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Mapping Digital Advances: A Comprehensive Digitalization Index for Analyzing OECD Economies

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Abstract The digitalization phenomenon is defined as the adoption and widespread use of information and communication technologies (ICTs) by households, businesses, and the government as the main actors in the economy. Considering its transformative role in economic growth, innovation, and reducing inequality, digitalization has become a key dynamic of modern economies. In this context, this study proposes a novel composite index—the Digital Progress Index (DPI)—to evaluate the digitalization levels of OECD countries from 2010 to 2020. The DPI builds upon the conceptual framework of the World Bank's Digital Adoption Index (DAI), adapting its three-dimensional structure that covers households, businesses, and government. To uncover country-specific patterns, cluster analysis is employed, classifying OECD countries into less developed, developing, and developed groups based on their DPI scores. This classification offers valuable insight into the role of digital transformation in shaping socio-economic structures.

Keywords digitalization · digital economy · OECD · composite index · cluster analysis

JEL Classification O31 · O33 · C43

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Mapping Digital Advances: A Comprehensive Digitalization Index for Analyzing OECD Economies

Digitalization is considered a critical component of contemporary societies and economies. The dissemination of information and communication technologies (ICTs) continues to profoundly transform the manner in which actors at all levels—ranging from businesses to educational institutions and governments to households—interact and conduct transactions. This radical transformation is bringing forth numerous benefits, including enhanced business processes, increased accessibility of informational resources, and the creation of novel opportunities for innovation. The advantages of digitalization not only position it as a technological advancement but also as a foundational driver of socio-economic development. Accordingly, an understanding of and examination of digitalization is of critical importance for the analysis of the fundamental dynamics of our age and the design of policies that will shape the societies of the future.

In this study, the phenomenon of digitalization is defined as the adoption and widespread use of ICTs by households, businesses, and the government as the actors of the economy. In this context, the level of digitalization of a country is defined as the extent to which digital technologies are adopted by households and public institutions as well as businesses in that country. In addition to a transformation strategy, the diffusion of digital technologies leads to a reshaping of numerous factors, including economic growth, innovation capacity, welfare, and inequality (Acemoğlu & Restrepo, 2016; Almeida, Santos, & Monteiro, 2020; Krieger-Boden & Sorgner, 2018; Kuhn et al., 2024; Lindgren, Madsen, Hofmann, & Melin, 2019; Rohm, D. Kaltcheva, & R. Milne, 2013; Sjödin, Parida, Leksell, & Petrovic, 2018). This comprehensive impact demonstrates that digital technologies not only automate business processes and increase productivity but also transform social structures and individual lifestyles (Bawden, 2001; Ragnarsson, 2022; Venter, 2019; Williams, 2005). Consequently, it is of paramount importance to ascertain the level of digitalization in countries, both for the design of policies and strategies aimed at facilitating digital transformation processes and for the comprehension of the interplay between digitalization and socio-economic factors (OECD, 2020).

In the analysis of social and economic phenomena, the use of a single indicator to explain complex social and economic structures is insufficiently explanatory and unreliable from a scientific standpoint. One example of this is the phenomenon of welfare. A significant number of studies employ gross domestic products or national income per capita as indicators of welfare. While these variables are an effective tool for measuring a country's economic performance, they are not a comprehensive measure of prosperity. The concept of welfare encompasses not only improvements in economic performance but also enhancements in social factors. Composite indices provide a more comprehensive approach to measuring complex or multidimensional phenomena. A composite index is defined as a combination of multiple indicators used to measure a phenomenon that is characterized as multidimensional (Greco, Ishizaka, Tasiou, & Torrisi, 2019). In other words, it is a method that expresses multiple indicators in an integrated manner and is used to measure complex phenomena. Examples of widely used composite indices include the Human Development Index (HDI) developed by the United Nations Development Program (UNDP), the Environmental Performance Index (EPI) developed by Yale and Columbia Universities, the Global Innovation Index (GII) developed by the World Intellectual Property Organization (WIPO), and the World Competitiveness Index (WCI) published by the World Economic Forum.

The phenomenon of digitalization, as analyzed in this study, exhibits a multidimensional and complex structure that is similar to the phenomenon of welfare. In the literature, fixed and mobile broadband subscriptions and internet usage rate are frequently employed as indicators of digitalization (Adams & Akobeng,

2021; Asongu & Odhiambo, 2019; Habibi & Zabardast, 2020; Jing, Ab-Rahim, & Ismail, 2019; Myovella, Karacuka, & Haucap, 2020; Nga Ndjobo & Ngah Otabela, 2023; Nguyen, 2022; Richmond & Triplett, 2018; Tchamyou, Asongu, & Odhiambo, 2019; Ullah et al., 2024; Wang & Xu, 2023; Yin & Choi, 2023). However, an examination of the digitalization phenomenon that relies solely on indicators such as technological infrastructure or internet access leads to an inadequate representation of digitalization. A country's level of digitalization is influenced by many factors other than technological infrastructure and internet access, such as digital literacy, personal computer ownership, training in digital skills, use of digital technologies at work, employment of IT professionals, prevalence of e-commerce, use of social media, use of e-government services, and citizens' access to these services. Accordingly, this study aims to measure the digitalization phenomenon with a composite index that includes many indicators including digital access, usage, and competencies as well as the role of digital technologies in business and daily life and to provide a multidimensional examination of digitalization.

While there are many studies on digitalization in the literature (Cámara & Tuesta, 2017; CISCO, 2019; DESI, 2022; Vidruska, 2016; World Bank, 2016), a consensus on a standardized measurement methodology has yet to be reached. Some indices in the literature, such as the Network Readiness Index and Digital Adoption Index, are only available as cross-sectional data sets and therefore do not permit the measurement of progress in the digital transformation of countries over a specified period. Indices such as the Digitization Index (DiGiX) and ICT Development Index (IDI) mostly focus on elements related to infrastructure and the cost of digital technologies and address the digitalization that occurs in business processes. However, these indices do not permit the evaluation of digitalization in terms of all economic actors (Bánhidi, Dobos, & Nemeslaki, 2020; Cámara & Tuesta, 2017; DESI, 2022; Korzhyk, Gomes, & João, 2024; Smallenbroek, Caperna, & Papadimitriou, 2023; Vidruska, 2016).

This study aims to assess the progress of digital transformation in OECD countries between 2010 and 2020. To achieve this, a digitalization index has been developed to comprehensively evaluate the advancement of OECD countries in the digitalization process. The index constructed in this study incorporates the main sectors of the economy: households, businesses, and the government. Therefore, this study presents a general digitalization index encompassing all actors and sub-indices for each actor.

The assessment of digitalization within the context of economic actors will facilitate a more comprehensive analysis of the impact of digitalization on socio-economic factors. However, most existing indices either focus only on technological infrastructure or measure digitalization from the perspective of a single actor, and many do not allow for temporal comparisons. These limitations prevent a holistic understanding of the digital transformation process. To address these limitations, the index developed in this study offers the following contributions to the literature: (i) it is the first digitalization index focused on OECD countries, (ii) it is the first digitalization index that shows how the digitalization levels of economic actors—households, businesses, and government—have changed over a certain period, (iii) it is a digitalization index that evaluates digitalization not only from a technological perspective but also in conjunction with economic and social factors along with technological infrastructure, and (iv) it is a panel data index that permits both the comparison of countries with each other and the tracking of each country's development over the 2010–2020 period.

The structure of this study is as follows: the second section presents the conceptual framework of digitalization. The third section emphasizes the originality of this study by examining the indices in the literature and highlighting their advantages and disadvantages. The fourth section describes the dataset characteristics and the methodology of the study. In the fifth section, the findings of the developed index

are analyzed, and the digitalization process in OECD countries is evaluated across household, business, and government dimensions. Finally, the sixth section presents the conclusions.

Literature Review

Conceptual Framework: The Concept of Digitalization

Digitalization is often considered in the context of integrating business processes with digital technologies. The first modern use of this concept in connection with information communication technologies was in 1971 by Robert Wachal in the discussion of "limitations and potentials of computer-aided research" (Schallmo & Williams, 2018). When studies in the literature are examined, it is seen that there is a conceptual confusion regarding digitalization. Accordingly, different terms such as digitization, digitalization, and digital transformation are encountered in the literature on digitalization. These terms are closely related and often used interchangeably (Brennen & Kreiss, 2016). However, some differences between these terms reveal the importance of drawing distinctions between them.

Digitization is defined as the conversion of analog data into digital forms. In other words, digitization is a unique technical process that enables the conversion of analog information streams into digital bits (Manoff, 2006). The concept of digitization, which refers to the creation of digital versions of documents, microfilm images, photographs, sounds, and other physical objects, was first introduced in the 1950s (Pearce-Moses & Baty, 2005). The concept of digitalization is explained as the adoption of digital or information communication technologies by institutions, industries, and countries and the widespread use of these technologies. Another definition of digitalization describes it as innovative business models that allow people, processes, data, and objects to interact with each other in a digital environment in the creation of outputs (Gorenšek & Kohont, 2019). Accordingly, digitalization is defined as transforming the business model within the framework of new technologies and using information technologies to create new areas that generate added value (Kavadias, Ladas, & Loch, 2016).

The restructuring of numerous areas of economic and social life using digital technologies is conceptualized as digital transformation or digitalization (Gorenšek & Kohont, 2019). Digital transformation is defined as the use of digital technologies to improve the performance of businesses (Berman, 2012). According to Butt (2020), digital transformation is defined as the use of rapidly developing and changing digital technologies to solve various problems. Mazzone (2014) defines it as the ongoing digital evolution of a business, business model, idea process, or technical method. The concept of innovation is also used when discussing the digital transformation of businesses. However, there are differences between the concepts of digital transformation and innovation. While digital transformation emphasizes a long-term process of change towards multiple goals, innovation emphasizes only the moment of invention and the process of implementation of the invention. On the other hand, there is a strong relationship between innovation and digital transformation. While Gobble (2018) states that innovation and digital transformation processes trigger each other, Ciarli et al. (2021) argue that these processes are interdependent.

As defined by Westerman et al. (2011), digital transformation is the strategic use of digital technologies to significantly enhance the efficiency of businesses and create new business opportunities. Upon examination of these definitions of digital transformation, it becomes evident that business and macroprocesses are the primary areas affected by digital transformation. However, (Henriette, Feki, & Boughzala, 2015) posit that all business processes, in addition to supporting strategies, workforce skills, organizational designs, and user experience, are also subject to the influence of digitalization. The European Commission's Digital Strategy (2022) emphasizes digital transformation and the integration of businesses with digital technologies and their societal impact. This perspective posits that digital transformation will optimize production,

reduce emissions and waste, enhance the competitive advantage of businesses, and offer new services and products to consumers (Verina & Titko, 2019).

Digital transformation is defined as a disruptive and constructive change process. The disruptive aspect of digital transformation is explained as the disappearance of some sectors and professions or the unsustainability of some business models because of radical changes in existing business models and industrial structures. The constructive aspect of digital transformation can be defined as the emergence of business models that provide a competitive advantage thanks to new technologies and digital innovations. These business models offer new opportunities to both businesses and society (Koch & Windsperger, 2017; Yoo, Henfridsson, & Lyytinen, 2010). Digital transformation is a process of restructuring that begins with the adoption and utilization of digital technologies and progresses towards the comprehensive transformation of numerous elements that enable an organization to continue creating value (Henriette et al., 2015). Although digitalization is primarily concerned with the digitization of business processes, the creation and delivery of new value for consumers that incorporate digital elements are also crucial aspects of digitalization (Schallmo & Williams, 2018). Digital transformation can result in significant alterations to business performance and output as well as to customers' perceptions of the business. As stated by Nath et al. (2020), the transformation process involves the simultaneous reconfiguration of cultural and technological changes, along with business process and business model changes.

Approaches to Measuring Digitalization

There are different approaches to measuring digitalization. One of the digitalization measures in the literature is the Digital Adoption Index (DAI) developed by the World Bank (2016). The DAI is a composite index measuring the level of diffusion of digital technologies within and across countries. Although this index shows the level of digital technology adoption in households, businesses, and government sub-dimensions, it has a significant disadvantage in that it is only available for 2016. In addition to the digitalization index developed by the World Bank, there is also an index developed by Cámara & Tuesta (2017) as part of the BBVA Research Program. This index, also referred to as DiGiX, is called the Digitization Index. DiGiX is described as a digitization index that assesses the factors, market actors, and institutions that enable a country to leverage digital technologies to increase its welfare and competitiveness. Using the two-stage principal component analysis method, this index is calculated for 99 countries in the period 2016–2022, excluding 2017 and 2021, and is only available for five years. DiGiX focuses on three dimensions: supply, demand, and regulatory conditions. Based on these three dimensions, six components are derived: infrastructure, cost, regulation, content, household, and business adoption (Cámara & Tuesta, 2017). The exclusion of human capital for digital technologies and the restriction of the temporal scope to five years (2016–2022) limit the scope of DiGiX.

The Network Readiness Index (NRI), created by the World Economic Forum, is designed to assess the preparedness of countries around the world for developments in information technologies and their use of these technologies. Calculated for 143 countries, this index is composed of four dimensions: technology, people, governance, and impact. Since its inception in 2002, the NRI has been calculated using the equal weighting method, with some indicators being measured based on the assessments of local experts. This has been criticized on the grounds that some of the variables considered for the NRI, which is calculated for many countries, may be biased (Vidruska, 2016). The most significant disadvantage of the NRI is that it provides cross-sectional data. The index data fail to reflect the dynamic progress of each country, instead merely representing its static situation at a given point in time. Consequently, the NRI is unsuitable for panel data analysis.

The DESI, or Digital Economy and Society Index, provides insight into the competitiveness of European Union countries regarding digital technologies. The 2022 methodology of this index comprises four sub-dimensions: connectivity, human capital, digital technology integration, and digital public services. The most important limitations of the index are that the weightings, indicators, and the number of sub-dimensions change from year to year and that it has been published since 2014, focusing only on European Union countries (Bánhidi et al., 2020; DESI, 2022).

The IDI, also known as the ICT Development Index, is a digitalization index reported by the ITU from 2009 to 2017. The ITU discontinued publication of the index in 2018 due to limited data availability and technical constraints. In 2022, the revised methodology was accepted by the commission, and in 2023, the index data created with the new methodology was published. Nevertheless, the index created with the new methodology was not directly comparable to the index published between 2009 and 2017. Furthermore, it is evident that data from 2020 and 2021 were used in the computation of the 2023 index. This index, which assesses the extent to which digital connectivity is universal and meaningful according to the new methodology, has two sub-dimensions: universal connectivity and meaningful connectivity. Universal and meaningful connectivity means having basic internet access and a strong connection to the internet, which is considered a human right by the United Nations and the ITU. In this respect, the index aims to measure the state of having a strong internet connection rather than to measure digitization. This is a major limitation of the IDI. The most critical disadvantages of the IDI are that the index published with the old methodology is only available for the period 2009–2017, the index published with the new methodology is only available for the year 2023, and these are not comparable data (Korzhyk et al., 2024; Smallenbroek et al., 2023).

The CISCO Digital Readiness Index, published by CISCO, a technology company, is an index that measures how ready countries are to take advantage of the benefits of future digital technologies. Calculated for 146 countries, this index consists of seven sub-dimensions. These are the basic needs, ease of doing business, start-up environment, technology infrastructure, business and government investments, human capital, and technology adoption (CISCO, 2019). On the other hand, the methodological explanations do not specify how the sub-dimensions are combined and what weighting method is used. In addition, this index was only published in 2018, 2019, and 2021. The CISCO Digital Readiness Index is considered to have two significant shortcomings. The first is the lack of methodological information, which makes it difficult to assess the reliability of the index. The second limitation is that the index is calculated for only three years, which limits its usefulness.

It is seen that many researchers have completed studies on measuring the level of digitalization. The first of these is the study conducted to determine the digitalization level of businesses in the EU-27 countries (Tutak & Brodny, 2022). The most significant limitation feature of this index developed with the Ratio Analysis (MOORA) method is that it focuses only on businesses. Due to the focus of this index on businesses, it is seen that an index that includes digital infrastructure elements has been developed while determining the level of digitalization. However, since this index is based only on data for 2020 and 2021, it does not represent the change in digitalization over time. In another study focusing on the prevalence of digital technologies, six components, namely ubiquity, affordability, reliability, speed, usability, and skill, were considered, and the digital development of countries was classified as “constrained, emerging, transitional, advanced” in the period 2000–2010 with a sample of 150 countries (Sabbagh et al., 2012).

In another study using a methodology similar to that used by Sabbagh et al. (2012), a digitalization index was developed for the period 2004–2011 by considering 184 countries (Katz, Koutroumpis, & Martin Callorda, 2014). Although it is stated in the methodologies of these indices that they focus on the economic and social dimensions of digitalization, it was seen that they mostly focus on digital infrastructure and the costs of

digital technologies from an economic perspective and focus on indicators such as GDP per capita, number of technicians, and skilled labor force from a social perspective. Although these indices have a comprehensive structure, the economic and social aspects of digitalization today include e-commerce transactions, the ICT skills of the workforce, and the prevalence of the use of these skills in business processes. When evaluated from this perspective, it was evident that both indices reflect today's developments in a limited way. In another study, the ICT exposure index, which can be characterized as limited but lean, was developed (Maiti & Awasthi, 2020). The index comprises four indicators: internet usage rate, secure internet servers, mobile cellular subscriptions, and fixed telephone subscriptions. Calculated for 67 countries from 2000 to 2014, the scope of this index is limited in terms of the indicators it includes and the fact that it has not been revised until today.

A review of the digitalization indices in the literature revealed the absence of an index that measures the level of digitalization of the three main economic actors: households, businesses, and the government in OECD countries. Such an index would allow for the comparison of the level of digitalization across countries and monitor the development of each country in the digital transformation process over a given period. This study aimed to fill this gap in the literature. Therefore, this study evaluated the digital transformation processes of OECD countries and classified them according to their digital development.

Data and Methodology

The composite index construction followed a structured, multi-step process including indicator selection, normalization, weighting, aggregation, and ranking. These methodological steps were designed in accordance with established practices in composite indicator development and aimed to ensure robustness and comparability across units. The complete set of procedures is presented in Appendix A, Table A 1 (Greco et al., 2019; Mazziotta & Pareto, 2013; OECD, 2008; Salzman, 2003).

In this study, digitalization was defined as the adoption and widespread use of digital technologies by households, businesses, and the government, which are represented as economic actors. The World Bank's Digital Adoption Index (DAI) methodology was used to construct this index (World Bank, 2016). Thus, by adopting the three-dimensional structure of the Digital Adoption Index, which is expressed as households, businesses, and the government, the aim was to determine the level of digitalization of OECD countries separately and holistically for households, businesses, and the government, which are the main economic actors.

The household sub-dimension encompasses individuals' and households' access to digital technologies and their ability to use these technologies. The business sub-dimension assesses the digital infrastructure of companies, their degree of integration of digital technologies into business processes, and their participation in digital innovations. The government sub-dimension examines the digitization of public services and the widespread use of e-government services. The objective of this index is to provide a comprehensive assessment of digital progress in the context of the three main actors of the economy and to highlight the differences in digitalization levels between countries.

In determining the indicators representing digitalization for households, businesses, and government, which are the sub-dimensions of the index to be constructed, the literature was reviewed, and the advantages and disadvantages of the indicators representing the level of digitalization of each economic actor in OECD countries were evaluated in terms of measurability, reliability, and comparability. Consequently, whether each indicator is explanatory for the digitalization phenomenon and whether the indicator expresses the level of digital progress of the economic actor in question were assessed.

In the selection process of these indicators, not only the conceptual relevance but also the empirical validity and practical applicability were considered. Each indicator was assessed through a set of guiding questions, including: "Which dimension of digitalization does it represent?", "Which functional aspect of the economic actor does it reflect?", "Is it comparable across countries and over time?", "Is it based on reliable and accessible data sources?". This multi-layered evaluation was structured around four criteria: conceptual relevance, representativeness, measurability, and comparability. All criteria are presented in Table A 2 in the Appendix.

In consideration of the availability of data on the household, business, and government sub-dimensions of digitalization in OECD countries and the objectives of each sub-dimension, 11 indicators for the household sub-dimension, eight indicators for the businesses sub-dimension, and six indicators for the government sub-dimension from 2010 to 2020 were identified. The definitions of the selected indicators and associated sub-dimensions are provided in Appendix A, Table A 3. The indicators comprise a comprehensive data set based on the OECD's "Going Digital Toolkit" project, which has been designed for the purpose of analyzing and managing the economic and social impacts of the digital transformation of OECD countries. The indicators in this dataset provide a multitude of perspectives to measure the progress in the digitalization process of OECD countries, to evaluate the effectiveness of digitalization policies, and to design future strategies for the digital economy.

Most of the indicators used in this study, as detailed in Appendix A, Table A 3, are available for 25 OECD countries[1] from 2010 to 2020. The dataset encompasses 25 OECD countries with annual data extending from 2010 to 2020. There are very few missing values in the data for the indicators to be included in the index. The missing values were estimated using the linear interpolation method. As the OECD provides the data on indicators in percentage form, there is no requirement for the data to be normalized.

In this study, equal weighting and linear aggregation methods, which are also employed in the Digital Adoption Index methodology developed by the World Bank (2016), were used. The equal weighting method has been widely accepted in the literature due to its simplicity and objective perspective (Bandura, 2008; Chowdhury & Squire, 2006; Katz et al., 2014; OECD, 2008; World Bank, 2016). The basic principle of the equal weighting method is that the individual indicators that comprise the index contribute equally to the overall value of the index. The linear aggregation method is aligned with the equal weighting method, thereby establishing a structure in which each indicator exerts an equal impact on the index value. These methodologies treat each indicator as equally important and impactful, thereby increasing the transparency of results while minimizing the subjective effects of the methodological process.

While determining the digitalization levels of OECD countries is critical, it is equally important to classify these countries according to their digitalization progress. This classification enables the identification of countries exhibiting comparable digitalization patterns and the characterization of these groups. Therefore, this study uses cluster analysis to understand the digitalization patterns in OECD countries.

Cluster analysis is a statistical analysis that groups data points with similar characteristics into homogeneous clusters. This technique is generally used to understand patterns and relationships in a data set, discover hidden structures within the data, and classify data points according to certain criteria. Cluster analysis is classified into two categories: hierarchical and non-hierarchical. Hierarchical clustering analysis involves grouping data points into a tree structure and proceeds with aggregation or disaggregation steps

[1]Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, France, Germany, Greece, Hungary, Hungary, Iceland, Iceland, Italy, Latvia, Latvia, Lithuania, Lithuania, Norway, Poland, Portugal, Slovakia, Slovakia, Slovenia, Slovenia, Spain, Sweden, the Netherlands, the United Kingdom and Turkiye.

based on a similarity measure. Non-hierarchical cluster analysis groups data points according to a specified number of clusters (Pérez-Ortega et al., 2019).

This study used the K-means method for non-hierarchical cluster analysis. This method randomly assigns data points to clusters and then reassigns each data point to the nearest cluster center. These steps are iteratively repeated to optimize the cluster centers (Pérez-Ortega et al., 2019). The most important stage of clustering analysis is to determine the optimal number of clusters. The most widely used method for determining the number of clusters is the elbow method. In this method, the k-means algorithm is applied for each cluster number and WCSS (within clusters sum of square) are calculated for each clustering. Thus, the number of clusters is determined by examining the elbow formed in the graph where WCSSs are shown according to the number of clusters (Wierzchoń & Kłopotek, 2018).

Results

Findings of the Composite Index

The digitalization index constructed in this study is called the Digital Progress Index (DPI). The sub-dimensions expressed as households, businesses, and government are sub-indices of the DPI. Accordingly, these sub-dimensions are called the Household Digital Progress Index (HDPI), Business Digital Progress Index (BDPI), and Government Digital Progress Index (GDPI).

Figure 1 shows the annual DPI values calculated for each OECD country between 2010 and 2020.

Figure 1

Digital Progress Index (DPI) for OECD Countries, 2010–2020.

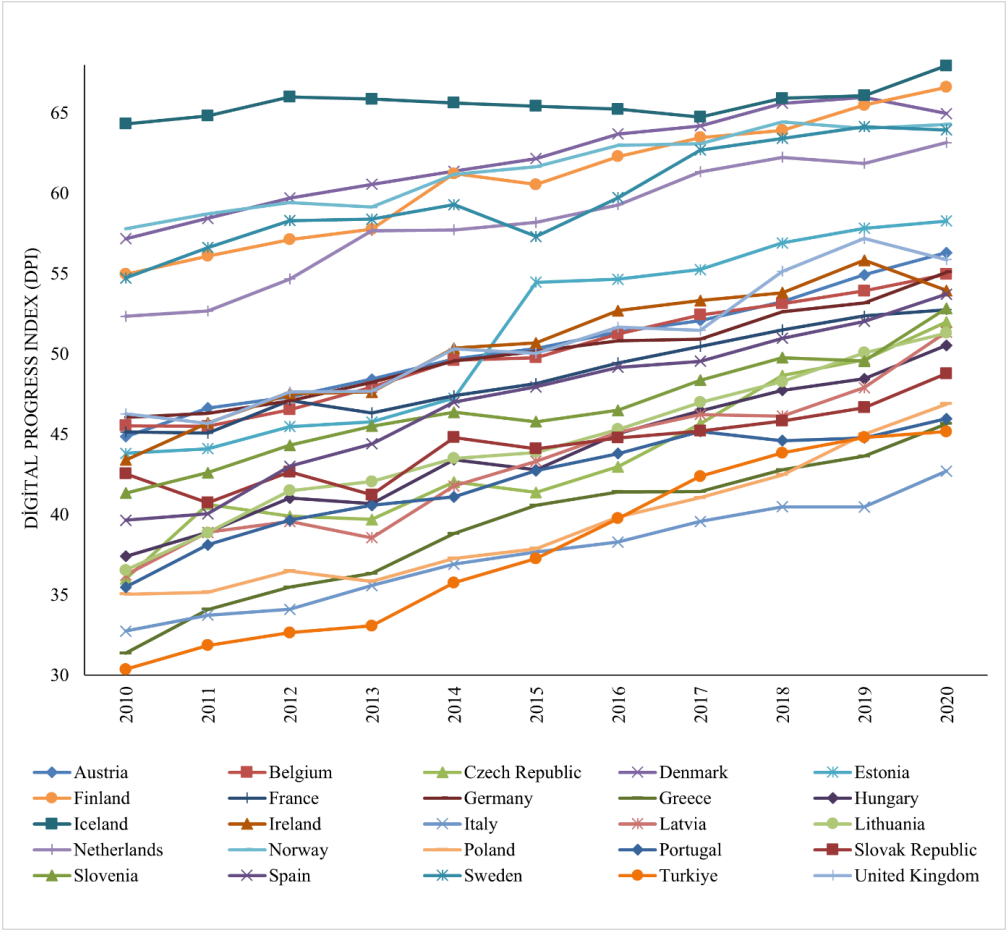
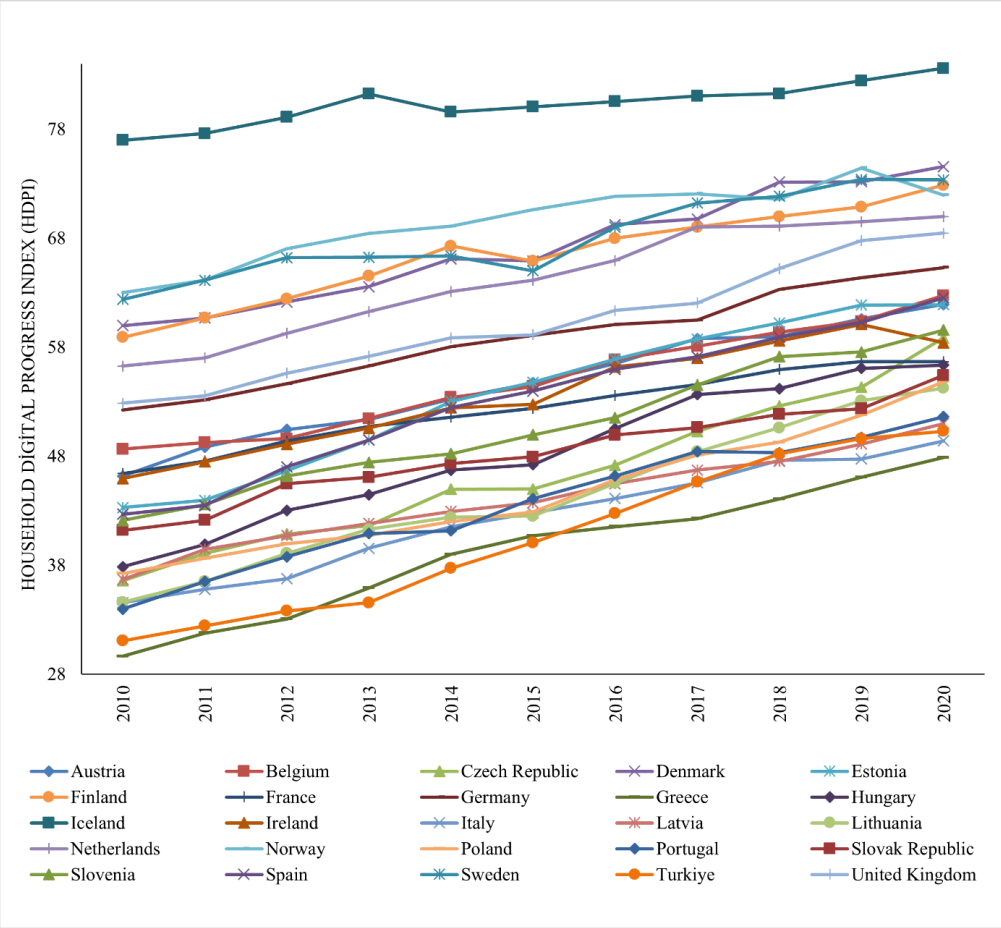


Figure 1 shows a consistent upward trend in digitalization levels among most OECD countries over the observed period. The average DPI increased from 43.6 in 2010 to 54.6 in 2020, indicating notable progress in digital transformation during the past decade. Nevertheless, the level and pace of this progress differ considerably across countries. Iceland, Finland, Denmark, Norway, and Sweden exhibit sustained performance in digital development, maintaining leading positions across a range of digital indicators. In contrast, countries such as Italy, Turkiye, Greece, Portugal, and Poland displayed lower overall scores but a steady improvement over time. These findings show that digital transformation does not evolve uniformly across the OECD, emphasizing the persistence of the digital divide.

Figure 2

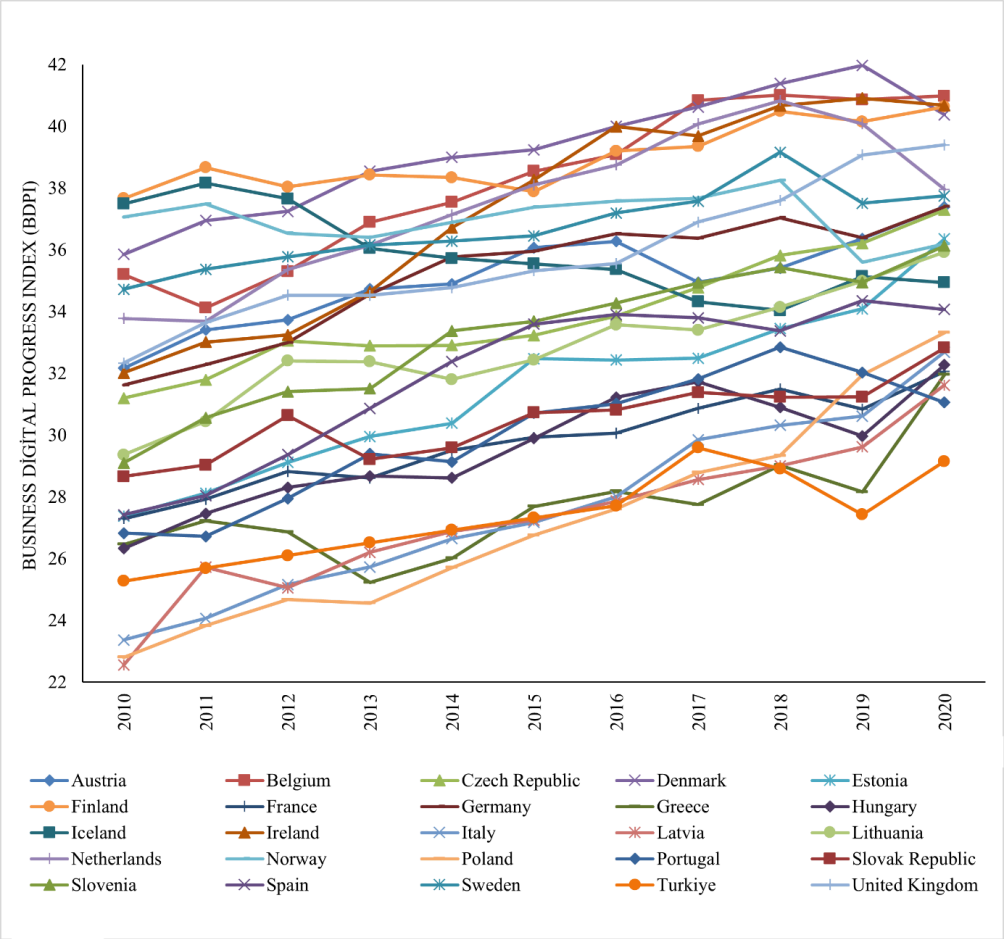
Household Digital Progress Index (HDPI) for OECD Countries, 2010–2020



Household-level digitalization increased significantly across the OECD countries between 2010 and 2020. Over this period, the average HDPI rose by approximately 15 points, from 46.1 to 61.3. Countries such as Iceland, Denmark, Sweden, Finland, and Norway consistently recorded the highest HDPI values, reflecting strong performance in areas such as digital access, individual digital skills, and internet usage. In contrast, countries including Greece, Italy, Turkiye, Latvia, and Portugal started from lower digitalization levels of household but exhibited steady improvement throughout the decade. This trend indicates that while digital technologies have become more widespread among households, the digital divide continues to persist within parts of the OECD.

Figure 3

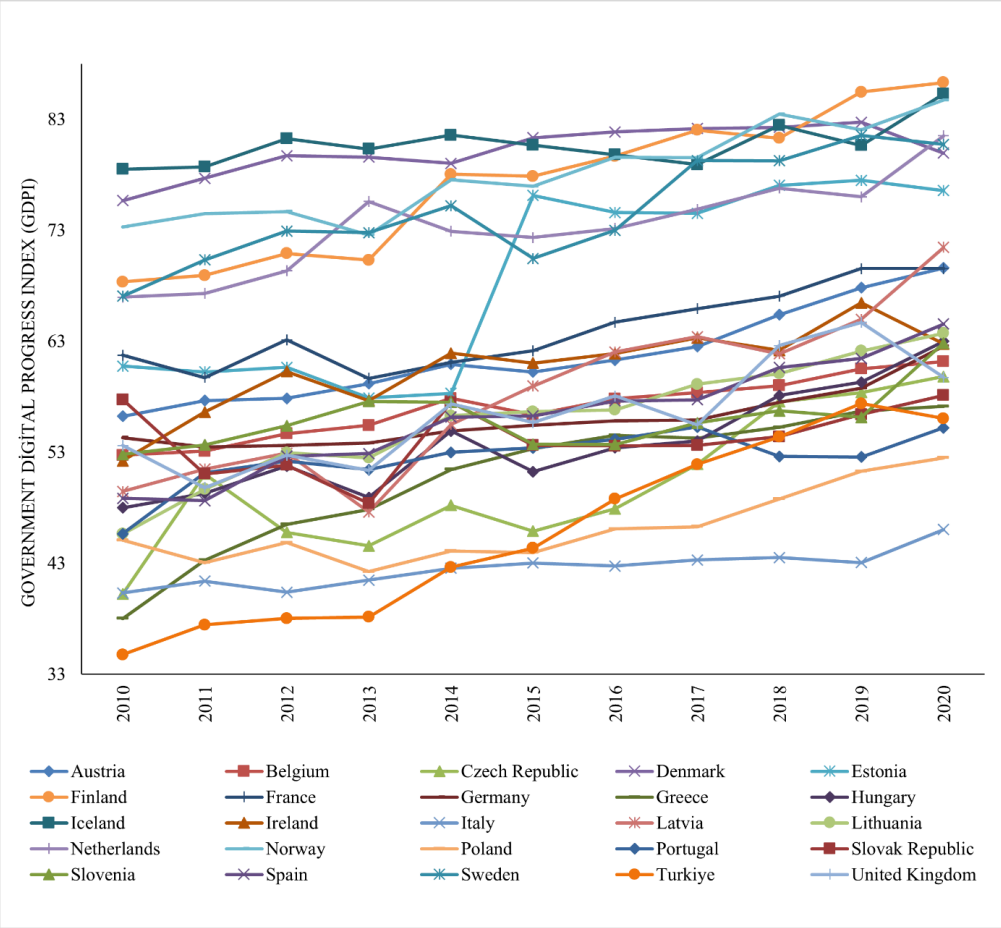
Business Digital Progress Index (BDPI) for OECD Countries, 2010–2020



Business-level digitalization showed a limited yet steady increase across OECD countries between 2010 and 2020. During this period, the average BDPI rose from 30.2 to 35.6. Countries such as Belgium, Ireland, Finland, Denmark, and the United Kingdom recorded the highest scores, indicating their advanced position in digital business processes, the use of digital tools, and technology integration. In contrast, countries including Turkiye, Portugal, Latvia, Greece, and France remained at relatively lower levels. Nonetheless, these countries also demonstrated a consistent upward trend over the past decade. These findings show that business digitalization has progressed more slowly compared to household or government sectors, and that sectoral dynamics play a key role in shaping the digital divide among countries.

Figure 4

Government Digital Progress Index (GDPI) for OECD Countries, 2010–2020.



Government-level digitalization increased significantly across the OECD countries. During this period, the average GDPI rose from 54.7 to 66.8 between 2010 and 2020. Countries such as Finland, Iceland, Norway, the Netherlands, and Sweden recorded the highest values, indicating their advanced position in e-government services, digital public administration, and online citizen engagement. In contrast, countries including Italy, Poland, Portugal, Turkiye, and Greece remained at lower levels, yet demonstrated steady improvement over the decade. These findings show that while public sector digitalization has progressed across the OECD, disparities between countries continue to persist.

The descriptive statistics of the variables included in the index are presented in Appendix A, Table A 4. The descriptive statistics of the variables in the household sub-dimension indicated that, on average, 80.1% of all OECD households had a personal computer from 2010 to 2020. Additionally, 37.1% of households had broadband subscriptions, of which 37.1% were mobile and 69.5% were fixed. In OECD countries, 80.5% of the total population used a computer in the last 12 months, and 82.2% used the internet in the last 12 months. The share of those using the internet to access social media platforms was 53.6%, on average. While the proportion of individuals who regularly utilize a computer for work-related tasks was 58.8%, on average, the proportion of those who employed a computer with internet access for work-related activities was 51.2%, on average, and the proportion of individuals who utilized an internet-enabled portable device for work-related purposes was 25.7%, on average, in OECD countries. The average proportion of the total population with the requisite skills to find, download, and upload written material from the internet was 46.4%. Additionally, 8.5% of the total population possessed coding skills.

The descriptive statistics of the variables in the business sub-dimension indicated that 22.5% of businesses in OECD countries provide ICT training to their employees, 8.3% offer ICT specialist positions, 75.9% of businesses in OECD countries have a website or homepage, 18.6% have a download speed of 30-100 Mbit/s, and 94% have broadband subscriptions, both fixed and mobile, on average, in 2010-2020. When considering the e-commerce-related indicators of businesses, it was observed that 17.2% of businesses in OECD countries received orders through e-commerce from 2010 to 2020. Furthermore, the turnover obtained from e-commerce transactions constituted 6.1% of the total turnover of businesses on average.

The descriptive statistics of the variables in the government sub-dimension indicated that 55.5% of all households and 91.1% of all businesses in OECD countries utilized the Internet to interact with public authorities from 2010 to 2020. During this period, 34% of internet users in OECD countries utilized e-government services to download official forms, 36.1% to send official forms, and 49.4% to receive information. Conversely, on average, 96.5% of internet users in OECD countries did not encounter a lack of skills when using e-government services.

The descriptive statistics of the HDPI as a sub-dimension of the DPI are presented in Table 1.

Table 1

Descriptive Statistics of the Household Digital Progress Index for OECD Countries

Countries	Mean	Std. Dev.	Min.	Max.
Iceland	80.3	2	77	83.6
Norway	69.5	3.5	63	74.4
Sweden	68.1	3.8	62.4	73.4
Denmark	67.1	5.2	60	74.6
Finland	66.4	4.4	58.9	72.9
Netherlands	64.1	5.1	56.3	70
United Kingdom	60.2	5.4	52.9	68.5
Germany	58.8	4.4	52.2	65.3
Belgium	54.9	4.9	48.6	62.7
Austria	54.7	5.1	46.2	61.9
Estonia	53.7	7	43.3	61.9
Ireland	53.5	4.9	46	60.1
Spain	53.1	6.7	42.7	62.5
France	52.3	3.6	46.4	56.7
Slovenia	50.7	5.9	42.1	59.6
Hungary	48.2	6.5	37.9	56.4
Slovak Republic	48.2	4.4	41.2	55.4
Czech Republic	46.5	6.9	36.6	58.9
Poland	44.7	5.7	37.2	54.8
Lithuania	44.4	6.6	34.6	54.3
Latvia	44.1	4.3	36.7	51
Portugal	43.6	5.8	34	51.6
Italy	42.3	5.1	34.6	49.4
Turkey	40.6	7.2	31.1	50.3
Greece	39.3	6	29.6	47.9

As indicated in Table 1, the OECD countries with the highest average level of digitalization in the household sub-dimension are Iceland, Norway, Sweden, Denmark, and Finland. The high levels of digitization observed in the household sub-dimension in these countries indicate that significant progress has been achieved in the integration of technology and the development of digital infrastructure. These developments are evident in various fields, including households' access to technology, the use of technology by individuals in their daily and professional lives, and the development of digital skills. The widespread use of computers and internet access in households, the use of mobile devices, and high rates of internet and social media use indicate that individuals in these countries lead a life integrated into the digital world. Furthermore, the widespread use of digital technologies in business contexts provides evidence that these countries' education systems are also adapting to the digital age.

According to Table 1, the OECD countries with the lowest average level of digitalization in the household sub-dimension are Greece, Turkiye, Italy, Portugal, and Latvia. The low level of digitization in the household sub-dimension in these countries indicates that households are disadvantaged in various fields, including education, health, and the labor market. The absence of access to digital technologies can impede learning opportunities, particularly in the field of education, and prevent individuals from acquiring and developing the skills required by the modern world. The absence of digital integration within households can be reflected in labor markets, resulting in a gap of skilled labor or difficulties in adapting to digitalized business systems. To enhance households' capacity to adapt to digital technologies, it is necessary to implement digital literacy initiatives, enhance digital infrastructure, and expand access to digital technologies in these countries.

The descriptive statistics of the BDPI, a sub-dimension of the DPI, are presented in Table 2.

Table 2

Descriptive Statistics of the BDPI for OECD Countries

Countries	Mean	Std. Dev.	Min.	Max.
Denmark	39.2	1.9	35.9	42.0
Finland	39.0	1.1	37.7	40.6
Belgium	38.2	2.6	34.1	41.0
Netherlands	37.4	2.5	33.7	40.8
Ireland	37.3	3.5	32.0	40.9
Norway	37.0	0.8	35.6	38.2
Sweden	36.7	1.3	34.7	39.2
Iceland	35.9	1.4	34.0	38.2
United Kingdom	35.8	2.2	32.3	39.4
Germany	35.2	2.0	31.6	37.4
Austria	35.0	1.5	32.2	37.4
Czech Republic	33.9	1.9	31.2	37.3
Slovenia	33.2	2.3	29.1	36.1
Lithuania	32.8	1.9	29.4	35.9
Spain	31.9	2.6	27.4	34.4
Estonia	31.5	2.7	27.4	36.4
Slovak Republic	30.5	1.2	28.7	32.8
Portugal	30.0	2.1	26.7	32.8
France	29.8	1.5	27.3	32.1

Countries	Mean	Std. Dev.	Min.	Max.
Hungary	29.6	1.9	26.3	32.3
Greece	27.7	1.8	25.2	32.0
Italy	27.6	3.0	23.4	32.7
Latvia	27.3	2.5	22.6	31.6
Turkey	27.3	1.4	25.3	29.6
Poland	27.2	3.4	22.8	33.3

As indicated in Table 2, the OECD countries with the highest average digitalization level in the business sub-dimension are Denmark, Finland, Belgium, the Netherlands, and Ireland. This indicates that businesses in these countries adapt to technological developments rapidly and effectively. The high levels of digitalization in the business sub-dimension in these countries are an indicator of the capacity of businesses to adopt and integrate digital technologies. In these countries, both the digital skills training provided to employees and the increase in the employment of IT specialists facilitate the adaptation of the workforce to the requirements of the digital age, increase the competitiveness of businesses, and enable them to use digital technologies more effectively. In countries with developed digital infrastructures and easy access to digital technologies, fast communication, effective data management, and analysis enable businesses to adapt to new markets faster and develop innovative solutions. On the other hand, in countries with a high level of digitalization at the business sub-dimension, the fact that most businesses have digital assets such as websites strengthens their competitive opportunities in global markets by increasing their visibility in digital environments. The widespread use of e-commerce indicates the fact that these businesses have developed sophisticated digital marketing and online sales strategies. This simultaneously facilitates businesses' access to new markets and increases the opportunity to communicate directly with consumers.

According to Table 2, the OECD countries with the lowest average level of digitalization in the business sub-dimension are Poland, Latvia, Turkiye, Italy, and Greece. The low level of digitalization in the business sub-dimension in these countries reflects the challenges faced by the business sector in the process of digital transformation and technological integration. Limited infrastructure and access to digital technologies constrain businesses in these countries. Therefore, it is of paramount importance to increase infrastructure investments in digital technologies to enhance the efficiency of businesses' online operations. In addition, there is a need to enhance the digital skills of employees, to employ IT specialists, and to enhance the digital visibility of businesses. In fact, in today's digital economy, these have become necessities rather than needs. The integration of business processes with digital technologies and the employment of individuals who can use these technologies effectively represent critical elements of competitiveness in the digital economy.

The descriptive statistics of the GDPI, a sub-dimension of the DPI, are presented in Table 3.

Table 3

Descriptive Statistics of the GDPI for OECD Countries

Countries	Mean	Std. Dev.	Min.	Max.
Iceland	80.7	2.0	78.5	85.3
Denmark	80.2	2.2	75.7	82.7
Norway	78.1	4.2	72.6	84.7
Finland	77.2	6.6	68.3	86.3
Sweden	74.8	4.8	67.1	81.6
Netherlands	73.4	4.3	67.0	81.5
Estonia	68.6	8.7	57.9	77.5

Countries	Mean	Std. Dev.	Min.	Max.
France	64.0	3.6	59.7	69.5
Austria	61.7	4.3	56.2	69.6
Ireland	60.6	3.8	52.2	66.5
Latvia	58.2	7.4	47.6	71.5
Belgium	57.0	2.8	52.7	61.2
United Kingdom	56.5	4.6	49.8	64.7
Spain	56.1	5.1	48.6	64.6
Germany	56.0	2.7	53.5	62.6
Lithuania	56.0	5.4	45.6	63.7
Slovenia	56.0	2.8	52.8	62.8
Slovak Republic	54.2	3.1	48.4	58.1
Hungary	53.8	4.7	48.0	63.0
Portugal	52.4	2.6	45.7	55.3
Greece	50.8	6.1	38.0	57.1
Czech Republic	50.1	6.3	40.2	59.8
Poland	46.2	3.3	42.2	52.5
Turkey	45.8	8.3	34.8	57.4
Italy	42.5	1.6	40.3	46.0

As indicated in Table 3, the OECD countries with the highest average level of digitalization in the government sub-dimension are Iceland, Denmark, Norway, Finland, and Sweden. The high level of digitalization in the government sub-dimension in these countries indicates that the digital transformation of public services has been successfully realized and that citizens and businesses have effective access to digital public services. The prevalence of internet use by individuals and businesses in their interactions with public authorities in these countries reflects the ease of use and accessibility of e-government services. In these countries, the ease of interacting with public officials online indicates that digital technologies are used effectively in public services and that citizens have high levels of digital literacy. The widespread use of e-government services facilitates access to public services and saves time. E-government services, on the one hand, increase the efficiency and effectiveness of the services provided by the state to its citizens and, on the other hand, reduce inequalities in access to public services and support a more transparent governance approach.

According to Table 3, the OECD countries with the lowest average digitalization level in the government sub-dimension are Italy, Turkiye, Poland, the Czech Republic, and Greece. The fact that these countries have low digitization levels in the government sub-dimension indicates that there are some challenges in the digitalization of public services and the integration of e-government applications. The lack of widespread use of e-government services is often attributed to deficiencies in digital literacy and infrastructure. Insufficient adoption of digital technologies in public services may limit the efficiency of public services. In these countries, ensuring the integration of public services with digital technologies and increasing digital infrastructure investments and digital literacy have the potential to increase the accessibility of public services, reduce inequalities in public services, and support transparent governance.

The descriptive statistics of the DPI are presented in Table 4.

Table 4

Descriptive Statistics of the DPI for OECD Countries

Countries	Mean	Std. Dev.	Min.	Max.
Iceland	65.6	1.0	64.3	67.9
Denmark	62.2	3.0	57.2	66.0
Norway	61.5	2.4	57.8	64.4
Finland	60.9	3.9	55.0	66.6
Sweden	59.9	3.2	54.7	64.1
Netherlands	58.3	3.8	52.3	63.2
Estonia	51.3	5.9	43.8	58.3
United Kingdom	50.8	3.9	45.7	57.2
Austria	50.5	3.5	44.9	56.3
Ireland	50.4	3.9	43.4	55.8
Belgium	50.1	3.4	45.5	55.0
Germany	50.0	2.9	46.1	55.1
France	48.7	2.8	45.1	52.8
Spain	47.0	4.7	39.6	53.7
Slovenia	46.6	3.3	41.3	52.8
Lithuania	44.4	4.6	36.5	51.3
Slovak Republic	44.3	2.4	40.7	48.8
Hungary	43.9	4.2	37.4	50.5
Czech Republic	43.5	4.9	36.0	52.0
Latvia	43.2	4.6	36.2	51.4
Portugal	42	3.3	35.5	46
Poland	39.4	4.1	35	46.9
Greece	39.2	4.4	31.4	45.7
Turkey	37.9	5.6	30.4	45.2
Italy	37.5	3.2	32.7	42.7

As indicated in Table 4, Iceland, Denmark, Norway, Finland, and Sweden are the OECD countries with the highest average values of the DPI, encompassing the sub-dimensions of household, business, and government, from 2010 to 2020. The high overall level of digitalization in these countries indicates that the integration of digital technologies in household, business, and government sub-dimensions has been achieved effectively. It is evident that these countries have successfully implemented their digital transformation strategies and effectively utilized the opportunities offered by digital technologies, thereby demonstrating a clear understanding of the potential benefits of digital technologies and their effective integration into national strategies. The high levels of digitalization in these countries also indicate the effective use of digital technologies in the household, business, and government sub-dimensions and the spread of these technologies to many areas of daily life. This indicates that these countries possess notable advantages in areas such as economic development, social inclusion, and the efficiency of public services.

As shown in Table 4, the OECD countries with the lowest average values from 2010 to 2020 according to the DPI are Italy, Turkiye, Greece, Poland, and Portugal, respectively. The low overall level of digitalization in these countries indicates the challenges in integrating digital technologies in the household, business, and government sub-dimensions. The lack of adequate digital infrastructure, limited access to digital

technologies, and the underdeveloped digital skills of individuals in these countries indicate that digital technologies are not being utilized effectively in daily life, business, and public service. It is posited that this situation negatively impacts the competitiveness of countries in the global economy, reduces the standard of living of citizens, and increases inequalities. Furthermore, the lack of digitalization represents a potential impediment to sustainable development and social integration.

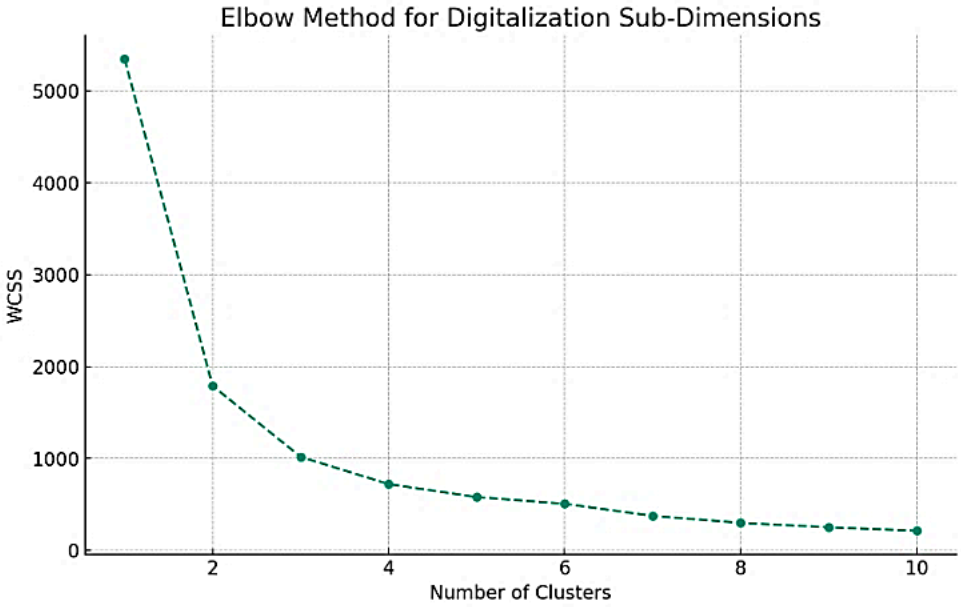
Cluster Analysis: Digitalization Patterns of OECD Countries

A cluster analysis was employed to conduct a comprehensive examination of the digitalization process occurring in OECD countries, based on the sub-dimensions of households, business, and government. The values of HDPI, BDPI, and GDPI, which are the sub-dimensions of DPI for OECD countries, for 2020 are considered. In the initial stage of the cluster analysis, the data is normalized both for the visualization of the clusters and for ease of comparison. For this purpose, z-score normalization is employed for the DPI. Consequently, the elbow method is employed to ascertain the optimal number of clusters for normalized index data with a mean of zero and a standard deviation of one.

The WCSS values according to the number of clusters for HDPI, BDPI, and GDPI, which are sub-dimensions of DPI, are shown in Figure 5.

Figure 5

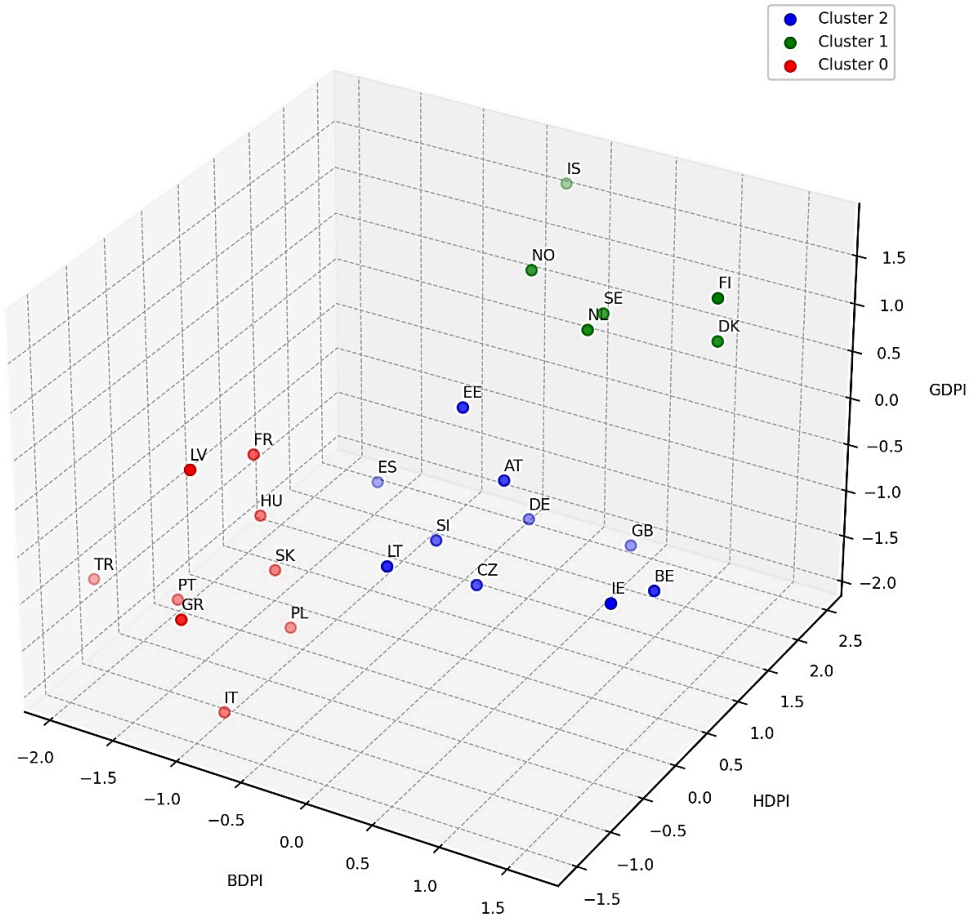
Elbow Method for Optimal Number of Clusters



The determination of the optimal number of clusters, considering the characteristics of the dataset and the objectives of the analysis, represents a critical stage in the cluster analysis process. Figure 5 illustrates that the elbow point is at WCSS = 3. Consequently, the number of clusters is determined to be k = 3. The 3D plot of the clusters obtained using the k-means method for k = 3 is shown in Figure 6.

Figure 6

3D plot of normalized HDPI, BDPI and GDPI



The 3D plot in Figure 6 clearly shows the clusters of OECD countries according to their normalized HDPI, BDPI, and GDPI values. The descriptive statistics of the clusters obtained using the k-means method for k = 3 are presented in Table 5.

Table 5

Descriptive Statistics of the Clusters

	BDPI				HDPI				GDPI			
	Mean	**Min.**	**Max.**	**Std. Dev.**	**Mean**	**Min.**	**Max.**	**Std. Dev.**	**Mean**	**Min.**	**Max.**	**Std. Dev.**
Cluster 0	−1.12	−1.94	−0.69	0.37	−0.97	−1.49	−0.52	0.36	−0.73	−1.89	0.42	0.73
Cluster 1	0.71	−0.20	1.51	0.67	1.44	0.96	2.46	0.53	1.48	1.19	1.77	0.24
Cluster 2	0.58	−0.47	1.61	0.66	0.00	−0.79	0.79	0.43	−0.23	−0.64	0.89	0.47

As indicated in Table 5, the lowest values for HDPI, BDPI, and GDPI are observed in the OECD countries belonging to Cluster 0. These countries include France, Greece, Hungary, Italy, Latvia, Poland, Portugal, Slovakia, and Turkiye. Consequently, the countries in Cluster 0 are identified as “less developed countries in terms of digitalization.” This indicates that the digitalization of households, businesses, and public services in these countries is relatively underdeveloped. These countries exhibit limitations in several key areas, including households’ access to digital devices, internet usage, and access to social media platforms; businesses’ digital skills development training, employment of ICT experts, and broadband internet speeds;

and the interaction of public services over the internet and use of e-government services. Accordingly, countries in Cluster 0 still have important steps to take towards digital transformation. These steps include increasing households' and businesses' access to and use of digital technologies, designing training programs to improve digital skills, and establishing projects to digitize public services and expand the use of e-government services. such developments will contribute to the economic and social development of less developed countries in terms of digitalization by accelerating their digital transformation.

According to Table 5, the OECD countries in Cluster 1 have the highest values, particularly for HDPI and GDPI. These countries are Denmark, Finland, Iceland, the Netherlands, Norway, and Sweden. Accordingly, the countries in Cluster 1 are identified as "developed countries in terms of digitalization." The high HDPI and GDPI values of these countries indicate that households and public services are highly digitalized. This is indicated by the pervasiveness of broadband internet access; the extensive use of the internet, social media, and e-government services; and the straightforward accessibility of digital services within society. The fact that countries in this group have achieved these high levels of digitalization indicates that they have made significant investments in digital infrastructure and integrated digital technologies into many aspects of daily life. In addition, countries within Cluster 1 accord a high degree of importance to the development of digital skills and the implementation of digital education programs. Such training programs facilitate economic growth, innovation, and competitiveness by enhancing the capacity of businesses and individuals to use digital technologies. The designation of these countries as developed in terms of digitalization indicates that they exemplify innovation and technological leadership. Their digitalization strategies offer successful practices that can serve as benchmarks for other countries to emulate.

The countries in Cluster 1 exhibit lower BDPI values compared with HDPI and GDPI. This indicates that businesses in these countries are less advanced in adopting and integrating digital technologies than households and the public sector. However, "lower" does not imply that the businesses of these countries are not advanced in terms of digitalization, as these countries have generally achieved high levels of digitalization. This reflects the specific challenges that businesses face in digital transformation or specific sectoral dynamics. The digital transformation of businesses not only strengthens the technological infrastructure but also re-shapes business models, organizational structures, and market approaches. In this context, the challenges for businesses to adopt and implement digital technologies require not only technical investments but also efforts to improve the skills of the workforce, foster innovative business models, and promote digital culture. This observation indicates potential avenues for further advancement of the digitalization process in the business sector of the countries in Cluster 1.

As indicated in Table 5, the OECD countries in Cluster 2 exhibit mid-level values for HDPI, BDPI, and GDPI. These countries are Austria, Belgium, Czechia, Estonia, Germany, Ireland, Lithuania, Slovenia, Slovenia, Spain, and the United Kingdom. Accordingly, the countries in Cluster 2 are identified as "developing countries in terms of digitalization." It is evident that these countries have made significant progress in their digitalization processes. However, there remain areas for further improvement compared to the leading countries in digitalization. The categorization of countries in Cluster 2 as "developing countries in terms of digitalization" shows that these countries possess a significant capacity to accelerate digital transformation and further advance their digitalization processes. It is evident that for these countries to advance their levels of digitalization, they must prioritize increasing investments in digital infrastructure, developing digital skills training programs, and fostering innovative digital services. Furthermore, they can facilitate this process by promoting the broader use of digital technologies and integrating digital transformation strategies across all economic and social sectors.

Conclusion and Discussion

The process of digitalization has a profound impact on numerous aspects of societies and economies. The advent of digitalization has provided an avenue for the emergence of innovative processes, the evolution of new forms of labor division, and the transformation of business models within the context of societal and economic actors. As a result, digitalization has become a key factor for individuals, businesses, and governments. Given the pivotal role of digitalization, it is imperative to evaluate this phenomenon through quantitative data.

This study proposes a composite index to assess the phenomenon of digitalization. Digitalization is defined as the adoption and widespread use of digital technologies by households, businesses, and the state, which are considered the main actors of the economy. The DPI, or Digitalization Progress Index, is calculated from 2010 to 2020 and includes data from OECD countries. The principal limitation of the DPI is that most variables included in this index are limited to data collected for OECD countries. Consequently, the index is not calculable for other countries, given the current databases. In contrast, the absence of scaling or normalization in the index calculation process ensures that the published index values will remain unaltered when calculating the updated index values in the future. In this regard, it is a significant advantage that the DPI is an index that will be calculated and kept updated for future periods.

A cluster analysis was conducted using the DPI for OECD countries. The results of the cluster analysis classified OECD countries as underdeveloped, developing, and developed in terms of digitalization based on the index values in 2020. According to this classification, the following countries are classified as "developed in terms of digitalization": Denmark, Finland, Iceland, the Netherlands, Norway, and Sweden. The following countries are classified as "developing in terms of digitalization": Austria, Belgium, the Czech Republic, Estonia, Germany, Ireland, Lithuania, Slovenia, Spain, and the United Kingdom. Finally, the following countries are classified as "less developed in terms of digitalization": France, Greece, Hungary, Italy, Latvia, Poland, Portugal, Slovakia, and Turkiye. The use of this classification in future studies is of particular importance for understanding the socioeconomic impacts of digitalization and for the design of policies to manage the effects of digital transformation.

The index proposed in this study and the classification of digital development obtained through cluster analysis can be used in future research to comprehensively study the effects of digitalization. In future research, a more in-depth examination of the effects of digitalization on social and economic transformations will provide valuable insights for policymakers. An investigation into the long-term effects of digital technologies on education, health, the environment, and social inequalities will contribute to an understanding of the multifaceted dimensions of digital transformation.

Further research could examine the relationship between DPI trends and macroeconomic variables, including employment, innovation and productivity, for countries across different digital development groups. Furthermore, while this study concentrated exclusively on OECD countries, it is possible to adapt this methodology to non-OECD economies or at the regional level to investigate within-country digital divides. Finally, although beyond the scope of this study, future research could also use time series econometric techniques such as impulse-response analysis in a VAR framework. Such methods can reveal causal relationships between digitalization and macroeconomic indicators, provided that the necessary data structure is available.

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Appendix | Ek

Table A 1

Steps for Constructing a Composite Index

Step	Description
Theoretical Framework and Defining the Phenomenon	In this step, the phenomenon, which is multidimensional and complex in structure, is defined and its scope and limitations are determined. Once the phenomenon to be measured is defined, the sub-dimensions are determined according to the theoretical framework of the phenomenon.
Selection of the Indicators	In this step, indicators representing the phenomenon and its sub-dimensions are selected. When assessing these indicators, factors such as analytical robustness, relevance to the phenomenon being studied, and data availability are considered. The descriptive statistics of the indicators were examined to evaluate the strengths and weaknesses of each indicator. This process enables the identification of variables to be included in the analysis.
Data Collection and Treatment	In this step, data for the indicators to be included in the index are collected. Once the data are collected, the missing values and the data treatment method are determined. The commonly used data treatment methods are mean, median or mode imputation, regression analysis, and linear and non-linear interpolation.
Normalization of Indicators	In this step, one of the normalization methods needs to be applied to include variables with different units of measurement in the index. Commonly used normalization methods are ranking, z-score normalization, min-max transformation, and distance to the reference point. Which normalization method is used depends on the properties of the dataset and the objectives of the composite index.
Weighting and Aggregation	In this step, the method of weighting and aggregation of the variables is determined. Although there are various weighting methods, the commonly used methods are equal weighting, factor analysis, principal component analysis, and heuristic weighting. Once the weights are determined, one of the aggregation methods expressed as linear, geometric, and multi-criteria is selected. The advantages and disadvantages of both the weighting and aggregation methods are evaluated by considering the theoretical framework and the characteristics of the dataset.
Calculation of the Rankings	In this step, the index value is calculated according to the determined weight and aggregation methods, and the ranks of the units for which the index value is calculated are determined.
Interpretation & Visualization	In this step, the index is interpreted and visualized. In addition, techniques such as cluster analysis are used to classify the data.

Table A 2

Criteria Used in the Selection of Digitalization Indicators

Criterion	Questions
Conceptual Relevance	Does the indicator represent a specific dimension of digitalization? Is it related to core aspects such as access, usage, or skills? Does it reflect meaningful progress in digitalization?
Representativeness	Does the indicator capture a key function of the economic actor? Is it aligned with the specific objectives of the sub-dimension? Is the indicator relevant to the digital practices or activities of the actor in question?
Measurability and Reliability	Is the data regularly reported? Is it available over the period 2010–2020? Does the indicator rely on reliable and available data sources?
Comparability and Applicability	Is the indicator available for most OECD countries? Can it be used for valid cross-country comparisons? Is the indicator compatible with the empirical scope and structure of the index?

Table A 3
Definition of the Variables

Sub-dimension	Variable	Definition
Household	household_1	Share of households with at least one working personal computer at home (% of all households)
	household_2	Share of households with mobile broadband internet access at home (% of all households)
	household_3	Share of households with fixed broadband internet access at home (% of all households)
	household_4	Share of individuals who used a computer in the last 12 months (% of total population)
	household_5	Share of individuals who used the internet in the last 12 months (% of total population)
	household_6	Share of individuals who used the internet to access social media platforms in the last three months (% of total population)
	household_7	Share of individuals who regularly use computers at work (% of total employment)
	household_8	Share of individuals using a computer with internet access at work (% of total employment)
	household_9	Share of individuals using internet-enabled portable devices at work (% of total employment)
	household_10	Share of people who found, downloaded, and installed software from the internet in the last 12 months (% of total population)
	household_11	Share of individuals who coded using a specific programming language in the last 12 months (% of total population)
Household	business_1	Share of businesses providing training to develop skills related to digital technologies to people employed in the last 12 months (% of businesses with 10 or more employees)
	business_2	Share of businesses offering ICT specialist positions in the last 12 months (% of businesses with 10 or more employees)
	business_3	Share of businesses employing IT specialists in the last 12 months (% of businesses with 10 or more employees)
	business_4	Share of businesses with a website or homepage (% of businesses with 10 or more employees)
	business_5	Share of businesses with broadband download speeds of at least 30 Mbit/s and at most 100 Mbit/s (% of businesses with 10 or more employees)
	business_6	Share of businesses with broadband connection, both fixed and mobile (% of businesses with 10 or more employees)
	business_7	Share of total business turnover—excluding VAT—from orders received over the internet in the last 12 months (% of businesses with 10 or more employees)
	business_8	Share of businesses that received orders over the internet in the last 12 months (% of businesses with 10 or more employees)
Government	goverment_1	Share of businesses using the internet to interact with public authorities in the last 12 months (% of businesses with 10 or more employees)
	goverment_2	Share of individuals who used the internet to interact with public authorities in the last 12 months (% of internet users)
	goverment_3	Share of individuals who used the internet in the last 12 months to download official forms from government or public service websites (% of internet users)

Sub-dimension	Variable	Definition
	goverment_4	Share of individuals who used the internet in the last 12 months to submit completed forms from government or public service websites (% of internet users)
	goverment_5	Share of individuals who have used the internet to obtain information from a government or public service website in the last 12 months (% of internet users)
	goverment_6	Share of individuals who have used e-government services in the last 12 months to submit completed official forms on government or public service websites (% of internet users)

Table A 4

Descriptive Statistics for the Variables

Variable	Mean	Std. Dev.	Min.	Max.
household_1	80.1	11.6	44.2	97.6
household_2	37.1	22.5	1.8	91
household_3	69.5	14	32.3	97.9
household_4	80.5	12.6	41	98.4
household_5	82.2	12.2	39.8	99.5
household_6	53.6	14.3	26.3	93.8
household_7	58.8	17.3	28.7	100
household_8	51.2	16.4	24.8	100
household_9	25.7	17.9	5.5	93.8
household_10	46.4	17.4	16.4	83.1
household_11	8.5	4.7	1.3	27.6
business_1	22.5	8.4	8.8	44.4
business_2	8.3	2.7	3.6	17.9
business_3	22	5.8	10.2	35.3
business_4	75.9	11	48.4	96.3
business_5	18.6	8.6	3.7	47.7
business_6	94	5.3	68.2	100
business_7	6.1	3.1	1.2	20.1
business_8	17.2	6.5	4.7	34.7
goverment_1	91.1	5.1	73.7	99.6
goverment_2	55.5	19.2	10.8	93.7
goverment_3	34	14.6	5.5	84.2
goverment_4	36.1	19.8	5.2	86.6
goverment_5	49.4	18.2	10.5	89.5
goverment_6	96.5	2.2	87.7	99.9