


Article

Digital Transformation of Hungary's Economy between 2015 and 2021: Results and Future Objectives

László Török 

Department of Engineering Management and Enterprise, Industrial Process Management Institute, Faculty of Engineering, University of Debrecen, Ótmető u.2-4., 4028 Debrecen, Hungary; dr.torok.laszlo@eng.unideb.hu

Abstract: Hungary is a member of the European Union (E.U.), so more than three-quarters of its trade relations are with the E.U. Hungary's strategic objective is to be among the top-ten E.U. member states in digitalization by 2030. This study aims to examine the country's digitization development and planned digitization programs and, based on these, to predict Hungary's expected digitization status. This study also attempts to answer whether Hungary is among the ten most digitally developed E.U. member states. We use the K-means clustering method to assess the current state of digitization and different generic methods to determine future development. The results show that Hungary's digital development is close to the middle level of the E.U. However, future digital development in Hungary will be more dynamic than in the European Union. This more dynamic Hungarian growth is predicted to catch up with the average of the E.U.'s digital development. However, the results of the extrapolation calculations show that the Hungarian goal of Hungary being among the ten most developed digital countries in the E.U. by 2030 is unrealistic.

Keywords: Hungary; digital transformation; DESI; sustainable development; generic methods; convergence

1. Introduction

The dawn of the digital age and the conscious planning and building of the information society at the government level have, by no means, coincided. It was only in the 1990s that most European states began to address this (then not so) new phenomenon at the highest levels of social governance. This has led to a trend that continues today, a kind of 'laggard attitude' that can hardly keep pace with the acceleration of technological development in an area so sensitive to technological progress.

As a result of the constant interaction between smart devices, sensors, and people, more and more data are being produced, processed, and stored. The internet and sensors can track an astonishing amount of data about a person, and this scale is growing exponentially with new generations of info-communication devices (see IoT3). The growing digital connection between people and smart devices presents significant opportunities, threats, and challenges.

To provide a theoretical framework for the topic indicated in the title of this paper, a general introduction to digital transformation is needed first. Digital transformation is, nowadays, an indispensable tool for remaining competitive in the market. Digital transformation is the reorganization of corporate culture, common ways of working, applications, business processes, customer experience, and, in some cases, the introduction of entirely new solutions using digital technologies [1,2]. Rethinking traditional business practices aims to increase competitiveness, efficiency, and profitability. At the same time, digital transformation also involves transforming existing business processes and introducing entirely new systems. Several researchers point out that digital transformation has become critical in social and economic development today. According to the mainstream approach, digital transformation has been applied by researchers to the digital transformation of



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business processes. Still, the terminology can also be used for the macroeconomy as a whole, in parallel to the macroeconomic impact of Industry 4.0 [3,4].

Shortening the digital transition period, improving access to technologies, and facilitating technological adaptation and digital transformation are critical for all economies. Digital transformation has also become a cornerstone for innovation and sustainable growth. Previous findings also highlight that digitalization has emerged as an inescapable factor for economies where digital transformation needs to be treated as a crucial issue [5–8].

The state's role in the digital switchover is crucial to ensuring an appropriate regulatory environment for technology provision, distribution, and access. This provision can take different dimensions, such as the regulatory side, legislation, and indirect or direct support to entities involved in the digital switchover [9–13].

In 2016, Hungary joined the European re-industrialization wave, one of the areas of which is the digital development of economies. In 2016, the European Commission launched the digital economy (D.E.) initiative to strengthen the competitiveness of E.U. member states in digital technologies and to ensure that all European businesses can benefit from digital innovation.

Hungary's digitalization strategy focuses on four primary areas: digital infrastructure, digital capabilities, digital economy, and digital state. The plan's primary goal is for Hungary to be among the top-ten E.U. member states in digitalization by 2030. According to this, they want to reduce the proportion of those who do not use the internet to 2 percent in the age group between 16 and 61.

Hungary's fourth-generation (4G) network coverage is outstanding; it exceeds 99.5 percent. However, the future belongs to the fifth-generation (5G) network. In addition, 5G technology offers greener solutions in many areas, contributing to sustainable and environmentally friendly development. One of the advantages of 5G is that, in addition to higher data traffic, it can even reduce the energy consumption of mobile networks below the current level. Hungary is committed to becoming an important European center for 5G developments. To this end, the Hungarian 5G coalition was established with the involvement of the info-communication technology sector, the scientific and research sphere, and government institutions, which provide support for innovation centers in the field of 5G.

The primary goal of this study is to compare Hungary's digital transformation results with the digitalization average of the 27 member states of the European Union. To carry out the comparison and analysis, this study shows why measuring the digitalization of the Hungarian economy is essential. It presents the methods of measuring the development of digitalization. It also aims to establish the most important results of the development of digitalization, as well as what additional development policy conditions need to be met to ensure the development of the Hungarian economy. Finally, it examines the domestic development policy measures that support the digitization of industry and their impact on Hungarian society. Hungary's digital future vision includes the following priorities: digitalization of transport, digital twins, digitization of healthcare, data-based operation, efficient and sustainable energy, digitization of public services, and cyber security.

1.1. Theoretical Basis of Research

Hungary has made great strides in digitization in recent years; however, it continues to struggle with significant lags in many areas essential for a competitive economy. These lagging areas in Hungary are society's digital skills and businesses' digital preparedness.

Hungary's 2030 goal of being among the ten most digitally developed countries in the E.U. presents the country with essential challenges in digital development. The scientific examination of the DESI can help us evaluate Hungary's digital development objectively and measurably compared to the European average. This allows us to understand the areas where the country needs further efforts regarding digital infrastructure, skills development, and digital services. Through scientific analysis, the critical areas on which digital development efforts should be focused can be revealed for Hungary to achieve its goals and successfully enter the ten most developed countries in the E.U.

This analysis aims to check Hungary's progress in digitalization and determine whether the country has a chance to become one of the ten most digitally developed countries in the E.U. in the digitalization transition.

Many different indicator systems are used to describe digital transformation and development in the scientific literature and the announcements of international organizations. These methods are:

1. ICT Development Index (IDI): An index developed by the U.N.'s International Telecommunication Union (ITU), which measures the development of information and communication technologies in countries.
2. Networked Readiness Index (NRI): This index, created by the World Economic Forum, measures the networking skills and infrastructure in a given country and represents how healthy countries are preparing for the challenges of the digital economy and society.
3. Digital Readiness Index (DRI): An index created by the Fletcher School and Mastercard, which measures the progress of the transition to the digital economy in each country, considering digital infrastructure, government policies, and the business environment.
4. Digital Society Index (DSI): An index created by the Vodafone Institute that measures the development and progress of the digital society in terms of human rights, economic growth, and social participation.

1.2. Hungary's Digital Development among E.U. Countries

Before starting the investigation, it is advisable to record the situation of Hungary's digital development based on a comparison with that of E.U. member states. For this, the study applies the K-means method to the 2020 values of the DESI. This procedure is more beneficial than other methods because it gives the cluster centers, which can be evaluated with the dimension weights proposed by the E.U. to establish an order between the clusters.

Based on the data in Table 1, four E.U. member states are in the first cluster, while Hungary is in the last cluster.

Table 1. Clusters of E.U. member states based on DESI value (2020).

Clusters (1–6)	Member Country
Cluster 1.	Denmark, Finland, France, Netherlands
Cluster 2.	Ireland, Malta, Luxembourg, Sweden
Cluster 3.	Austria, Belgium, Estonia, Germany
Cluster 4.	Cyprus, Lithuania, Spain
Cluster 5.	Bulgaria, Czech Republic, Greece, Latvia, Romania, Slovenia
Cluster 6.	Croatia, Hungary, Italy, Poland, Portugal, Slovakia

In this study, the DESI (Digital Economy and Society Index) provides the theoretical basis for comparing Hungary and the E.U. DESI is an indicator used by the European Union to measure the development of the digital economy and society in E.U. member states. The index compares countries on critical E.U. Digital Unit Market dimensions, such as internet access, digital skills, digital public services, and business digital capabilities.

I present the mathematical terms of the DESI and their meaning in the Methodology section.

The Introduction presented the basic concepts of digital development, its importance, the main areas of the digitalization strategy, the theoretical foundations of the research, and the position of Hungary's digital development among the E.U. member states. The Literature Review presents the relevant literature related to the topic of this study. The Methods section describes the measurement techniques of digital transformation. This part highlights the procedures that are used in Hungary and presents the components of the DESI used in this study in detail.

Generic methods are applied to the future of the digital development of Hungary and the E.U. (1. Linear Support Vector Machines (L-SVM); 2. Kernel Support Vector Machines (K-SVM); 3. Random Forests (R.F.); 4. Extremely Random Forests (ERF); 5. Neural Networks (N.N.)) in 4.3. The study is presented in a subsection. The Results section presents Hungary's state of digital transformation based on DESI values. Its values are compared to the E.U.'s average values. This section also contains Hungary's digital public policy programs, which the country introduced to achieve faster digital development. The Results section closes with future DESI values calculated using generic methods for Hungary and the E.U. The Discussion and Conclusions sections conclude this study.

2. Literature Review

There is extensive international literature on digital economy (D.E.) research [14–17]. The digital transformation of the economy is the new springboard for economic growth today because it contributes to increased business performance.

Digitalization is the most important technological trend of the early 21st century. With the increasing role of data and the rise of algorithms, its impact is being felt in all areas of life. This is especially true in the economy, where digitally lagging companies are at a competitive disadvantage [18]. Companies increasingly use digital solutions to achieve better business results, regardless of industry. However, the immediate goal of companies using digital tools is to be able to produce new or improved products and services [19]. The accepted view among researchers is that digitalization is a decisive factor in the growth of a company's production and in improving its competitiveness [20–23].

One of today's prominent research topics is investigating the relationship between the digital transition and sustainability. In the next section, I present publications on this relationship.

In one study, the authors analyzed the relationship between the Digital Economy and Society Index (DESI), the Sustainable Development Goal Index (SDG Index), and the Spillover Index (S.S. Index) using correlations. The DESI measures the level of digital development of E.U. member states, and the SDG Index and the S.S. Index are based on several indicators that provide a multidimensional perspective on sustainable development. The results show a positive and significant relationship between DESI and the SDG Index, and the effect gradually decreases over the period under study—the correlation between DESI and the S.S. The value of the index was negative [24].

A study examined the digital transformation of companies. The results show that digital transformation involves changing companies based on constant innovation. According to another study result, change does not simply mean the adoption of new technology but also highlights the sizeable digital gap between companies, which depends on the size of the company and the type of industry [25].

A study examined the relationship between sustainability and economic output (GDP). The evidence shows that Europe has not yet been able to eliminate the negative relationship between GDP and sustainability, even though all aspects of digitization, innovation, and environmental protection policies positively affect economic output [26].

The authors of [27] investigated the digital twin relationship in sustainable manufacturing supply chains. The research findings show that the digital supply chain twin must include things and people from the entire supply chain and not be limited to local manufacturing systems.

A study examined the relationship between digitization, demographic yield, and sustainable economic growth. Long-term results have shown that demographic returns and digitization drive sustainable economic development in all volumes. In parallel, energy intensity and financial sustainability are negatively related to sustainable economic growth, while urbanization, capital formation, and industrialization positively influence it [28].

In a study, the authors proposed a concept called “digital hybridity” to enhance the sustainability of social enterprises. Digital hybridity is the phenomenon of applying digital innovation by combining social welfare logic and commercial logic. The authors' evidence

offers an alternative technological solution for sustainability, in which digital innovation enables social enterprises to merge competing institutional logics [29].

At the end of the literature section, I mention the studies that examined the topic of the digital transition [30–35].

3. Methods

3.1. Measurement Techniques of Hungary's Digital Transformation

The primary objective of this study is to compare and analyze the digital transformation performance of Hungary with the average of the 27 E.U. member states. To do so, this paper presents the importance of measuring the digitalization of the Hungarian economy and introduces methods to measure the development of digitalization. It also aims to identify the most important results of the development of digitalization and the further development policy conditions that need to be met to ensure the development of the Hungarian economy. Finally, it examines the domestic development policy measures taken following the initiative to digitize the Hungarian industry and their impact on society.

To achieve the significant micro- and macroeconomic performance improvements expected from digitalization, it is a priority to measure the digital economy as accurately as possible based on a uniform methodology. As in several studies, this study will measure the level of adaptation of the Industry 4.0 concept [36–41] and readiness for digitalization in the industry by comparing Hungary with the E.U.

This study uses the DESI as the theoretical basis for comparing Hungary and the E.U. The DESI (Digital Economy and Society Index) is an indicator used by the European Union, which measures the development of the digital economy and society in E.U. member states.

The theoretical basis of DESI is that the use of information and communication technologies and the spread of e-commerce have a positive effect on economic growth, employment, and social welfare. The index helps measure and evaluate these changes in the countries of the European Union.

The DESI compares countries on critical E.U. Digital Unit Market dimensions, such as internet access, digital skills, digital public services, and business digital capabilities.

DESI = (Access dimension + Skills dimension + Usage dimension + Integration dimension + Commercial digital capacity dimension).

The index measures several indicators and variables in each dimension and then takes a weighted average to determine a country's DESI value. The purpose of the DESI is to provide a comparable measure of the digital development of E.U. member states.

The mathematical expressions and relationships of the five dimensions in the DESI are as follows:

1. Access dimension = (Broadband coverage + Broadband download speed + Mobile broadband coverage).
2. Skills dimension (Basic digital skills + Advanced digital skills + User skills).
3. Usage dimension (Internet activities + Access to online content + Use of e-services).
4. Integration dimension (Organizational integration + Administrative integration + E-commerce integration).
5. Commercial digital capacity dimension (Digital capacity of companies + Digital infrastructure + Usage of e-commerce).

The study methodology uses the DESI to compare Hungary and the E.U. Still, Table 2 presents several methods suitable for measuring the digital maturity of a company or a country using different approaches.

The data presented in Table 1, which can be used for the methodologies to assess the degree of digitization, are taken from national statistical offices (e.g., Hungarian Central Statistical Office) and European Union databases (e.g., Eurostat, COCOM).

Table 2. International indicators measuring digitization and technological development.

Measurement Technique	Purpose of the Measurement Technique
Industry 4.0 Graduation Model (I4.0GM)	A qualitative measurement model, developed within the Industry 4.0 Model Factories Flagship Project framework, measures enterprises' readiness for Industry 4.0.
E.U. + 18 countries' digital literacy (I-DESI)	The extension of the DESI indicator to a global level, which compares digital performance, will include 18 countries outside the European Union.
Industry 4.0 Readiness Index (R.I.)	Measures readiness for Industry 4.0.
Enterprise Digitalisation Index (EIBIS)	European Investment Bank Group survey on digital readiness of businesses, digital infrastructure, software use
European Index of Digital Entrepreneurship Systems (EIDES)	Measures the entrepreneurial ecosystems in the E.U. member states, especially in the context of digitalization.
World Economic Forum Global Competitiveness Index (WEF)	Composite derived from multivariate analysis and information collection ranking. It includes direct and indirect aspects relevant to industry, R&D&I, and digitalization.
ICT Development Index (IDI)	It is based on internationally agreed-upon ICT indicators published annually by the U.N. International Telecommunication Union since 2009. The indicator measures the information society.
Status of digitization (DESI)	It measures the progress of E.U. member states in building a digital economy and society.

Source: based on the descriptions of each measurement method, own editing.

3.2. DESI of Digital Literacy

The Digital Economy and Society Index, or the DESI, is an annual indicator produced by the European Union. The index measures the progress made by E.U. member states in building a digital economy and society. The index allows for comparing the digital performance of member states and tracking the development of digital ecosystems. The DESI covers four main policy areas (indicators) [42].

Figure 1 illustrates the indicators included in the DESI. The dimensions are logically linked and cannot be separated, but their methodological separation allows the complex social phenomenon of digitalization to be studied.

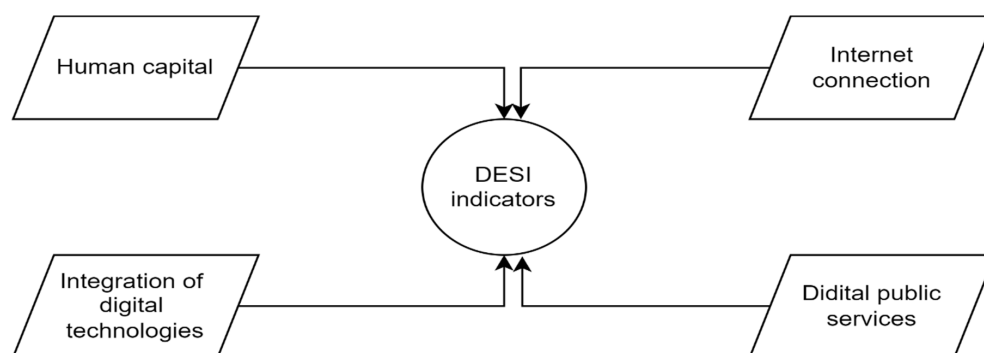


Figure 1. Dimensions of the indicator measuring the development of the digital economy and society. Source: based on [43], own editing.

The studies analyzing the digital transformation of national economies also examine these four indicators and the changes in their values [44–47].

4. Results

4.1. The State of Digital Transformation in Hungary Based on DESI Values

This study examines the evolution of the DESI indicator and GDP per capita from 2015 to 2021, based on the average values of the European Union and Hungary (Table 3).

Table 3. GDP per capita and DESI values from 2015 to 2020, correlation.

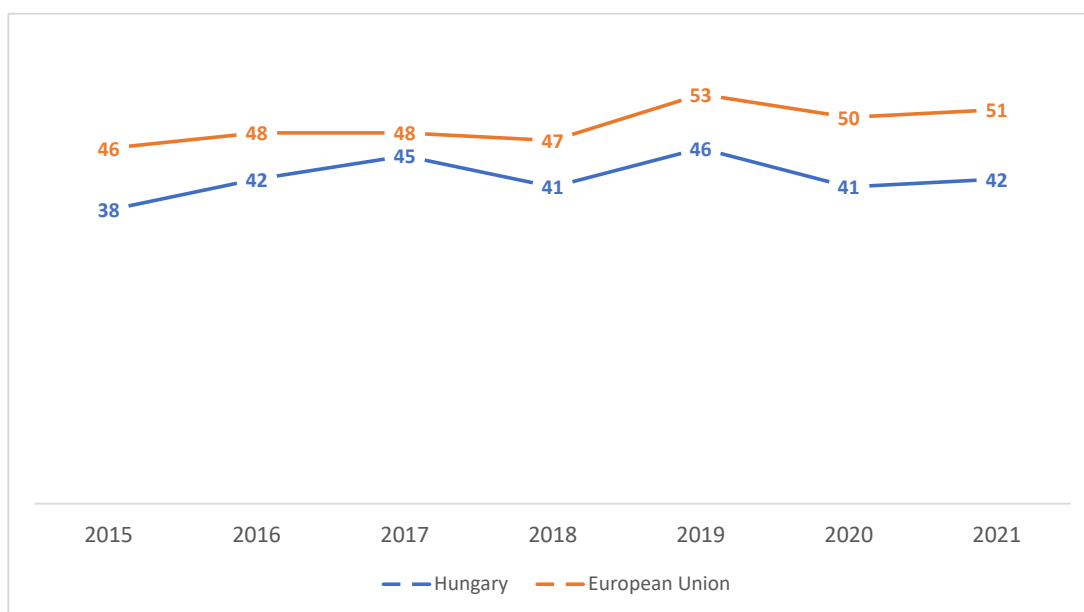
	2015		2016		2017		2018		2019		2020		2021		Pears. (r)
	GDP	DESI	GDP	DESI	GDP	DESI	GDP	DESI	GDPP	DESIII	GDP	DESI DE	GDP	DESI	
H.U.	23	38	25	42	26	45	27	41	28	46	30	41	37	42	0.18
EU	42	46	43	48	45	48	41	47	44	57	42	48	49	51	0.51

Source: GDP: [48]; I-DESI (2015–2018): [49]; I-DESI (2019): [50]; I-DESI (2020): [51], Pearson's coefficient (own editing).

According to Table 2, the annual evolution of the E.U. average and Hungarian DESI indicators clearly shows the growth path in the digital economy and society. The average value of the European Union indicator in 2021 is 51, while Hungary's result is 42, which places the country below the E.U. average (23rd in the ranking of member states). The evolution of GDP per capita also shows a growth path for the E.U. and Hungary (except for the decrease in 2020). However, the correlation between DESI and GDP is ambivalent. Pearson's (r) value for Hungary is 0.18. The cheerful but weak relationship between the two variables suggests that digital development has not determined the country's GDP growth. In contrast, the Pearson (r) value of 0.51 for the E.U. indicates a strong relationship between digital development and GDP.

Several studies have examined the relationship between digital development and GDP. One of the many articles analyzed the relationship between sustainability and digitization using data from Visegrad countries. In their study, they looked for correlations between the DESI, gross domestic product (GDP), human development index (HDI), and social progress index (SPI) dimensions. The result of that study shows that GDP is higher in more digitized countries. Also, [52] demonstrated the correlation between DESI and GDP by examining the situation of digital enterprises in Central and Eastern Europe. Using data from 2015 to 2019, he showed the relationship between countries' GDP per capita and DESI. He calculated that among the DESI dimensions, the use of internet services, the integration of digital technologies, and digital public services positively impact GDP per capita. However, he found no significant relationship between internet access, human capital, and GDP per capita.

The DESI values for the European Union and Hungary are shown in Figure 2.

**Figure 2.** DESI values for Hungary and E.U., 2015–2021. Source: [42].

4.2. Hungary's Digital Development along the Four Dimensions

The DESI of a country's digital development can be broken down into four sub-dimensions, as illustrated in Figure 1. In the following section, the study uses [42] as a basis to present Hungary's digital development in the European Union according to the four sub-dimensions.

4.2.1. Human Capital (First Sub-Dimension)

Hungary scores 40.5 on the human capital dimension, down from the E.U. average (47.1) and 22nd in the ranking. About half of Hungary's population has only basic digital skills, and the proportion of people with basic software skills is low. Only a quarter of the population aged 16–74 have digital skills above basic. The number of ICT graduates in employment has increased slightly (3.8 percent) but is below the E.U. average (4.3 percent). ICT training for employees is provided by 16 percent of enterprises, compared to the E.U. average of 20 percent.

4.2.2. Internet Access (Second Sub-Dimension)

In terms of infrastructure, Hungary is among the best performers in the E.U. Fixed broadband internet penetration is 83 percent (E.U. average 78 percent). Hungary also performs well in the internet access dimension of the DESI. Hungary's score in 2021 was 52.0, above the E.U. average (50.2) and ranked 12th. The results above the E.U. average were driven by fixed broadband, broadband of at least 100 Mbps, broadband of at least 1 Gbps, high-speed systems, and 5G readiness.

4.2.3. Digitalization of Industry (Third Dimension)

Hungary's biggest challenge is improving the results of the most relevant dimension for the digitization of industry, integrating digital technologies into business activities. In digitization, the country ranks 26th in the E.U. Only 14 percent of Hungarian enterprises have an integrated (ERP) system for electronic information exchange, which is less than half the E.U. average (36 percent). The use of electronic invoices, social media, big data, cloud services, and artificial intelligence is also low. The share of small- and medium-sized enterprises selling online is also below the E.U. average (17 percent) at 13 percent. However, using information and communication technologies (ICT) has led to a significant share of green measures (65 percent of Hungarian enterprises), only 1 percentage point below the E.U. average.

4.2.4. Digital Public Services (Fourth Dimension)

Hungary is ranked 25th in the digital public services dimension, with a score of 49.2 in 2021, below the E.U. average (68.1). This dimension is below the E.U. average for all indicators (digital public services for citizens and businesses, automatic filling of forms, open access data). However, from 2021 onwards, the digital public services dimension has included the e-government sub-dimension, before which the e-health sub-dimension was also included, with a weight of 20 percent, using three indices. While the country's score in the digital public services dimension was 57.8 percent in 2020, according to the European Commission's 2020 Country Assessment, it was only 49.2 percent in 2021, according to the 2021 Country Assessment.

Hungary's digital development is the second most underdeveloped group, including Eastern and Southern European member countries. The classification seems realistic to the extent that, based on all I-DESI dimensions, Hungary achieves a lower level of development than the average level of E.U. member states and performs particularly poorly in digital public services. Hungary's results are not terrible compared to the performance of Central and Eastern European countries (e.g., Slovakia, the Czech Republic, Poland). However, the performance of some countries in the Central and Eastern European region, especially Estonia, shows that, with an appropriate digital development strategy and policies, the upper part of the E.U. middle field could also be caught up to. Overall, the

digital development of the Czech Republic is the highest among Central and Eastern European countries. Still, its advantage cannot be significant, and in the case of clustering in Central and Eastern Europe, it is at roughly the same level as Hungary.

4.3. Three Priority Development Programs

Hungary has launched several development programs to accelerate digital transformation.

4.3.1. Digital Wellbeing Program (DWP)

The objectives of the program are not specific numerical targets but rather targets. The primary aim is to ensure that all Hungarian citizens have the opportunity to improve their digital literacy continuously. The second objective is to give every Hungarian business the chance to increase its competitiveness by recognizing and exploiting the benefits of digitalization. The third is to provide the Hungarian economy a chance to be one of the winners in the international competition of digital transformation. To achieve this, several concrete measures have been taken, such as allowing every household to subscribe to an internet connection with at least 30 Mbps bandwidth, reducing the general sales tax on the internet, making it more accessible to citizens. The Digital Education Strategy (DES) and the Digital Workforce Program (DWP) have been prepared in the framework of the DWP (see Figure 3).

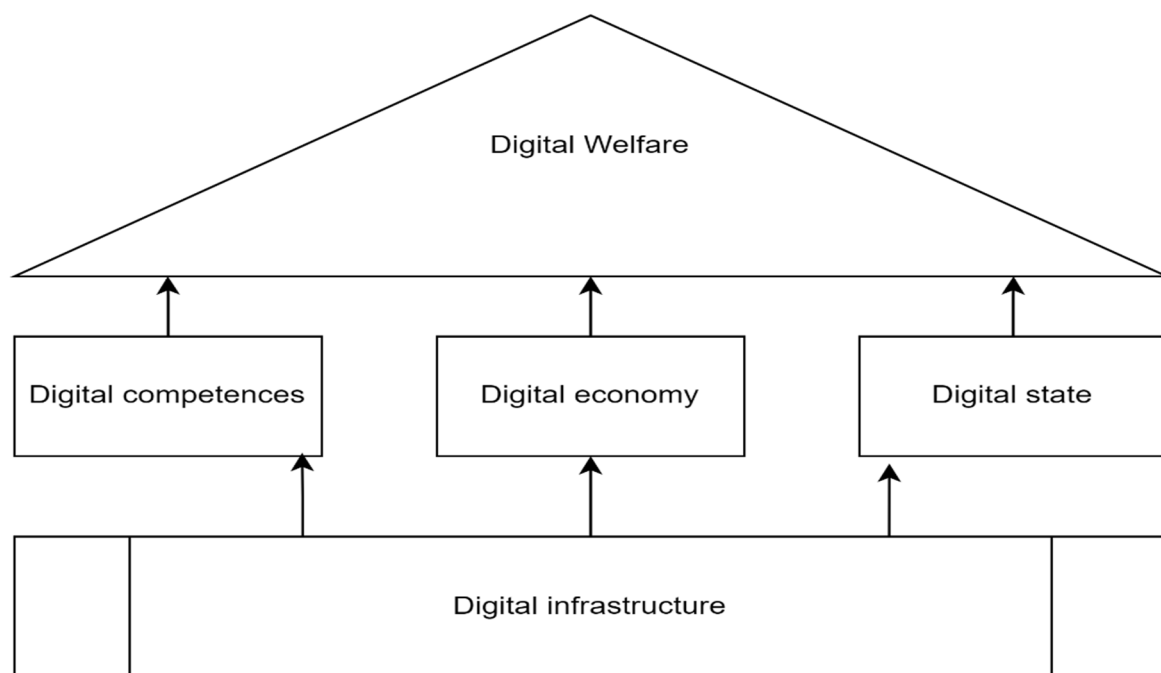


Figure 3. Diagram of the Digital Wellbeing Program (DWP). Source: own editing.

4.3.2. National Digitization Strategy (NDS)

The overall objective of the NDS is to ensure that Hungary recognizes and exploits the potential of digitalization in the economy, education, research and development, innovation, and public administration. By exploiting these opportunities, the NDS should significantly contribute to increasing the country's competitiveness and the well-being of its citizens. The NDS has four pillars: I: Digital Infrastructure; II: Digital Competences; III: Digital Economy; and IV: Digital State. The Digital Infrastructure objective is to ensure the availability of wired and wireless digital infrastructure with adequate service capability and quality to avoid becoming a bottleneck in developing the digital ecosystem. The Digital Competence objective is to increase the proportion of digitally literate workers and the number of I.T. professionals by continuously improving the digital competence and user awareness of

the population and the workforce's digital skills. The Digital Economy objective aims to increase the digital readiness of businesses, the integration of digital technologies, and to stimulate the development and uptake of innovative digital solutions in all sectors. The Digital State objective aims to increase the range of customer-friendly digital public services available and foster openness and motivation among citizens and businesses. To support this, we must create cross-border service delivery in the areas required by the E.U. and increase the efficiency of public administration front-office and back-office processes through automation.

4.3.3. Support for the Digital Development of SMSes (SDD-SMSe)

This development policy program aims to bring the Hungarian economy into the ranks of economies with high technological development and leading innovation capacities.

To achieve this, many Hungarian-owned enterprises need a strategic scope for digitalization and the ability to increase their added value significantly. To achieve this, the program sets out specific objectives, such as expanding the digital automation of taxation; developing a sustainable model of training programs to increase the digital readiness of SMSes; enabling SMSes to access and manage e-government services easily; training SMSe workforces beyond the acquisition of technical skills, with an emphasis on digital skills in all areas; creating a digitally based labor market forecasting system and an evidence-based career tracking system for SMSes.

4.4. The Digital Future of Hungary's Economy

Table 2 shows the DESI values for the digital development of the European Union and Hungary for 2015–2021. This part of the study uses macroeconomic methods accepted in economics to forecast the future digital development of Hungary and the European Union. This projection is essential because the quantitative analysis of past phenomena and processes and the exploration of past trends and correlations are necessary if the need for extrapolation does not accompany it. Any well-founded and professional analysis of the past is of no value if it does not allow researchers to conclude the future.

The following generic methods were used to calculate extrapolation: 1. Linear Support Vector Machines (L-SVM); 2. Kernel Support Vector Machines (K-SVM); 3. Random Forests (R.F.); 4. Extremely Random Forests (ERF); 5. Neural Networks (N.N.).

The equation used by Linear Support Vector Machine (L-SVM) and Kernel Support Vector Machine (K-SVM) models:

$$f(x) = W \cdot x + b, \quad (1)$$

where w is the weight vector, x is the input data vector, and b is the offset.

The equation used by Random Forests (R.F.) and Extremely Random Forests (ERF) models is as follows:

$$y = \sum_{i=1}^N w_i b_i(x) \quad (2)$$

where y is the estimated output, N is the number of trees, w_i is the weight for a given tree i and $b_i(x)$ is the decision function.

The equation used by Neural Networks (N.N.) is as follows:

$$y = \sigma(w \cdot x + b), \quad (3)$$

where σ is the activation function, w is the weight vector, x is the input data vector, and b is the offset.

Note: For Kernel Support Vector Machines (K-SVM) and Linear Support Vector Machines (L-SVM), the equations are the same, and only the kernel type is different. Random Forests (R.F.) and Extremely Random Forests (ERF) also work based on similar principles, so the equations are the same.

The data in Tables 3 and 4 show that future digital development in Hungary will be more dynamic than in the E.U. Hungary's DESI value was 42 in 2021, rising to 43.8 in 2026 (according to the most optimistic ERF model). In contrast, the EU DESI was 51 in 2021, rising to 51.4 (according to the most optimistic R.F. model). In theory, more dynamic growth in Hungary means catching up with the EU DESI average. Hungary's digital divide will decline and reach the upper end of the E.U. average by 2026. However, the dual effect of a lower average DESI value and the base effect explain Hungary's apparent convergence.

Table 4. Projected DESI values for Hungary and the European Union for 2023–2026.

	L-VSM		K-SVM		RF		ERF		NN	
	HU	EU	HU	EU	HU	EU	HU	EU	HU	EU
2023	40.0	49.4	42.8	49.9	43.6	50.1	43.8	50.0	43.6	49.6
2024	41.0	49.9	42.9	50.3	43.6	50.6	43.8	50.4	43.7	50.0
2025	41.9	50.3	43.1	50.7	43.6	51.0	43.8	50.9	43.7	50.4
2026	42.9	50.7	43.3	51.1	43.6	51.4	43.8	51.3	43.7	50.9

Source: own calculation.

At the same time, the slight increase in the E.U.'s average DESI indicates that the pace of digital development is generally slower in the European region.

According to Figure 4, based on the Neural Networks model, Hungary's digital development is closest to the E.U. average by 2026.

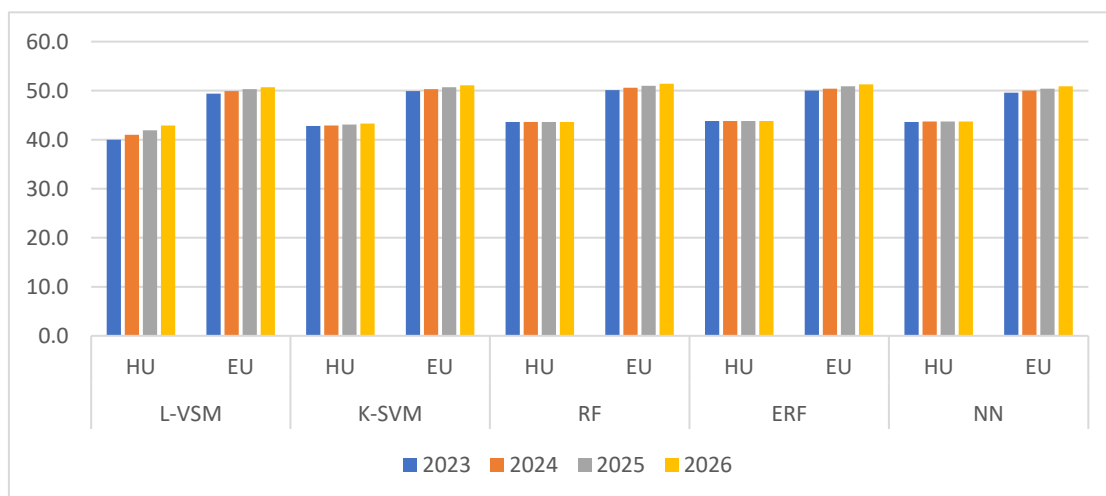


Figure 4. Future values of DESI in Hungary and the E.U. (2023–2026).

Regarding the future of Hungary's digital transition, the country is in a good position regarding physical investments. Still, the country's DESI values regarding knowledge and skills and investment in them are wrong. To catch up with the E.U. leader, the government must invest more in digital intangibles (knowledge and skills) in the future.

5. Discussion

Several studies have examined the convergence of digital development. For example, Ref. [53], analyzing the DESI synthetic index and its components, concludes that there is an overall increasing convergence in the level of development of the digital economy and society among E.U. member states. The study also confirmed that the dynamics of changes in the levels and values of the indicators vary at the level of the DESI indicator as well as in the five underlying analysis areas. During the analysis of the DESI synthetic index and its

components, it was concluded that the convergence between the EU-28 countries in terms of the level of development of the digital economy and society is generally increasing.

According to [54], their results show that the core formed in 2015 by four digitally well-performing Northern European countries (Denmark, Finland, Netherlands, Sweden) in 2015 has gradually been clustered around other countries. They estimate that in 2025, eight member states will be part of the group of the best-performing digitally performing countries in the E.U. The results of several studies have shown that achieving digital convergence in the E.U. is a relevant task. Research by [55] supports the idea that E.U. investment should focus on digital convergence as part of the COVID-19 recovery plan by establishing a link between DESI and economic growth.

A previous study also examined the causes of the emergence of digital inequalities in Europe and the means to eliminate them. The research results led to the identification of two latent dimensions and five country groups. Researchers have concluded that a digital divide exists within the European Union. According to their conclusion, European integration and the different economies of the member countries explain this division [56].

This study examined Greece's digital catch-up, and its results revealed the areas where there are convergences and differences between Greece and the other EU-28 member states. The forecast used in the research made it possible to evaluate the significant impact of the Greek development policies at the time on digital competitiveness. The results showed that Greece faces substantial challenges due to the low level of digitization, both on the demand and supply sides. A study looked at the possibilities of rapidly increasing DESI levels. The research showed that the current value of the DESI is 98 percent, which is determined by the trend of the country's previous digital development under investigation. It follows from the last statement that it is impossible to robustly accelerate the development of a country's digital economy in a less-developed country [57].

Researchers examined the digital development of Central and Eastern European countries. The results showed a positive relationship between the dependent and independent variables. This relationship confirmed that the digitization of the economy and developed human capital ultimately increased the population's well-being. In addition, the results are consistent with specific findings for each of the 11 CEE countries, which show that the influence of digitalization and human capital differs in the latter in terms of overall impact and amplitude [58].

Its political impact may be that it can provide policymakers with guidelines for developing digital development strategies. Based on the results, they can create policies and measures that promote Hungary's digital transition and economic development. The financial impact of this study may be that its results could inspire Hungarian businesses to emphasize the use of digital technologies and innovations. This can contribute to the growth of Hungarian corporate competitiveness and improve economic performance. Finally, the social impact of this study may be that it can draw attention to the problem of Hungary's digital lag and encourage a wide range of society to use digital tools and opportunities better. Good practice for presenting the effects of scientific publications is described [59,60].

There are also stable systems and relevant references related to the topic of this study, as several studies draw attention to the fact that digital processes contribute to ensuring the stability of production systems and performance control procedures [61–63].

6. Conclusions

Hungary's digital performance shows that for most indicators, it is either in the middle of the E.U. or cruising towards the bottom of the rankings and trying to move up from there. Hungarian development policy has set itself the ambitious goal of becoming a leading player in the region in as many dimensions of digitalization as possible by 2030. Thanks to the consistent implementation of the country's digitalization strategy, the government made steady progress in digital transformation until 2021, moving from 23rd to 20th place

in the European Union ranking [42]. However, even with this ranking, it is still significantly below the E.U.'s top ranking.

The correlation between DESI and GDP is ambivalent. In Hungary, the Pearson (r) value is 0.18, which shows a positive but weak relationship between the two variables, indicating that digital development had a limited impact on the country's GDP growth. On the other hand, in the E.U., the Pearson (r) value is 0.51, which shows a strong relationship between digital development and GDP.

The free digital education tendering scheme, which aims to eradicate digital illiteracy and reduce the digital divide, has been particularly successful among domestic development programs. Developing digital competencies among the working-age population is essential, as these skills have become necessary for employment, and surveys show that we are significantly behind the European Union average in digital skills.

Closing this digital divide is not only about reducing the number of citizens who are not internet users. The gap resulting from the different quality of internet use is at least as necessary for competitiveness. The aim is to ensure that citizens use the information network to find and use information that can contribute to developing individual skills rather than/alongside entertainment. In addition to the development of education, efforts should be made to ensure that various other sectors can "meet each other" and meet the needs of society. In the design and implementation of ongoing domestic strategies, international good practices, examples, and opportunities for cooperation should be explored, examined, and taken into account and transposed into the domestic context so that the desired digital goals can be achieved by Hungarian society as soon as possible. Healthcare providers in the five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) will assess available digital innovations against common standards [64].

Through training, education, conferences, etc., Hungarian business leaders have realized that digitalization is not an end but a means to business success. Digitalization is now a mandatory element of corporate strategy, which, if neglected, puts a company at a significant disadvantage vis-à-vis its competitors. The state provides substantial financial support to accelerate the digital transformation of Hungarian companies [65].

Suppose that we compare the goals and tools of the Hungarian digital transition presented in Sections 3 and 4 of this study with those of the E.U. With the Digital Compass (The Road to the Digital Decade) political program, which is valid until 2030, we experience a significant similarity in digitization. We conclude that it is the same as safe and sustainable digital infrastructures [66,67].

Hungary's digitalization strategy is ambitious, and the partial results have been encouraging. Still, the goal of becoming one of the leading countries in the European region in this field within a few years looks pretty distant. This significant lag is confirmed by the data in Table 3. However, the country's convergence of digital status towards the E.U. average seems feasible shortly. Despite increasing convergence, the gap between the best-performing and lowest-scoring E.U. member states in digital development (such as Hungary) will remain relevant.

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