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Article

Digital skills as sustainable frame of human resource competitiveness: A comparative approach

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Abstract: Imagining people's functions in everyday life and work without the use of ICT, seems difficult. Their application is ubiquitous everywhere, regardless of which aspect it is viewed from, because it has a strong function in ensuring the competitiveness of various systems at the micro and macro levels. Numerous national and multinational strategies try to encourage educational systems to put a greater focus on ICT to more efficiently acquire skills, competencies, and knowledge, which should represent added value to all generations in the future. This article analyzes the progress of the ICT development index (IDI) in Scandinavian countries by comparing these countries in the European region. It is known that the Scandinavian countries belong to that part of the countries that have recognized the importance of involving ICT in education programs, which improves the economy of a certain country. Given this, the research reveals how ICTs play a key role in improving socio-economic development in Scandinavian countries.

Keywords: ICT development index (IDI); Scandinavian countries; comparison; education

1. Introduction

Technological innovations have significantly contributed to the increasing implementation of ICTs in everyday life, including in economic sectors (Portolan and Stanković, 2023; Shankar et al., 2021). The use of ICTs is becoming more and more widespread, and their dynamic development constantly brings new global trends. Consequently, the consequence of this is the strengthening of the skills of people who need to acquire them to be able to use them as well as possible (Alrawadieh et al., 2021). In the educational aspect, ensuring greater digital literacy of teachers is a result of the convergence of the impact of ICTs on learning, thus improving the teaching plans and programs in the educational curricula. (Jacobsson and Linderoth, 2021). Such effects on students lead to the skills of knowledge about creativity in work and the strengthening of individual expression following the dynamics of technological changes in society. However, all this can only be achieved with quality attention to investments in infrastructure aligned with the strategy of efficient ICT implementation (Erguzen et al., 2018).

ICTs have very quickly developed the interaction of people with the whole world and made many work and life processes more accessible, simpler, easier, hence today it is difficult to accept knowledge that does not exist. (Jacobsson et al., 2017; Tømte et al., 2020). Technological innovations of the last decade played a major role in shaping different business systems (Portolan and Stanković, 2023). It is difficult to imagine any business system in which the Internet and the use of modern technologies are not represented. ICTs have created a revolution in almost all functional units of the company, and especially in those departments whose business is related to the relationship with end users (Shankar et al., 2021). Innovations force companies to rethink the way they do business because, among other things, consumer demands change with the advent of new technologies (Atkinson, 2020). Retailers have often been among the first to adopt new technologies as such innovations have fueled some significant disruptions in the sector, and the most changes are visible in the information ability of consumers (Aslam, 2023). The adoption of ICTs aims to extract useful information from users and offer opportunities to enhance the online experience based on which an important relationship with retailers is established (Sharma et al., 2020). As a result, today's shoppers can order online through voice assistants (VA), use augmented reality (AR) to virtually try on products, have packages delivered by autonomous vehicles and drones, or shop in stores without a cash register. It is certainly important to emphasize that the ICTs used in the business of retail stores have a strong connection with marketing strategies because the right actions would contribute to greater customer trust in retail technologies (Aw et al., 2022).

Also, it should be mentioned the strong effect of ICTs on the hotel and catering industry in recent years, which is certainly the cause of the dynamic trend of applying new technologies in terms of the progress of all components of the organization, starting from business processes, through the strategy and structure of human resources (Portolan and Stanković, 2023). ICTs benefit everyone in the business system as well as in the environment, therefore guests can search and buy customized hotel services more efficiently, while it allows suppliers to manage and develop product distribution without space and time restrictions using effective digital tools (Yorkulov et al., 2022). The advantages that ICTs provide to the hotel industry are great, from the point of view of using the Internet, the costs are low, which allows anyone to use it for any purpose, such as: obtaining information, training on the web, purchasing products, and assistance (Alrawadieh et al., 2021). From the aspect of demand for accommodation, innovations have enabled users of hotel services to, based on their budget and free time, more easily research the locations of destinations, accommodation units, and transportation options and thus make more effective travel decisions (Pizam et al., 2022; Verhoef et al., 2021).

In addition, insufficient involvement and recognition of business and life situations about the using ICTs leads to, on the one hand, a low level of work productivity, while on the other hand, there may be a danger of a lack of expedient timely information and wasting time in search of relevant information. (Technology for Inclusion - UNESCO Digital Library, 2023). The role of ICT is so strong that it becomes a functional condition for the business of companies and the life of society as a whole, as it enables quality management of resources and effective communication. (Christensson et al., 2013). Furthermore, ICTs change the structure of the labor market by engaging different types of work and making decisions for education, life needs, and the like. For most individuals, ICT competence and knowledge are increasingly important as the ability to work with digital tools and technologies becomes essential for all aspects of people's lives. (Jacobsson et al., 2017). They are recognized as the fundamental form of education today in the modern era, so their adoption from an early age is of great importance for every country.

The countries of the Scandinavian region are certainly recognized as an example of such development and progress countries of ICTs (Christensson et al., 2013). That region stands out for its efficient breakthrough in the world in terms of the applicability of digital technologies, because the institutions of those countries have set strategies whose main goals are to influence the mindset and habits of the population regarding the use of ICTs (Hatlevik and Hatlevik, 2018; Khetarpal, 2015). Scandinavian countries' strategies include programs for shaping the digital future and the progress of technologies that will have a significant impact on everyday life (Hatlevik and Hatlevik, 2018). There is a special focus on the activities of achieving digital skills from an early age, creating people's habits to possess a certain level of digital literacy (Hunady et al., 2022; Tømte et al., 2020). Furthermore, educational institutions should be the initiators that will influence the awareness of young people to use ICTs for appropriate purposes to build a better and more capable staff that will improve the company's operations in the future (Chaidi et al., 2021).

The entropy weight method and the ITU framework are both approaches used in decision-making and multi-criteria analysis, but they differ in their underlying principles and applications. It provides a systematic approach to incorporating subjective judgments and uncertainty into environmental management processes (Aras and Yildirim, 2022). However, the method of entropy weights is used more when measuring the degree of uncertainty or randomness associated with certain fluctuations (Mi et al., 2021). Aras and Yildirim emphasize the objectivity of applying the entropy weight method in integrated reporting on the capital market and in measuring the financial performance of companies. The aforementioned study proved the high applicability and significance of the method of entropy weights in research for the observed period from 2014 to 2017 on the capital market. Also, Mi et al. 2021 use a quantitative risk assessment method not based on entropy weights for safety integration of a typical industrial control system (Mi et al., 2021). The ITU framework is specific to the telecommunications industry and differs from the entropy weight method in particular in its scope, approach, and purpose of use (ITU 2017 Global ICT Development Index, 2017). This framework offers guidelines and standards specific to the Telecommunications industry and the Information and Communication Technologies sectors, with the expectation that it will also be applied in the financial sector and accounting, specifically in the development of Internet and mobile banking (Srivastava, 2011). The technical, regulatory, and economic considerations offered by the ITU framework can assist in accounting regulation (International Telecommunication Union Digital Watch Observatory, 2022). The important application of the ITU framework is also recognized in studies related to cybersecurity and child protection on the Internet. Experts from the International Telecommunication Union believe that this framework is suitable for monitoring the digital divide between ICTs and climate change in business (International Telecommunication Union Digital Watch Observatory, 2022).

The main goal of this research is to present methods of examining ICT development in the region that was mentioned as one of the most potent in this topic, namely Scandinavia, with the ICT Development Index (IDI) indicators. The methods of entropy weight and the ITU framework for calculating the ICT Development Index (IDI) attempt to determine the level and dynamics of ICT development in a certain region and the development potential presented by the indicators of the IDI sub-index for strengthening the growth of ICT skills and abilities within a particular country. In addition, an attempt is made to demonstrate the development gap in countries and the differences between countries concerning the development of ICTs at the regional level.

2. Methodology

This part of the article provides an overview of the methods used to evaluate ICT development index (IDI) values and the way index values are interpreted with different areas of indicator observation. The research considers two methods for calculating the ICT Development Index (IDI), one is an established method formatted by the ITU side and the other one is a proposed integrated calculation method based on entropy weight. A method of entropy weight coefficient, which represents the mean value of all data collected stochastically. Data entropy is the expected value of the random variables that gives the sum of the collected data and it is reliable when there is an equal probability for happened cases (Deng et al., 2020; Mercurio et al., 2020). This theory was presented by Shannon in his work from 1948, "A Mathematical Theory of Communication. The theory is based on the elements of the process of obtaining the desired data, which are the data source, the collection method, and the data recipient (Shannon, 1948; Weawer, 1953). Often the context of the obtained data is quite subjective, hence the entropy weight method is applied to create an objective character among the data (Aras and Yildirim, 2022; Erkhembaatar and Otgonbayar, 2021).

Thus, the data ranking is more meaningful for interpretation. To neutralize the subjectivity of opinion with entropy weight, the steps are given in the relations:
where x_{ij} are elements of the matrix *R*; *x* represents the value of the *j*-th sample and the *i*-th indicator.

$$Rij = (xij)mxn \tag{1}$$

With the normalization process, operators are obtained:

$$\begin{cases} d_{ij} = x_{ij} \mid max\, x_{ij}\ , positive\ value \\ d_{ij} = x_{ij} \mid min\, x_{ij}\ , negative\ value \end{cases} \tag{2}$$

The new matrix is:

$$D_{ij} = (d_{ij}) \tag{3}$$

The relative weight of x_{ij} is:

$$Y_{ij} = (Y_{ij}) \tag{4}$$

$$y_{ij} = {d_{ij}}\Big/{\sum_{i=1}^{m} d_{ij}} \tag{5}$$

The properties of entropy weights are extreme values, in the case of high dij, entropy values are high and the uncertainty of the assessment is high as well. The entropy value is obtained based on the following relation:

$$D_{ij} = (d_{ij})_{mxn} \tag{6}$$

where *k* is a positive constant coefficient, then *E* fluctuates from 0 to 1; $0 \leq E \leq 1$. In addition, the weight is obtained from the value of the index that is related to certain information defined by the entropy weight method, therefore the weight index is obtained by the relation:

$$w_i = \frac{1 - E_i}{\sum_{i=1}^{m}(1 - E_i)} \quad (7)$$

The indices obtained are indicator values of the observed phenomenon, in this way the indices of ICT development are presented, the interpretation and analysis of which is provided for the part related to the research results. Otherwise, the entropy theory has a strong effect when taking into account the association between measures that are observed simultaneously. In this context, it is a recognizable instrument for quantifying large and highly fluctuating dana (Niepostyn and Daszczuk, 2023). Measuring indicators of ICT development provides great benefits for examining the real impact of technologies in society. They show high reliability and show the actual situation in terms of technical readiness for further stages (Measuring ICT: The Global Status of ICT Indicators Eldis, 2020). Their assessment and implementation are cost-effective and could be beneficial for the country.

Table 1. ICT Development Index (IDI): framework for indicators and weights by ITU methodology.

Description of indicators	Code	Weights (Indicators)	Weights (Sub-index)
		ICT access sub-index (*L*)	
Fixed-telephone subscriptions per 100 inhabitants	A1	0.20	
Mobile-cellular telephone subscriptions per 100 inhabitants	A2	0.20	
International Internet bandwidth (bit/s) per Internet user	A5	0.20	0.40
Percentage of households with a computer	HH4	0.20	
Percentage of households with Internet access	HH6	0.20	
		ICT usage sub-index (*M*)	
Percentage of individuals using the Internet	HH7	0.33	
Fixed (wired)-broadband subscriptions per 100 inhabitants	A3	0.33	0.40
Active mobile-broadband subscriptions per 100 inhabitants	A4	0.33	
		ICT skills sub-index (*N*)	
Mean years of schooling rate	S1	0.33	
Secondary gross enrolment ratio	S2	0.33	0.20
Tertiary gross enrolment ratio	S3	0.33	

Based on the theoretical presentation of how the method for calculating the ICT development index was developed, ITU is officially in charge of assessing the IDI of countries in the world. The assessment of the index is intended to present changes in countries with different ICT growth rates in the world and builds on precisely determined data that which country can easily collect and whose analysis can be committed with high reliability (ITU 2017 Global ICT Development Index, 2017).

The mentioned ITU framework with a description of included indicators and their weight values is given in **Table 1**. It is of great value for each country when there is a growing trend in the implementation and development of ICT, observing society and the economy. The structure of the IDI concept is established and contains a unique representation consisting of three sub-indices and eleven indicators.

After collecting the data required for the calculation of all sub-indexes for a given country, the final calculation of the ICT development index (IDI) for that country can be accomplished based on the value of the sub-index, hence the calculation is performed as follows:

$$IDI = ((L * .40) + (M * .40) + (N * .20)) * 10 \tag{8}$$

Source: itu. int; 25.03.2023.

For the research, the ICT development index (IDI) in the Scandinavian countries is analyzed along with three sub-indexes and the mentioned indicators that are represented in the framework. The research is based on secondary data collected on the official website of the ITU, which is authorized to research and analyze IDI for countries in the world. The ITU methodology defines the IDI indicator weight (Deng et al., 2020). IDI and ICT indicators were assigned equal weight when calculating the access and usage sub-indices. ICT access and usage sub-indices each received 40% of the total weight. The ICT skills sub-index was given 20% less weight because it is built on proxy indicators (ITU | 2017 Global ICT Development Index, 2017). The study findings for the ICT indicators are used to determine the weights of the indicators (Erkhembaatar and Otgonbayar, 2021).

Consider that eleven IDI indicators in total need to be evaluated (OECD, 2014). The analysis of the IDI was performed by the entropy weights method and the framework set by the ITU for the Scandinavian countries in 2017. The ranking of each Scandinavian country is acted according to the order it occupies, observing the indicators for the Europe region. Moreover, a graphical analysis of the entropy weight values for individual sub-indexes of a Scandinavian country is performed and a comparison of the IDI values from ITU methodology for the entire European region is presented.

3. Results

The results of the research, analyzing the assessment of IDI according to the data of eleven indicators and three sub-indexes that were collected for the Scandinavian countries, respectively for Denmark, Finland, Norway, and Sweden, and an attempt is made to show the changes in the countries and the region that occur under the means of different effects of ICT. The values of the sub-indexes at the entire level of the European region are presented to compare the IDI and three sub-indexes with the countries of the Scandinavian region. Indicators for the calculation of each sub-index of ICT development are required to calculate the value of the sub-index of each Scandinavian country and the associated entropy weight.

The entropy values for indicators of IDI access sub-index of Scandinavian countries are displayed in **Figure 1**. A horizontal axis shows the four Scandinavian countries, Denmark, Finland, Norway, and Sweden, while a horizontal axis shows the entropy values of indicators A1, A2, A5, HH4, and HH6. The indicator A1, which refers to fixed-telephone subscriptions per 100 inhabitants, has a value from 0.03 to 0.11. The indicator A2, representing mobile-cellular telephone subscriptions per 100 inhabitants, this value ranges between 0.18 and 0.22. A5 indicator-International Index bandwidth (bit/s) per Index user has a value from 0.14 to 0.18. The value of HH4 linked with the percentage of households with a computer is 0.16 to 0.20. For the HH6 indicator percentage of households with Index access, the value varies between 0.17 and 0.20.

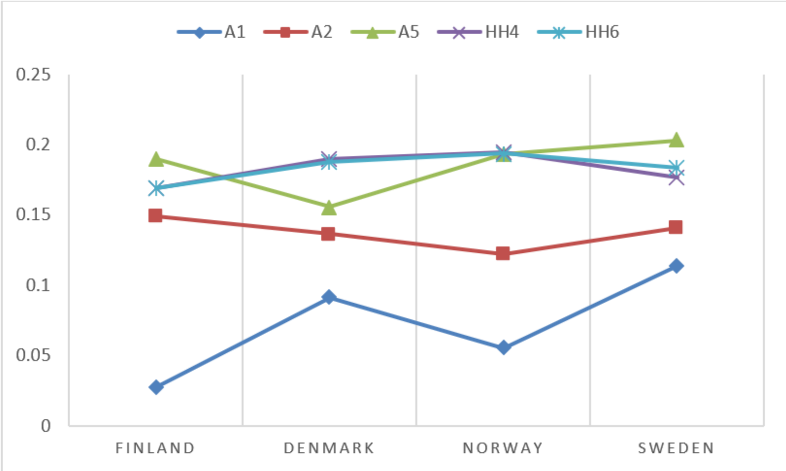

Figure 1. Entropy values of IDI indicator – ICT access sub-index for Scandinavian countries.

Source: Authors' work.

Figure 2 presents the entropy values for indicators of IDI usage sub-indexes in the Scandinavian region. These countries are shown on the horizontal axis, and the entropy values of indicators HH7, A3, and A4 on the horizontal axis. The HH7 indicator refers to the percentage of individuals using the Internet and has a range of values from 0.26 to 0.32. For indicator A3, representing fixed (wired)-broadband subscriptions per 100 inhabitants, the values range from 0.17 to 0.24, while indicator A4, linked with active mobile-broadband subscriptions per 100 inhabitants fluctuates from 0.26 to 0.50.

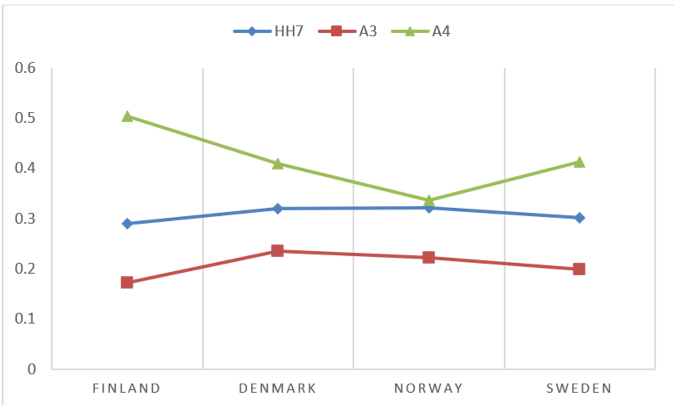

Figure 2. Entropy values of IDI indicator-ICT usage sub-index for Scandinavian countries.

Source: Authors' work.

Figure 3 demonstrates the entropy values for indicators of IDI skills sub-indexes in Scandinavian countries. The horizontal axis shows three indicators S1, S2, and S3, which are included in the IDI sub-index related to ICT skills, and the vertical axis shows the Scandinavian countries. Considering the observability of the S1 indicator - mean years of schooling rate, the values range from 0.25 to 0.38. The S2 indicator that represents the secondary gross enrolment ratio has values from 0.36 to 0.49, while the S3 indicator referring to the tertiary gross enrolment ratio has values in intervals from 0.21 to 0.29. The highest entropy value for the indicators of the IDI sub-indexes is 0.50 for the indicator A4-active mobile-broadband subscriptions per 100 inhabitants in-cluded in the indicators of the IDI sub-index for ICT usage. Furthermore, the lowest entropy value belongs to indicator A1-fixed telephone subscriptions per 100 inhabi-tants of the IDI sub-index for ICT access with a value of 0.03.

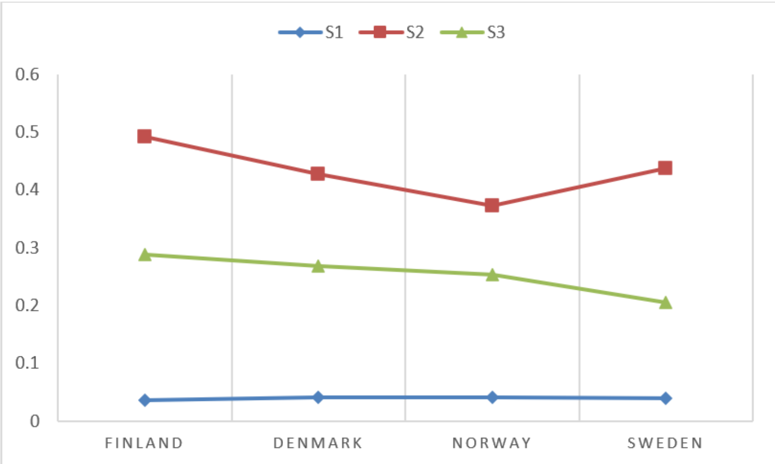

Figure 3. Entropy values of IDI indicator-ICT skills sub-index for Scandinavian countries.

Source: Authors' work.

The reference values of the sub-indices' indicators, their entropy weights, and the dif-ferences between the weights for the countries of the Scandinavian region are given in **Table 2**. According to **Table 2**, the differences in the percentage weights of sub-indices from IDI and ITU are presented based on the entropy methodology for calculating IDI and indicators and sub-indices for weight assessment. Results of differences between indicators for the ICT access sub-index are: (–0,38–5,59); for the ICT usage sub-index (–1,21–1,19); for the ICT skills sub-index (–1,92–6,83). The indicators differences indicate the highest variation in sub-indices related to ICT skills for the Scandinavian region based on entropy weights. As for the differences in percentages for sub-indexes, the ICT skills sub-index deviates the most with 9.98 percent, which reflects the discrepancy between the calculation method of entropy weights and the ITU methodology.

Table 2. ICT Development Index for Scandinavian countries: indicators, weights, differences.

Description of indicators	Indicator's codes	%	W_i, %	Difference indicators in percentages, %	%	W_i, %	Difference sub-index percentages, %
ICT access sub-index							
Fixed-telephone subscriptions per 100 inhabitants	A1	20	14.407	5.592	40	–43.89	–3.89
Mobile-cellular telephone subscriptions per 100 inhabitants	A2	20	23.735	–3.735			
International Internet bandwidth (bit/s) per Internet user	A5	20	20.377	–0.377			
Percentage of households with a computer	HH4	20	22.622	–2,622			
Percentage of households with Internet access	HH6	20	22.742	–2.742			
ICT usage sub-index							
Percentage of individuals using the Internet	HH7	33.33	33.165	0.165	40	39.86	0.14
Fixed (wired)-broadband subscriptions per 100 inhabitants	A3	33.33	32.145	1.185			
Active mobile-broadband subscriptions per 100 inhabitants	A4	33.33	34.535	–1.205			
ICT skills sub-index							
Mean years of schooling rate	S1	33.33	28.255	5.075	20	10.02	9.98
Secondary gross enrolment ratio	S2	33.33	35.247	–1.917			
Tertiary gross enrolment ratio	S3	33.33	26.505	6.825			

Source: Authors' work.

Table 3 presents the values of IDI sub-indexes by ITU methodology for each Scandinavian country and for the whole of Europe, which were calculated using the relation based on percentages and reference values of the IDI sub-indexes and their indicators. The mutual ranking of Scandinavian countries and the ranking of these countries at the European level according to IDI value are analyzed. Denmark has the highest IDI value among the Scandinavian countries, which is 8.71, and at the European level, it occupies a high position with third place. The highest values of ICT usage sub-index and ICT skills sub-index were displayed in that country (Denmark), while Norway has the highest value of ICT access sub-index.

Table 3. ICT sub-indexes, IDI values, rankings by country and region.

Country; Region	ICT access sub-indeks	ICT usage sub-index	ICT skills sub-index	IDI value	Rank in the Scandinavian region (4 countries)	Rank in Europe (40 countries)
Denmark	8.39	8.94	8.87	8.71	1	3
Finland	7.35	7.99	8.73	7.88	4	15
Norway	8	8.82	8.71	8.47	2	6
Sweden	8.55	8.4	8.15	8.41	3	8
Europe 40	7.8	6.94	8.02	7.5	-	-

Source: Authors' work.

Regarding IDI value, Sweden is second according to this criterion, and Finland has the lowest IDI value among other Scandinavian countries. It is established that the analyzed countries of the Scandinavian region are among the half of European countries that have a higher IDI value, even three Scandinavian countries are in the top 10 at the European level according to this norm.

4. Discussion

In recent years, digital skills have become the focus of attention for human social and entrepreneurial competence, especially after the COVID-19 pandemic, the impact of which has contributed to many people dedicating themselves to creating or improving their digital skills. Some skills that were not necessary for performing tasks are now extremely important and of particular relevance, such as communication in online and offline environments or organizational skills (Štofková et al., 2022).

As the development of ICT has a strong impact on the creation of more jobs, especially in the sector IT, but also in other sectors such as commerce, hospitality, industry, and healthcare, this impact simultaneously contributes to faster economic growth and prosperity of countries (Štofková et al., 2022). Therefore, the developed economies that have recognized this scenario have tried to promote digital skills in education through their policies, primarily targeting the younger population that represents the future workforce in the labor market. This study, which focuses on evaluating and comparing the ICT Development Index (IDI) with other European countries, presents the economies of the Scandinavian countries. However, it is now disputed whether the ITU's methodological framework, which contains three sub-indices, is relevant enough for evaluating the IDI or whether the conventional entropy weighting method is a more effective indicator for the IDI.

Although the development of ICT and the implementation of digital technologies for companies means the automation of business activities, which increases labor productivity, the status of certain occupations is lowered in this way, namely those for which automation simplifies work tasks. This is precisely why there is a change in the structure of the work in the form of increasing demand for jobs, i.e. the supply of jobs that require a greater dimension of digital competencies (Spencer et al., 2021).

However, the issue of access to digital technologies and opportunities for creating digital skills and their application is very important. Certain social classes because of their discriminatory living conditions do not have access to the Internet or the training to access it, especially among the poor population or the elderly (Sanders and Scanlon, 2021). Based on this, the cooperation between the private and public sectors of the country is crucial to improve the digital skills of the population through various measures, whether it is the strengthening of infrastructure or educational policies. They should be focused on mobile and internet coverage, higher internet speed, higher quality digital education, and greater digital literacy, which would greatly satisfy the future needs of everyday life (Fernández-Portillo et al., 2020; Spencer et al., 2021).

According to some authors (Fernández-Portillo et al., 2020; Sanders and Scanlon, 2021; Štofková et al., 2022), the potential lack of adaptation in digital skills creates obstacles both in everyday life and in the business sense. First of all, the risk of possible weak digital literacy in today's digital technologies can create stagnation in the personal growth of the population of a country, and also negatively affect the tendency of the demand for work in finding jobs in the market (Sanders and Scanlon, 2021). At least today there are many platforms that people can easily access to improve their digital skills. While in the wake of the dynamic trend of technological changes, formal education institutions adapt relatively slowly, informal education can play a key role because it offers young people opportunities for training and adaptation to market conditions (Spencer et al., 2021; Štofková et al., 2022). Educational institutions have a great responsibility when it comes to digital skills because they need to improve education methods without delay by designing more practical and personalized education programs based on digital technologies. Many authors agree that people need digital skills to be able to find high-quality work and they are not only crucial for education and health but also for the entire industry (Fernández-Portillo et al., 2020). Moreover, it is important to measure digital skills to analyze their development, especially among the younger population, that is, the segment that goes through the process of education, either formal as mandatory or informal in the form of some training and continuing education.

Regional characteristics can significantly influence the development of ICTs and socioeconomic results, and the consideration of influencing factors enriches the analysis of the ICT Development Index (IDI). A certain level of disparity in infrastructure, such as access to electricity, Internet connectivity, and telecommunication networks, affects the very development of ICTs (ESCAP, Inequality in Access to Information and Communication Technologies (ICTs) in East and North-East Asia and South-East Asia, 2021). For example, in Finland, the construction of buildings, parks, and roads with optical sensors is mandatory (Mobaraki et al., 2021). In Scandinavian rural areas or less developed regions (the territory of the North Pole, Nordic cap, etc.) there is a very limited infrastructure compared to urban areas, which leads to a disparity in the adoption and use of ICT at the regional and local level (ESCAP, Inequality in Access to Information and Communication Technologies (ICTs) in East and North-East Asia and South-East Asia, 2021). The above also contributes to the digital divide, where certain populations of people or areas have limited access to ICT resources and opportunities, so respecting regional specificities in the development of ICT would help in reducing the digital divide and promoting inclusive growth where resources for the development of ICTs are more limited (Castillo et al., 2019). Also, differences in regulatory regulations and taxation can shape the pace and direction of ICT development in different parts of countries or states (Annual Report on Taxation-European Commission, 2023).

Scandinavian countries belong to those countries where socioeconomic factors such as income levels, employment opportunities, and economic growth are favorable (Gärtner and Prado, 2016; Why Are Nordic Countries So Happy?, 2023). Such factors represent the basis of the demand for information technology services and are a prerequisite for the ability of individuals and companies to invest in ICT infrastructure and skills development (Du et al., 2022). The development of skills affects the literacy and expertise of the society itself when it comes to the use of ICTs, which is one of the important features that the governments of the Scandinavian countries have recognized and thus invested in educational programs (Proposal for a Council Recommendation, 2023). Generally speaking, at the world level, the implementation and development of ICTs for public purposes is an important lever for governments to be effective in gaining the trust of citizens on the border (Fischer et al., 2013). Digitization of public services is of particular importance for the public of every country. In this way, the development of ICTs and access to basic services such as health care, education, and public services (e-learning, e-administration, etc.) is influenced (Gasco-Hernandez et al., 2022; Matsudaira and Koh, 2022). Furthermore, collaborations between the government, the private sector, the academic community, and civil society organizations are key to fostering ICT development. Adapting partnerships to regional contexts and priorities can leverage local expertise and resources to achieve sustainable development solutions (Fischer et al., 2013; Wimmer et al., 2020).

The development in the information and communication technology (ICT) sector has led to significant changes in production methods and employment patterns across the European Union (EU). ICTs play a significant role in determining the competitiveness of economies based on knowledge and information (Erika, 2021). This is why Eurostat insists that it is very important to measure the development in the information and communication technology sector using the ITU methodological framework and to dynamically evaluate the IDI coefficient itself to better monitor the trend of the development of ICTs and the efforts that countries invest to achieve the desired goals of digital development (Muszyńska-Spielauer and Spielauer, 2023). Certainly, Eurostat recommends a certain possibility of modifying the weight percentages of the indicators that enter the IDI calculation, depending on the direction and scope of the state's tendency to strengthen digital development.

Based on the reviewed works (Fernández-Portillo et al., 2020; Štofková et al., 2022) that dealt with the issue of calculating the IDI indicator for certain regions of the country, this part of the paper considers possible limitations and potential modifications for the ITU methodological framework that is used to calculate the IDI indicator. Regarding the conducted research in which the ICT development index (IDI) was measured for the region of the Scandinavian countries through two different calculation methods, this part of the paper discusses the modification of the calculation method when calculating the IDI for certain countries or regions (Muszyńska-Spielauer and Spielauer, 2023). It also tries to give an insight into certain shortcomings and recommendations based on practical evidence in some works, in the measurement of IDI by Eurostat using the ITU methodological framework.

The IDI indicator of ICT development is intended to assess the adaptive use of ICTs among the population of a certain country and is not suitable for measuring the digital divide. In this way, the usefulness for policymakers is questionable, while for the transparency of the system, it is an ideal way to focus on measuring the actual acceptance and benefits of ICTs in a less complex way. IDI treats all its components as if they were entirely on the same conceptual footing (Muszyńska-Spielauer and Spielauer, 2023). As a result, it engages in double counting, confuses the role of means and ends, sums dependent and independent variables, and generally adds rather than multiplies its constituent parts. That is why it is of great importance, especially for the ITU methodological framework, to include certain items in the indicators for the digital divide and to revise the weights when calculating the sub-index. Therefore, future research should include certain sub-indicators within the IDI calculation, such as the perception of the readiness to use ICTs in order to obtain a more complete context of the willingness and conditions among the public when it comes to the use of new technologies. At the ITU, for a certain number of measures that enter the weight value of the indicator, they lead to overlap, hence it is difficult to harmonize the data in the context of econometric models and estimates for association and causal explanations (Erika, 2021). First of all, for such a case, a factor analysis can be performed to isolate the key constructs and identify those indicators that are redundant. Further research should refer to the separation of constructs when measuring the IDI and look at each indicator separately as a whole, especially in those studies of those regions or countries where there is a high level of amplitude between individual sub-indicators within the calculation. However, the lack of similarity in the choice of factors and indicators among different indices with a single-item measure may be due to the lack of a common conceptual basis, which raises the question of the reliability and validity of the framework. For example, indicators using the network readiness index are environment, readiness, and usage, while those using digital access are infrastructure, accessibility, knowledge, quality, and usage (Koivunen et al., 2022).

In the case of the author's research (Fernández-Portillo et al., 2020) for the group of countries of the Iberian Peninsula, namely Spain, and Portugal, a gap is revealed between the current needs and the actual level of digital skills and development of ICTs, which were measured by the ITU methodological framework for IDI. Although the use of ICT has increased, the labor market and future careers require higher levels of digital skills. The limitation of the ITU methodological framework in the research according to the authors (Fernández-Portillo et al., 2020) is the absence and neglect of measuring the affirmation of ICTs for professional purposes, especially among those workers whose knowledge of digital skills at work is extremely important and crucial for their business tasks. When calculating the IDI indicators of ICT development in the countries of Spain and Portugal, the ITU framework is supplemented with an ICT adaptation indicator for those activities that are related to the IT sector. According to the authors (Fernández-Portillo et al., 2020), adding the mentioned indicator to the modified IDI calculation gives a better impression of the affirmation of ICTs among private companies whose business is related to the IT sector.

The authors (Gerpott and Ahmadi, 2015) compared the development of ICTs in developed countries and developing countries. They stated the existence of many other additional factors that have the potential to significantly explain the level of development of ICTs in countries about the nature of economic development. The biggest limitations of the ITU framework in the research are the accessibility of ICT services, bypassing the concept of the quality of ICT services in the country, and the level of institutional efficiency of the telecommunications sector. The mentioned authors believe that the ITU framework for measuring the IDI excessively weights the indicators of the sub-index concerning digital use and skills. By modifying the ITU framework with indicators that measure the accessibility, quality, and efficiency of ICT services in a country to higher weight values in the model, the authors create a new IDI measurement scale for countries called MIMLI (Gerpott and Ahmadi, 2015). By adding indicators of accessibility, efficiency, and quality in the research, it led to significant differences compared to the ITU. On the MIMLI scale, developed countries had better ICT development by an average of 1.90, while developing countries had an even lower rate of development. However, the limitation of the MIMLI scale for measuring the development of ICTs in countries is in the quality dimension, which consists of two indicators - the share of fast Internet connections and uninterrupted mobile calls whose data is not fully available. It is also difficult to consider in the model indicators such as broadband Internet, Internet infrastructure, and the quality of regulatory bodies in the telecommunications sector (Gerpott and Ahmadi, 2015). One of the recommendations related to this research would be a comparison of ICTs development indices in Scandinavian countries measured by different models. A comparison of the two metrics would enable a more relevant determination of significant differences between the index measured by the ITU framework methodology, and such as the modified MIMLI scale.

Thailand has seen significant progress in ICT development in recent years, particularly in its positive effects on overall economic benefits. The report on digital development by UNCTAD in 2021, puts Thailand to be one of the most dynamic countries in the IDI rankings over the past five years, largely due to improved mobile broadband penetration (Digital Economy Report, 2021, 2021). Waves of 5G network rollout in Thailand will drive growth in ICT access and use, which in turn should positively impact on long-term social and economic development (Digital Economy Report 2021, 2021). Thailand recognizes the great potential of ICT and is focusing on increasing to become an ICT leader in ASEAN. Term – ASEAN is an international organization that has 10 member countries in Southeast Asia: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam (Digital Economy Report, 2021, 2021). The research paper by the authors (Khalid and Naumova, 2021) presents a model of progress towards a higher level of ICT development and the achievement of the first rank of IDI indicators in ASEAN. The model modifies the indicators of the first and second sub-index in the ITU framework. The percentage of individuals using the Internet and fixed broadband subscriptions per 100 inhabitants increase the weighting values by 10%, while at the same time, active mobile broadband subscriptions per 100 inhabitants and mobile mobile telephony per 100 inhabitants decrease. According to the author .., in the model, the indicators of the first sub-index of the ITU framework are equalized and have almost all equal weight values (Khalid and Naumova, 2021). This model showed that Thailand can take the lead among the ASEAN region and be a flywheel for other countries in the region in the development of ICT because the modification affected the growth according to the IDI indicator. Although the model contains limitations which are visible in giving greater priority and thus a weighting value to those indicators that are considered to be able to show better results of an individual country, while other indicators are either reduced or equalized in the sub-indices to manipulate the measurement indicators for those indicators that could harm the overall IDI indicator (Khalid and Naumova, 2021). Certainly, such a model hints at potential value for policymakers who seek to exploit the possibility of manipulating indicators related to the levels of ICT development and digital skills of a country.

5. Conclusion

This paper describes the methods of calculating the ICT Development Index (IDI) for four countries of the Scandinavian region, Denmark, Finland, Norway, and Sweden. A comparison was made with the values of the IDI and the ranking of these countries at the European level. The research results imply the existence of a certain discrepancy in the percentages of the sub-index indicators when calculating the ICT Development Index (IDI) using the method of entropy weights and the established methodological framework by the ITU official platform. The ITU method is designed for exactly those indicators that are included for each sub-index, while the entropy weights method is more suitable for a wider and more diverse spectrum of indicators. When calculating the entropy weights for the ICT skills sub-index indicators, the biggest difference was observed in the percentages that in the further calculation refer to the IDI value, which represents an unbalanced calculation for the values of these indicators compared to the ITU framework.

According to the results for ICT Development Index (IDI) values conducted using the ITU methodological framework, high IDI values, and individual sub-indexes are perceived for three or four Scandinavian countries. As well, the value of IDI, Denmark, Norway, and Sweden belong to the ten countries at the level of the whole of Europe, which makes them a region of high ICT implementation and potential. Finland is fifteenth in order among all European countries concerning the value of IDI and is below the level of the other three countries of the Scandinavian region due to the low value of the ICT access sub-index. This confirms the perception that Scandinavian countries are regarded as countries with a strong tendency to invest in ICT (Christensson et al., 2013; OECD Regional Well-Being — How Is Life?, 2020). The Scandinavian countries managed to implement a strategy to make the current dynamics of digital development particularly attractive and aimed at IT companies that want to set up their data centers. That region has managed to combine its traditional comparative advantages, including the quality of infrastructure and a high level of human skills to develop the foundations of ICT utility (Nirina, 2023).

The limitations in this paper are connected to certain facts in the data processing process, and concern the character of the indicators that are included in the IDI calculation. The relevance of data on the indicators of the ICT skills sub-index depends on the involvement of the proxy system because the data for these indicators are collected manually or automatically with greater time savings and fewer errors, hence a higher level of data obtained by the proxy system will affect the effectiveness of the importance of the data itself. Moreover, the ITU method contains its rigidities because only certain indicators for which the system has access and a well-established way of processing are included. It is very important to consider to what extent the level of data subjectivity can be neutralized when implementing the entropy method.

The research offers directions for future research and a framework for applying the study to other regions with the aim of uncovering the strength of relationships between investments in ICT development and digital skills. A similar study can be extended to other areas, which would expand the context of the investigated problem and provide insight into the causality of additional factors that need to be investigated and their connection with digital skills as a sustainable modus for achieving human resource competitiveness. Forecasts that the value of IDI for a particular country will be higher with the assumption of greater involvement of the system of state institutions that can influence the increase in the use of ICT and digital literacy make sense to analyze. It would be desirable to consider, in future studies, the ICTs development index and the same sub-indicators that enter the ITU methodological framework for certain developing countries, for example in the region of Southeast Europe. Future research should examine the correlation using the set model between the degree of ICT implementation in certain countries and the relevant representation of curriculum use in educational institutions that influence the digital skills of the population of a country.

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