowing the comparison of countries in the variables under investigation. It could also be worthwhile to replicate the present study in island/island regions or the outermost regions of countries since different results may be found. It would still be essential to use more measures of the digital economy, allowing a more holistic analysis of the impact of information communication technologies on countries' economic growth.

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