3 Differentiation of the digital economic development in Europe

Mateusz Biernacki, Agata Luśtyk and Rafał Wisła

3.1 Introduction

The digital economy is a conceptual "umbrella" referring to markets, organizations and their networks that are based on digital technologies, communication, data processing and e-commerce (see Nathan et al., 2013). The term denotes a multidimensional, dynamic structure that must be analysed considering its various dimensions, such as economic aspects (changes in the nature of resources, production factors and economic processes), the area of technology (technological progress viewed from a macroeconomic perspective vs. technological innovation viewed from a microeconomic perspective), regulatory measures (challenges facing regulators, new risks affecting the institutional order) and sociological phenomena (changes in society functioning principles, attitudes towards work and human relations).

The Organisation for Economic Co-operation and Development (OECD, 2020) defines the digital economy as an economic system wherein data is used as a factor of production. Businesses operating in this type of economy use or process digital information aiming to increase its value (create value added). The enterprises adopt new business models enabled by new market conditions (digital services, digital distribution channels and digital networks) (OECD, 2020).

The digital components (digital resources and IT infrastructure) drive the digital economy value chain; new industry sectors and new business models emerge. The new value chain opens new spaces and promotes the consolidation of growth areas and job creation (Zhenlong, 2021). Digitalization dramatically modifies the very nature of products, the value creation process and the competitive environment in business. Based on the network-centric view, the firms may achieve a competitive advantage by actively shaping the digital environment and by interconnecting in the digital environment (Koch & Windsperger, 2017).

Carlsson (2004) emphasizes that the digital economy is more about new activities and products than about higher productivity. Its key resources include information and a series of economic and social activities that people carry out using the Internet and related technologies (Turcan et al., 2014). Continual

DOI: 10.4324/9781003450160-5

technological progress and growing data repositories and flows can be indicated as the key trends shaping digital transformation on a global scale.

The terminological context outlined above and in Chapter 1 gives rise to a fundamental question about a method suitable for quantifying the dynamics of these changes at various levels of economic analysis. The International Monetary Fund (IMF, 2018, pp. 2–6) indicates the lack of generally agreed understanding and definition of the digital economy as a major hurdle to reliable measurements of changes associated with that economy. The IMF (2018) distinguishes the concept of the digital sector and that of the digital economy. The concept of the digital sector is limited to the core activities of digitalization, such as ICT goods and services, online platforms and platform-enabled digital services, including the sharing economy. Considering enormous difficulties in quantifying the dynamics of changes in the digital economy environment, interdependencies observed in that economy and their characteristics, the IMF (2018) proposes to focus measurement efforts on a concrete range of economic activities at the core of digitalization.

In this chapter, we will not follow this recommendation. Instead, we propose an original method for a quantitative description of changes in the digital economy from a macroeconomic perspective. For this purpose, the taxonomic analysis will be used. The first section of this chapter contains a review of proposals aimed to measure the digital economy, considering various approaches to its definitions. The second section discusses two methods designed to identify changes in the digital economy from a macro perspective and gives the characteristics of data used in the following sections. The third section presents research results with a discussion of their limitations and downsides. The last section contains a summary.

3.2 A review of proposed methods for measuring the digital economy

The current approach to measuring the digital economy, adopted by international organizations (G20, 2018; IMF, 2018; OECD, 2020), is broad and addresses its various aspects: infrastructure, employment, applications, social change and innovation.

The infrastructural context consists of physical, service and security infrastructure. The measurement methods use such indicators as access to mobile and landline telephone networks, the development of next-generation access, the number of broadband service subscribers and the number of active mobile Internet subscribers. But in addition to accessibility and affordability, such factors as the connection quality and Internet transmission speed (both in mobile and DSL technologies) play an important role in measuring the individuals' and enterprises' capability of participating in the development of the digital economy. The OECD (2020) also discusses the concept of Internet of Things (IoT), i.e., an ecosystem of applications and devices that connect and exchange data with their environment and with each other without human intervention. The OECD (2020, p. 21) expects that the IoT will become a central element of the digital economy in G-20 countries.

The aspect of employment, digital competencies and labour market is operationalized using the following indicators (OECD, 2020, pp. 72–73):

- the number of jobs in the ICT sector,
- the proportion of enterprises that employ ICT specialists,
- the number of individuals teleworking from home,
- Eurostat Digital Skills Indicator,
- ICT usage in schools,
- the number of tertiary graduates in natural sciences and engineering,
- value added by information industries,
- information industry-related domestic value added,
- labour productivity in information industries,
- ICT contribution to labour productivity growth,
- ICT goods exports and imports,
- ICT services exports and imports.

The category of emerging applications, i.e., technological innovation, is quantified in terms of e-commerce or robotization in manufacturing (robot intensity) (OECD, 2020, pp. 28–34).

The social dimension of the digital economy is understood as using digital technologies to improve general well-being and the quality of life and to enhance communication capabilities. The principal quantifiers of changes include here the percentage of Internet users and the percentage of individuals using the Internet to interact with public authorities. The digitalization and automation of procedures are aimed to simplify those interactions and provide easy access to various official forms and means of efficient completion of government procedures (OECD, 2020, pp. 23–26).

The International Telecommunication Union (ITU, 2020, p. 4) describes access by individuals and households to ICT infrastructure as a factor accelerating social development and stimulating economic changes. The concept of the digital economy is understood as available digital infrastructure, digital products, their accessibility and society's digital skills. The ITU (2020, pp. 47–49) proposes a list of ICT household equipment indicators. These indicators include, e.g., the proportion of households with multichannel television, the proportion of households with Internet, household expenditure on ICT, the proportion of individuals using the Internet, the proportion of individuals who purchased goods or services online, the number of individuals with ICT skills and total household expenditure on ICT. The ITU adopts the following principal indicators of ICT infrastructure development and access to that infrastructure (2020, p. 235)

- fixed-telephone subscriptions per 100 inhabitants,
- mobile cellular telephone subscriptions per 100 inhabitants,

- fixed broadband Internet subscriptions per 100 inhabitants (broken down by speed),
- active broadband Internet subscriptions per 100 inhabitants,
- Internet throughput per inhabitant (bits/second/inhabitant),
- fixed broadband Internet prices per month,
- mobile cellular telephone prices and TV broadcasting subscriptions per 100 inhabitants.

Bukht and Heeks (2017) indicate temporal changes in conceptualizing the digital economy. They result from the development of infrastructure and its use (the Internet as a leading technology, mobile networks and cloud computing). Kling and Lamb (2000, pp. 295–324) identify four areas of the digital economy: highly digital goods and services (e.g., online education), mixed digital goods and services (e.g., books), IT-intensive services or goods production (e.g., accounting) and the segments of the IT industry that support these three segments of the digital economy (e.g., the computer networking industry). Bukht and Heeks (2017) also emphasize the importance of measuring the digital economy. They propose such measures as value added by the ICT sector, employment in the IT/ICT sector and comparing labour productivity in highly digital sectors with that in the traditional economy. Similarly, ITU (2020, pp. 236–237) uses a macro perspective to propose the proportion of ICT specialists in total employment, ICT sector share of gross value added, ICT goods imports as a percentage of total imports and ICT goods exports as a percentage of total exports.

The G20 DETF (2018) indicates that sound measurement is crucial for policymaking, as it helps to produce precise diagnostics, assess the potential impact, monitor progress and evaluate the efficiency and efficacy of implemented actions. The digital economy is believed to have a great potential for transforming jobs, hence the rapidly growing demand for measurement tools and indicators. The G-20 member states are encouraged to disclose measurements characterizing the digital economy in their national statistics, using various methods for monitoring the digitalization level. 30 key indicators are recommended, divided into four main thematic areas: (1) infrastructure, (2) empowering society, (3) innovation and technology adoption and (4) jobs and growth. In addition to these four areas, the report authors emphasize the importance of measuring such indicators as expenditure on research and development (R&D), machine learning, AI-related technologies and cloud computing services used by enterprises (G20 DETF, 2018, pp. 37–41, 48).

Currently (G20 DETF, 2018, pp. 4–8), multiple hurdles are identified for the systematic collection of comparable statistical data in the discussed area. Main obstacles include differences in data collection methodologies and approaches and a limited range of surveys. The methodological differences are evident in the currently used indicators aimed to measure the digital economy. It is not enough to improve the existing indicators; new measures and data collection methods must be identified. There are areas with internationally recognized standards for statistical data collection, but states have insufficient capabilities and resources to systematically implement those standards and then distribute the figures obtained.

The recommendations proposed by the authors of the G20 DETF report (2018) include:

- experimenting with concepts and data gathering within existing measurement frameworks,
- exploiting the potential of existing survey and administrative data,
- adding questions to existing surveys,
- augmenting existing surveys with topic-specific modules,
- developing short turnaround surveys to meet specific needs,
- defining policy needs and, in cooperation with other stakeholders, setting priorities for internationally comparable measurement,
- using the potential of big data for developing indicators to measure the digital economy.

The authors of the above recommendations (G20 DETF, 2018, p. 10) indicate a series of crucial actions aimed to improve the quality of presented measurements.

The International Standard Industrial Classification, like the Central Product Classification, adopts a definition of the digital economy understood as the ICT, media and entertainment sectors. In general, typically for an initial phase in defining new categories, numerous approaches are observed to the conceptualization of the digital economy. However, even the impressive number of proposed definitions and their variations are insufficient to embrace the dynamic growth in digital products and services. Those definitions frequently fail to include new categories, leading to an underestimated value of economic activities based on digital products. The variation and elasticity of definitions pose an obstacle in research, which requires accurate measurements or temporal and spatial comparisons. The challenges include (1) capturing the fast-changing quality of digital services, (2) distinguishing between revolutionary and evolutionary developed digital products, (3) measuring e-commerce and (4) measuring the sharing economy (IMF, 2018, pp. 7, 17).

3.3 Data

Most of the cited authors agree that in measuring the global economy, the most useful information is provided by ICT[1] and IC[2] sector data, being both globally applicable and comparable. Consequently, seven variables are proposed to construct a taxonomic indicator of the development of states' digital economy. These include:

$\mathbf{X_1}$ – percentage of the ICT personnel on total employment in the country
$\mathbf{X_2}$ – percentage of value added (at factor cost) in the ICT sector on GDP,
$\mathbf{X_3}$ – the value of the import stream of IC sector products,
$\mathbf{X_4}$ – the value of the export stream of IC sector products,
$\mathbf{X_5}$ – percentage of enterprises that employ ICT specialists,
$\mathbf{X_6}$ – business expenditure on R&D (BERD) in ICT sector as percentage of total R&D expenditure,
$\mathbf{X_7}$ – percentage of enterprises' total turnover from e-commerce sales; without financial sector.

The ICT and IC sectors are distinguished in line with the currently applicable *Statistical classification of economic activities in the European Community* (Eurostat, 2008, pp. 164–170, 224, 252–255, 308). Imports and exports of IC products are calculated as the value of foreign trade in products manufactured by the information and communication sector (IC: 58–63). The figures are collected from the databases published by the European Statistical Office (Eurostat) and cover the years 2012–2019. This is the largest time interval for which figures are available in all of the selected categories. The following method was employed in imputing missing data for individual years:

- if the value is unavailable at a period endpoint, i.e., for the year 2012 or 2019, it is replaced with the value for the nearest year,
- if the value is unavailable in between the endpoints, it is replaced with the mean from adjacent years,
- if more than one value are missing in a sequence, all subsequent replacement values are equal and imputed as above.

Separate taxonomic indicators are constructed in four selected groups of states. These include:

- EU15+1 – member states of the European Union prior to its enlargement in 2004 plus Norway,
- EU15 – member states of the European Union prior to its enlargement in 2004,
- EU13 – the states that joined the European Union after 2003,
- EU28 – all member states of the European Union in 2019.

Certain states are excluded from the EU15+1 and EU15 groups, due to the absence of figures, namely, Ireland, Luxembourg, Portugal and Sweden (hence, the same omissions in the EU28 group). Cyprus was excluded from the EU13 index for the same reason. The EU28 index covering the entire European Union does not include the five indicated states but includes the United Kingdom (that did not withdraw from the European Union until 2020).

3.4 Presentation of analysis results

3.4.1 Descriptive statistics

The first proposed variable describes the proportion of employment in the ICT sector in the total state's employment level. The economies that are characterized by a high indicator of technological and digital development should report a high percentage of employment in that sector. In all countries covered by the study, the proportion ranged on average[3] from 1.4% in Greece to 4.4% in Malta. Almost all countries disclosed in the analysed period an increase in the indicator, ranging from about 0–0.1 percentage points (hereinafter: pp) (the Netherlands, Finland and Hungary) to 1.3–1.6pp (Estonia and Latvia). The only exception is provided by Denmark, with a drop in ICT personnel ratio by 0.5pp. A substantial majority of the EU states were characterized by a moderate but stable increase in ICT personnel, reaching an annual average of 0.06pp and 0.5pp over the analysed period of eight years. No correlation was observed between the rate of increase in employment ratio and its value for the first year analysed, i.e., a high or low base level had no effect on future rises in employment.

The second discussed variable describes the proportion of ICT value added in the state's GDP. Variation in this variable is considerably greater than that in ICT personnel percentage and ranges on average from 2.1% in Greece to 7.4% in Malta. The remaining countries mostly fall within the interval 3%–5%, disclosing average annual growth of about 0.1pp. Falls in that proportion were observed in five countries over the period of eight years: Spain, Italy, Denmark, Slovakia and Malta (from –0.1pp to –0.8pp). The remaining states achieved a growth reaching on average 0.5pp, with its largest value observed in Bulgaria and Latvia (2pp). The percentage of ICT sector employment and ICT value added on GDP are correlated. A substantial majority of countries characterized by top ICT personnel proportions also belong to the group of leaders in creating ICT value added on GDP, and the countries characterized by the lowest ICT personnel indicators disclose a small ICT value added on GDP. However, exceptions are identified, such as Bulgaria. At an impressively high ICT value added on GDP, reaching 5.4% on average (the fourth highest result), the country is characterized by one of the lowest percentages of ICT personnel (2.5%, the eighth worst result). This may indicate an enormous difference between productivity in the ICT sector and in other industries.

Table 3.1 contains mean values of ICT value added on GDP, mean values of the percentage of ICT sector employment on total employment and the quotients of those indicators. The third column is described as productivity of the ICT sector in an economy. If that indicator is greater than 1, productivity in the sector is higher than in other economy sectors. Values less than 1 would indicate lower productivity in the ICT sector than in the remaining economy. Over the analysed years, the ICT productivity indicator in all countries surveyed was greater than the average in their economies, exceeding 2 in Bulgaria where only 2.5% of employees generated more than 5% of GDP.

Table 3.1 Values of variables $\mathbf{X}_1$ – percentages of employment in the ICT sector on total country's employment, $\mathbf{X}_2$ – percentages of value added in the ICT sector on GDP and ICT sector productivity indicators in the national economies

Country	*Percentage of value added in the ICT sector on GDP*	*Percentage of the ICT personnel on total employment*	*ICT sector productivity indicator*
Bulgaria	5.36	2.48	2.16
Croatia	4.17	2.36	1.77
United Kingdom	5.85	3.42	1.71
Malta	7.37	4.42	1.67
Hungary	5.80	3.55	1.63
Netherlands	4.90	3.06	1.60
Romania	3.45	2.17	1.59
Germany	4.19	2.74	1.53
Greece	2.14	1.42	1.50
Czechia	4.39	2.95	1.49
Poland	3.27	2.24	1.46
Belgium	3.94	2.72	1.45
Slovakia	4.30	3.03	1.42
Spain	3.27	2.33	1.41
Slovenia	3.61	2.61	1.38
Italy	3.30	2.40	1.38
France	4.09	2.99	1.37
Austria	3.41	2.53	1.35
Estonia	5.04	3.86	1.30
Latvia	4.33	3.39	1.28
Finland	4.63	3.75	1.24
Denmark	4.57	3.80	1.20
Lithuania	2.87	2.39	1.20
Norway	3.39	3.00	1.13

Source: Eurostat and own calculations.

A study into the percentage of imports and exports of IC products on the total country's imports and exports leads to similar conclusions regarding the dynamics and direction of changes over time. In imports, the proportion of IC products equalled on average 1.17% of the total imports value. The highest average proportions were observed in the Netherlands and the United Kingdom (3% and 2.5%, respectively), and the lowest – in Malta and Czechia (0.43% each). An increase in the discussed proportion was observed only in eight states, the remaining economies disclosed falls. In exports, the proportion of IC products equalled on average 0.4% of the total export value. The countries characterized by top average proportions included the United Kingdom and Netherlands (1.32% and 0.98%, respectively) while Malta and Italy disclosed the lowest proportions (0.06% and 0.14%, respectively). Like in nominal values, more countries disclosed an increase in the proportion of IC product exports in total exports; IC imports compared to total imports increased in 12 states, representing one-half of the analysed group. The largest increase between 2012 and 2019 was observed in Slovenia: by 0.69pp.

The fifth proposed variable is the percentage of enterprises that employ ICT specialists. The value of this indicator is comparable in most states and equals about 20% on average. The countries characterized by top values are Belgium and Finland (27% each), and the lowest values are observed in Romania and Poland (10% and 13%, respectively). Importantly, this proportion has dropped in almost all analysed countries for years. The mean indicator value in all those countries equalled 23.2% in 2012 and 20.6% in 2019, showing an average annual drop by –0.4pp. An increase was observed over the analysed period only in seven countries (Romania, Poland, Italy, France, Bulgaria, Malta and Denmark) – between 1pp and 9pp. Considering the discussed increase in the percentage of ICT personnel on total employment, a hypothesis can be proposed: the reduction was not caused by dismissing ICT specialists, but rather by a large number of newly established businesses that could not afford hiring this type of personnel in their initial phase of operation. However, this cannot be confirmed due to the absence of data.

Another variable is the BERD in ICT sector as a percentage of total R&D expenditure. This indicator dramatically varied not only from one country to another but also in individual countries over the analysed eight years. The lowest average proportions were characteristic of Slovenia and the Netherlands (10% each), and the highest – of Malta and Estonia (50% and 44%, respectively). The mean value for all countries equalled 18% in the first and 21% in the last analysed year, showing an average annual increase by 0.5pp. A drop in the proportion of expenditure was observed in eight countries and ranged from –1.5pp to –6.5pp. The increase rates were higher, reaching even 18pp in Estonia and 33pp in Bulgaria.

The last proposed variable is the percentage of enterprises' turnover from e-commerce sales on their total turnover, without the financial sector. This indicator reflects, in addition to the development level of the digital economy, such aspects as Internet access or computer use in society. The mean indicator value ranges from a modest 3% to an impressive 29%. The lowest values were observed in Greece (3.3%), Bulgaria (4%) and Romania (6.9%), the highest – in Czechia (29%), Belgium (24.7%) and Norway (21.5%). An increase in this indicator was observed in all states, except Germany, over the analysed years – the greatest in Belgium (an increase from 14% in 2012 to 33% in 2019). The indicator rose annually in all discussed states by 0.6pp on average (a total increase in the mean value from 13% to 17.4%).

3.4.2 Taxonomic analysis results

The first method used to assess the development of the digital economy in the European countries consists of the determination of a taxonomic indicator. All variables proposed above are understood as measures (but also stimulants) of the digital economic development. Following their normalization, the taxonomic approach was adopted, based on the maximum value of the total of Pearson correlation coefficients between the taxonomic indicator Sk_t^i and standardized variables $X_{i,j}$.

$M = [m_{ij}]$ represents a matrix of values of selected variables, where m_{ij} is the value of jth variable in the kth country, where $k \equiv i(\text{mod}23)$ for the countries of UE28; $k \equiv i(\text{modl}\,1)$ for the countries of UE15; $k \equiv i(\text{modl}\,2)$. This matrix consists of 184 rows and 8 columns (EU28), 88 rows and 8 columns (EU15) and 98 rows and 8 columns (EU15+1 and EU13). Given the properties of linear congruence, we obtain the equality $k = i + 23p$, further accordingly $k = i + 11p$ and $k = i + 12p$. Let X be the matrix after standardization, done using the following formula

$$X_{i,j} = \frac{M_{i,j}}{\max(M_{i,j})},$$

where the jth column of matrix M is the stimulant. In turn, in the case of dis-stimulants $X_{i,j} = 1 - \frac{M_{i,j}}{\max(M_{i,j})}$. The taxonomic indicator Sk_t^i is given by a linear combination of standardized variables and a certain vector of weights $\omega = (\omega_1, \ldots, \omega_7)$

$$Sk_t^i = \omega_1 X_{i,1} + \omega_2 X_{i,2} + \cdots + \omega_7 X_{i,7}.$$

The vector of weights $\omega = (\omega_1, \ldots, \omega_7)$ represents the argument of a function given by the formula

$$F(\omega) = \sum_{j=1}^{7} \text{cor}(X_{i,j}, X \cdot \omega),$$

where $X \cdot \omega$ is the simple multiplication of matrix X by the vector of weights ω. As a result of the above transitions and calculations, the expected taxonomic indicator is obtained. It has to be emphasized here that the determination of the vector of weights ω is rather burdensome, and optimization algorithms are used in practice.

The macro characteristics of the digital economy described above were used to construct a taxonomic indicator of the digital economic development in the defined analytical groups. The coordinates of weights in the EU15+1 group were determined using the optimization algorithm known as local multivariate optimization and had the following values:

X_1 – percentage of the ICT personnel on total employment in the country: 0.169,
X_2 – percentage of value added in the ICT sector on GDP: 0.171,
X_3 – the value of the import stream of IC sector products: 0.111,
X_4 – the value of the export stream of IC sector products: 0.084,
X_5 – percentage of enterprises that employ ICT specialists: 0.193,
X_6 – BERD in ICT sector as percentage of total R&D expenditure: 0.135,
X_7 – percentage of online sales on total sales in the enterprise sector, without financial sector: 0.137.

The greatest weights are assigned to the percentage of enterprises employing ICT specialists (0.193), the percentage of value added in the ICT sector on GDP (0.171) and the percentage of ICT personnel on total employment (0.169). Similar weights are assigned to the percentage of online sales on total sales in the enterprise sector, excluding the financial sector (0.137) and BERD in ICT sector as a percentage of country's total R&D expenditure (0.135). The least significant variables include imports of IC products (0.111) and exports of ICT products (0.084).

The greatest average value of the indicator in the EU15+1 group was achieved in 2012–2019 by the United Kingdom (0.730), followed by Finland (0.652). Six countries achieved indicators within the range of 0.590–0.525. The lowest values of the indicator were calculated for Austria (0.449), Spain (0.446), Italy (0.396) and Greece (0.361). Similar rankings according to this criterion were obtained for both 2012 and 2019. The positions in the ranking are thus highly stable, due to a relatively short time span of the analysis (Table 3.2).

The coordinates of weights in the EU15 group have the following values

X_1 – percentage of the ICT personnel on total employment in the country: 0.164,
X_2 – percentage of value added in the ICT sector on GDP: 0.169,
X_3 – the value of the import stream of IC sector products: 0.109,
X_4 – the value of the export stream of IC sector products: 0.084,
X_5 – percentage of enterprises that employ ICT specialists: 0.195,
X_6 – BERD in ICT sector as percentage of total R&D expenditure: 0.140,
X_7 – percentage of online sales on total sales in the enterprise sector, without financial sector: 0.139.

Table 3.2 Values of the taxonomic indicator of digital economic development in the EU15+1 group in 2012–2019

EU15+1 group	*Taxonomic indicator*							
	2012	2013	2014	2015	2016	2017	2018	2019
Belgium	0.501	0.497	0.505	0.543	0.553	0.580	0.591	0.609
Denmark	0.583	0.575	0.575	0.557	0.564	0.544	0.570	0.595
Germany	0.540	0.531	0.548	0.570	0.556	0.565	0.597	0.582
Greece	0.405	0.363	0.345	0.365	0.399	0.324	0.347	0.341
Spain	0.437	0.440	0.455	0.449	0.467	0.446	0.438	0.431
France	0.505	0.493	0.546	0.573	0.603	0.610	0.611	0.577
Italy	0.384	0.386	0.376	0.401	0.401	0.403	0.404	0.411
Netherlands	0.587	0.588	0.607	0.597	0.566	0.584	0.606	0.586
Austria	0.463	0.444	0.432	0.450	0.459	0.448	0.441	0.453
Finland	0.647	0.645	0.645	0.647	0.644	0.668	0.655	0.666
Norway	0.548	0.523	0.497	0.507	0.527	0.518	0.530	0.555
United Kingdom	0.766	0.753	0.731	0.739	0.720	0.692	0.706	0.728

Source: Own calculations.

The greatest weights are assigned to the percentage of enterprises employing ICT specialists (0.195), the percentage of value added in the ICT sector on GDP (0.169) and the percentage of ICT personnel on total employment (0.164). Similar weights are assigned to: BERD in ICT sector as a percentage of country's total R&D expenditure (0.140) and the percentage of online sales on the total sales in the enterprise sector, excluding the financial sector (0.139). The least significant variables include imports of IC products (0.109) and exports of ICT products (0.084).

The greatest average value of the indicator in the EU15 group was achieved in 2012–2019 by the United Kingdom (0.726), followed by Finland (0.653). Five countries achieved indicators within the range of 0.590–0.540. The lowest values of the indicator were calculated for Greece (0.363), Spain (0.445), Italy (0.345) and Austria (0.449). A comparison of the years 2012 and 2019 demonstrates that (1) the United Kingdom and Finland retained their positions as group leaders, (2) stable positions were occupied by Denmark (the fourth place in the ranking), Austria (the eighth place in the ranking) and Spain (the ninth place in the ranking), (3) Belgium moved up considerably from the seventh place (2012) to the third place (2019), (4) the Netherlands moved down from the third (2012) to the fifth place (2019) and (5) Germany, Greece, France and Italy retained similar positions in the ranking at the beginning and end of the analysed period (Table 3.3).

The coordinates of weights in the EU13 group have the following values

X_1 – percentage of the ICT personnel on total employment in the country: 0.168,
X_2 – percentage of value added in the ICT sector on GDP: 0.178,

Table 3.3 Values of the taxonomic indicator of digital economic development in the EU15 group in 2012–2019

EU15 group	*Taxonomic indicator*							
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Belgium	0.501	0.497	0.504	0.543	0.553	0.581	0.591	0.610
Denmark	0.581	0.573	0.572	0.555	0.562	0.542	0.569	0.593
Germany	0.539	0.530	0.546	0.568	0.553	0.563	0.594	0.579
Greece	0.408	0.365	0.347	0.367	0.401	0.326	0.349	0.343
Spain	0.437	0.440	0.455	0.449	0.467	0.446	0.438	0.430
France	0.504	0.492	0.545	0.571	0.601	0.609	0.610	0.576
Italy	0.383	0.385	0.375	0.400	0.400	0.402	0.403	0.411
Netherlands	0.584	0.585	0.604	0.594	0.564	0.582	0.604	0.584
Austria	0.463	0.444	0.432	0.450	0.459	0.448	0.440	0.452
Finland	0.649	0.647	0.647	0.649	0.645	0.669	0.656	0.667
United Kingdom	0.764	0.750	0.728	0.736	0.717	0.689	0.703	0.726

Source: Own calculations.

X_3 – the value of the import stream of IC sector products: 0.141,
X_4 – the value of the export stream of IC sector products: 0.116,
X_5 – percentage of enterprises that employ ICT specialists: 0.156,
X_6 – BERD in ICT sector as percentage of total R&D expenditure: 0.114,
X_7 – percentage of online sales on total sales in the enterprise sector, without financial sector: 0.127.

The greatest weight is assigned to value added in the ICT sector on GDP (0.178), the ICT personnel on total employment (0.168) and the proportion of enterprises that employ ICT specialists (0.156). The least significant variables include BERD in ICT sector as percentage of total R&D expenditure (0.114) and exports (0.116).

The greatest average value of the indicator in the EU13 group was achieved in 2012–2019 by Malta (0.599), followed by: Hungary (0.559), Czechia (0.528) and Poland (0.508). The lowest values of the indicator were calculated for Latvia (0.394), Bulgaria (0.388), Lithuania (0.335) and Romania (0.322). A comparison of the years 2012 and 2019 demonstrates that (1) Malta and Hungary retained their positions as group leaders, (2) Poland moved up from the fifth (2012) to the third place in the group in 2019, (3) Bulgaria moved up from the 11th place in the ranking (2012) to the seventh place (2019), (4) Croatia moved down from the seventh (2012) to the tenth place (2019) and (5) Romania occupies the last place in the ranking (2012–2019) (Table 3.4).

Table 3.4 Values of the taxonomic indicator of digital economic development in the EU13 group in 2012–2019

EU13 group	*Taxonomic indicator*							
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Bulgaria	0.278	0.308	0.347	0.371	0.429	0.444	0.456	0.475
Czechia	0.524	0.509	0.504	0.518	0.525	0.544	0.533	0.565
Estonia	0.452	0.450	0.461	0.472	0.496	0.507	0.526	0.547
Croatia	0.384	0.394	0.400	0.426	0.393	0.411	0.436	0.429
Latvia	0.354	0.363	0.373	0.389	0.392	0.398	0.417	0.468
Lithuania	0.335	0.310	0.299	0.318	0.318	0.372	0.360	0.371
Hungary	0.575	0.555	0.559	0.535	0.529	0.577	0.561	0.579
Malta	0.593	0.573	0.569	0.586	0.599	0.622	0.616	0.631
Poland	0.475	0.503	0.483	0.518	0.525	0.489	0.501	0.569
Romania	0.265	0.275	0.306	0.338	0.357	0.335	0.352	0.347
Slovenia	0.363	0.378	0.391	0.407	0.414	0.432	0.457	0.451
Slovakia	0.487	0.480	0.475	0.526	0.495	0.508	0.494	0.498

Source: Own calculations.

The coordinates of weights in the EU28 group have the following values

- **X_1** – percentage of the ICT personnel on total employment in the country: 0.169,
- **X_2** – percentage of value added in the ICT sector on GDP: 0.187,
- **X_3** – the value of the import stream of IC sector products: 0.125,
- **X_4** – the value of the export stream of IC sector products: 0.097,
- **X_5** – percentage of enterprises that employ ICT specialists: 0.165,
- **X_6** – BERD in ICT sector as percentage of total R&D expenditure: 0.129,
- **X_7** – percentage of online sales on total sales in the enterprise sector. without financial sector: 0.128.

The greatest weight is assigned to value added in the ICT sector on GDP (0.187), the ICT personnel on total employment (0.169) and the proportion of enterprises that employ ICT specialists (0.165). Similar weights are assigned to BERD in ICT sector as percentage of total R&D expenditure (0.129), the percentage of online sales on the total sales in the enterprise

Table 3.5 Values of the taxonomic indicator of digital economic development in the EU28 group in 2012–2019

Country	*Taxonomic indicator*							
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Belgium	0.427	0.425	0.434	0.471	0.479	0.503	0.511	0.525
Bulgaria	0.260	0.290	0.326	0.341	0.404	0.416	0.441	0.456
Czechia	0.468	0.454	0.453	0.449	0.461	0.477	0.470	0.495
Denmark	0.498	0.492	0.492	0.477	0.483	0.468	0.490	0.511
Germany	0.486	0.477	0.495	0.518	0.503	0.513	0.548	0.531
Estonia	0.436	0.439	0.454	0.461	0.484	0.498	0.523	0.544
Greece	0.336	0.298	0.283	0.298	0.330	0.266	0.285	0.281
Spain	0.376	0.377	0.391	0.387	0.403	0.386	0.379	0.372
France	0.446	0.432	0.491	0.518	0.550	0.549	0.548	0.508
Croatia	0.350	0.361	0.365	0.379	0.353	0.372	0.399	0.404
Italy	0.326	0.328	0.321	0.342	0.341	0.344	0.345	0.351
Latvia	0.335	0.348	0.355	0.375	0.377	0.383	0.396	0.443
Lithuania	0.313	0.292	0.282	0.297	0.294	0.348	0.334	0.341
Hungary	0.521	0.504	0.507	0.473	0.460	0.494	0.505	0.520
Malta	0.600	0.580	0.576	0.591	0.605	0.631	0.625	0.637
Netherlands	0.523	0.523	0.545	0.531	0.499	0.517	0.542	0.523
Austria	0.425	0.377	0.367	0.384	0.391	0.381	0.375	0.385
Poland	0.294	0.289	0.283	0.309	0.335	0.334	0.347	0.413
Romania	0.216	0.232	0.254	0.280	0.297	0.277	0.297	0.298
Slovenia	0.337	0.331	0.339	0.349	0.351	0.359	0.364	0.363
Slovakia	0.408	0.402	0.383	0.421	0.407	0.431	0.417	0.429
Finland	0.539	0.536	0.537	0.539	0.537	0.557	0.548	0.558
United Kingdom	0.699	0.687	0.664	0.675	0.652	0.620	0.633	0.652

Source: Own calculations.

sector (0.128) and imports (0.125). The least significant variable is ICT exports (0.097). The weight structure and values are similar to those in the UE15+1 group.

The greatest average values of the indicator in the EU28 group were achieved in 2012–2019 by the United Kingdom (0.660) and Malta (0.605). They are followed in the ranking by Finland (0.544), the Netherlands (0.525) and Germany and France (a similar level of 0.510). In the statement of mean values for the analysed period, Poland (0.326), Lithuania (0.313), Greece (0.297) and Romania (0.269) occupy the last four places in the ranking. Events between 2012 and 2019 showed (1) stable positions of the United Kingdom, Malta and Finland as ranking leaders, (2) significant progress in Poland, from the 21st (2012) to the 15th place (2019) and (3) considerable move down in the ranking of Spain from the 14th to the 18th place, Austria from the 12th to the 17th place and Greece (from the 17th to the last place in the list) (Table 3.5).

3.5 Conclusion

The analyses conducted in this chapter lead to the following conclusions. First, the current approach to measuring the digital economy, adopted by international organizations (OECD, IMF and ITU), is broad and addresses its various aspects: infrastructure, employment and digital applications. The infrastructural context includes physical, service and security infrastructure. The aspects of employment, digital skills and labour market are operationalized using, e.g., the number of jobs in the ICT sector, the number of individuals teleworking from home or the digital skill level. Technological innovation (applications) is quantified in terms of e-commerce or robotization in manufacturing.

Second, in measuring the global economy, the most useful information is provided by ICT and IC sector data, both being globally applicable and comparable. A substantial majority of the EU states were characterized by a moderate but stable increase in ICT personnel in the years 2012–2019. The percentage of ICT sector employment and ICT value added on GDP are correlated. A substantial majority of countries characterized by top ICT personnel proportions also belong to leaders in creating ICT value added on GDP, and the countries characterized by the lowest ICT personnel indicators disclose a small ICT value added on GDP.

Third, the completed taxonomic analysis demonstrates that the UE15+1 group was characterized in 2012–2019 by highly stable ranking positions of the countries (probably due to a relatively short time span of the analysis).

Notes

1 NACE Rev. 2, (2008): ICT Manufacturing (26.1 + 26.2 + 26.3 + 26.4 + 26.8) and ICT Services (46.5 + 58.2 + 61 + 62 + 63.1 + 95.1).
2 NACE Rev. 2, (2008): Section J—Information and Communication (IC): 58–63.
3 The mean for a country in 2012–2019.

References

Bukht, R. & Heeks, R. (2017). Defining, conceptualising and measuring the digital economy. *International Organisations Research Journal*, *13*(2), 143–172. https://doi.org/10.17323/1996-7845-2018-02-07.

Carlsson, B. (2004). The digital economy: What is new and what is not? *Structural Change and Economic Dynamics*, *15*(3), 245–264. https://doi.org/10.1016/j.strueco.2004.02.001.

Eurostat (2008). *NACE Rev. 2, Statistical Classification of Economic Activities in the European Community*. European Communities. ISBN: 978-92-79-04741-1. Available at: https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-ra-07-015.

G20 Digital Economy Task Force (DETF) (2018). *Toolkit for Measuring the Digital Economy*. Available at: https://www.oecd.org/g20/summits/buenos-aires/G20-Toolkit-for-measuring-digital-economy.pdf.

IMF (2018). *Measuring the Digital Economy*. Policy Paper, Washington, DC. Available at: https://www.imf.org/en/Publications/Policy-Papers/Issues/2018/04/03/022818-measuring-the-digital-economy.

ITU (2020). *Manual for Measuring ICT Access and Use by Households and Individuals*. ISBN: 978-92-61-30861-2. Available at: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/manual.aspx.

Kling, R. & Lamb, R. (2000). IT and organizational change in digital economies. In E. Brynjolfsson & B. Kahin (Eds.), *Understanding the Digital Economy* (pp. 295–324). MIT Press. https://doi.org/10.7551/mitpress/6986.001.0001.

Koch, T. & Windsperger, J. (2017). Seeing through the network: Competitive advantage in the digital economy. *Journal of Organization Design*, *6*(1), 1–30. https://doi.org/10.1186/s41469-017-0016-z.

Nathan, M., Rosso, A., Gatten, T., Majmudar, P. & Mitchell, A. (2013). *Measuring the UK's Digital Economy with Big Data*. National Institute of Economic and Social Research. Available at: https://www.niesr.ac.uk/wp-content/uploads/2021/10/SI024_GI_NIESR_Google_Report12.pdf.

OECD (2020). *A Roadmap toward a Common Framework for Measuring the Digital Economy: Report for the G20 Digital Economy Task Force*. OECD Publishing. Available at: https://www.oecd.org/sti/roadmap-toward-a-common-framework-for-measuring-the-digital-economy.pdf.

Turcan, V., Gribincea, A. & Birca, I. (2014). Digital economy – A premise for economic development in the 20th century. *Economy & Sociology: Theoretical & Scientifical Journal*, *2*, 109–115. Available at: https://ince.md/uploads/files/1455540156_14.turcan109_115.pdf.

Zhenlong, M. (2021). Digital economy value chain: Concept, model structure, and mechanism. *Applied Economics*, *53*(37), 4342–4357. https://doi.org/10.1080/00036846.2021.1899121.