Digital Skills Towards Competitiveness of Human Resources Efficiency: Comparative Approach

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Abstract

Imagining people's functions in everyday life and work without ICT seems complicated. Since it substantially ensures the competitiveness of different systems at the micro and macro levels, its application is ubiquitous, regardless of the aspect from which it is observed. Numerous national and multinational strategies try to encourage educational systems, focusing on ICT to acquire skills, competencies and knowledge more effectively. This should represent added value to all future generations. This article emphasizes the structural approach to market divergence, and it analyzes the representation of the ICT development index (ICT) in European countries that compares a set of Scandinavian countries and other European Union countries. It is known that Scandinavian countries belong to those countries that have recognized the importance of involving ICT in educational programs, which improves the economy of a particular selected country. Considering this, the research reveals how ICT is essential in improving socio-economic development in many countries.

Keywords: ICT development index; Scandinavian countries; skills; comparation
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Introduction

Technological innovations have significantly contributed to the increasing implementation of ICTs in everyday life, including in economic sectors (Chanyagorn & Kungwannarongkun, 2011). 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 in order to be able to use them as well as possible (Koivusilta et al., 2007). 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 & Linderoth, 2021). Such effects on students lead to the skills of knowledge about creativity in work and the strengthening of individual expression in accordance with 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, and easier. Hence, today, it is not easy to accept knowledge that does not exist. (Jacobsson et al., 2017; Tømte et al., 2020). 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, n.d.). 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 labour market by engaging in 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 examples 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 & 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 & 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 in order to build a better and more capable staff that will improve the company's operations in the future (Chaidi et al., 2021).

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 with regard to the development of ICTs at the regional level.

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 in relation to 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 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). Shannon presented this theory in his 1948 work, "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 in order to create an objective character among the dana (Erkhembaatar & Otgonbayar, 2021; Wiens, 1998).

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:

$$R_{ij} = \left(x_{ij}\right)_{mxn} \quad (1)$$

where x_{ij} are elements of the matrix R; x represents the value of the *j*-th sample and the *i*-th indicator.

With normalization process, operators are obtained:

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

New matrix is:

$$D_{ij} = (d_{ij})_{mxn}\ . \quad (3)$$

The relative weight of x_{ij} is:

$$Y_{ij} = (Y_{ij})_{mxn}\ , \quad (4)$$

$$y_{ij} = {d_{ij}}\Big/{\sum_{i=1}^{m} d_{ij}}. \quad (5)$$

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

$$E = -\frac{1}{\ln n}\sum_{j=1}^{n} y_{ij} \ln y_{ij}, \quad (6)$$

where *k* is 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:

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

The indices obtained are indicator values of the observed phenomenon; in this way, the indices of ICT development are presented, and the interpretation and analysis of which are 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 & Daszczuk, 2023). Measuring indicators of ICT development provides great benefits for examining the real impact of technologies in society (*Measuring ICT: The Global Status of ICT Indicators | Eldis*, n.d.). Their assessment and implementation are cost-effective and could be beneficial for the country. 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*, n.d.). 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 (Table 1).

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	0.40
Mobile-cellular telephone subscriptions per 100 inhabitants	A2	0.20	
International Internet bandwidth (bit/s) per Internet user	A5	0.20	
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	0.40
Fixed (wired)-broadband subscriptions per 100 inhabitants	A3	0.33	
Active mobile-broadband subscriptions per 100 inhabitants	A4	0.33	
ICT skills sub-index (N)			
Mean years of schooling rate	S1	0.33	0.20
Secondary gross enrolment ratio	S2	0.33	
Tertiary, gross enrolment ratio	S3	0.33	

Source: itu.int; 25.03.2023.

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:

$$IDI = ((L^*.40)+(M^*.40)+(N^*.20))^*10 \quad (8)$$

For the research, the ICT development index (IDI) in the Scandinavian countries is analyzed along with three sub-indexes and the indicators that are mentioned 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*, n.d.). The study findings for the ICT indicators are used to determine the weights of the indicators (Erkhembaatar & Otgonbayar, 2021).

Eleven IDI indicators in total need to be evaluated (OECD, 2014). The analysis of the IDI was performed using 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 European 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.

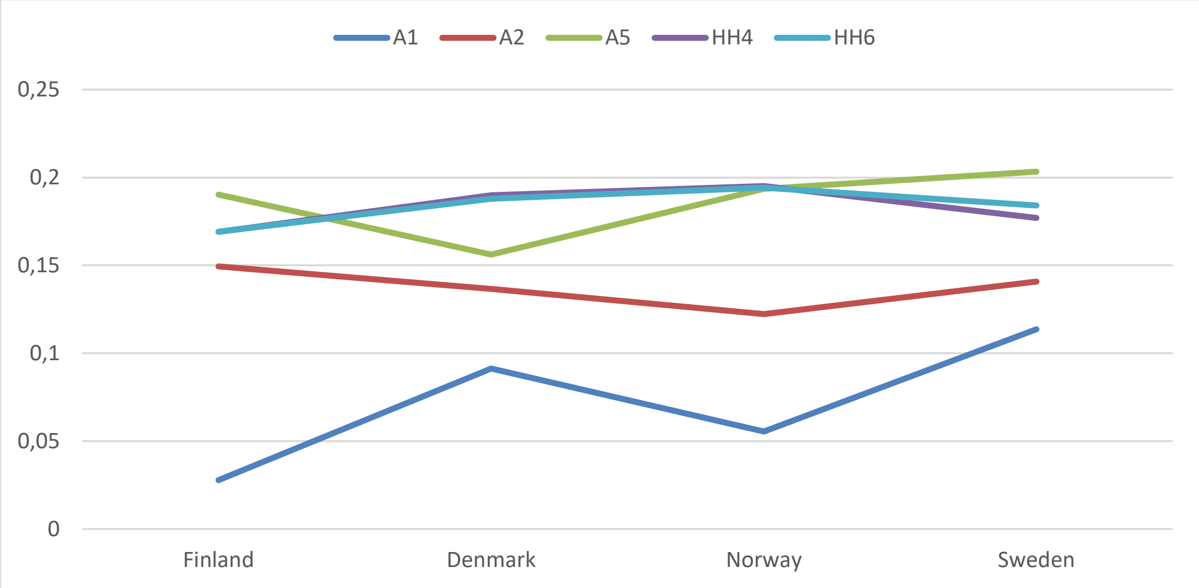
Results of Analysis

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, 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 in order 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, respectively 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 represents mobile-cellular telephone subscriptions per 100 inhabitants, and this value ranges between 0.18 and 0.22. A5 indicator – International Indeks bandwidth (bit/s) per Indeks 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 Indeks access, the value varies between 0.17 and 0.20.

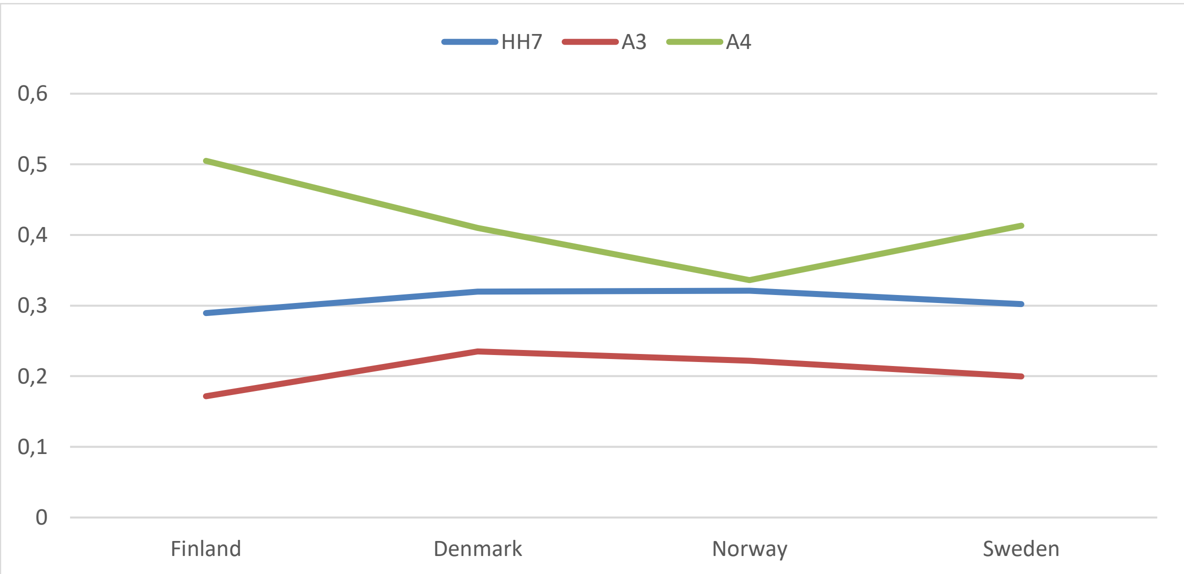
Figure 1
Entropy values of IDI indicator – ICT access sub-index for Scandinavian countries



Source: Author's 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 are shown 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.

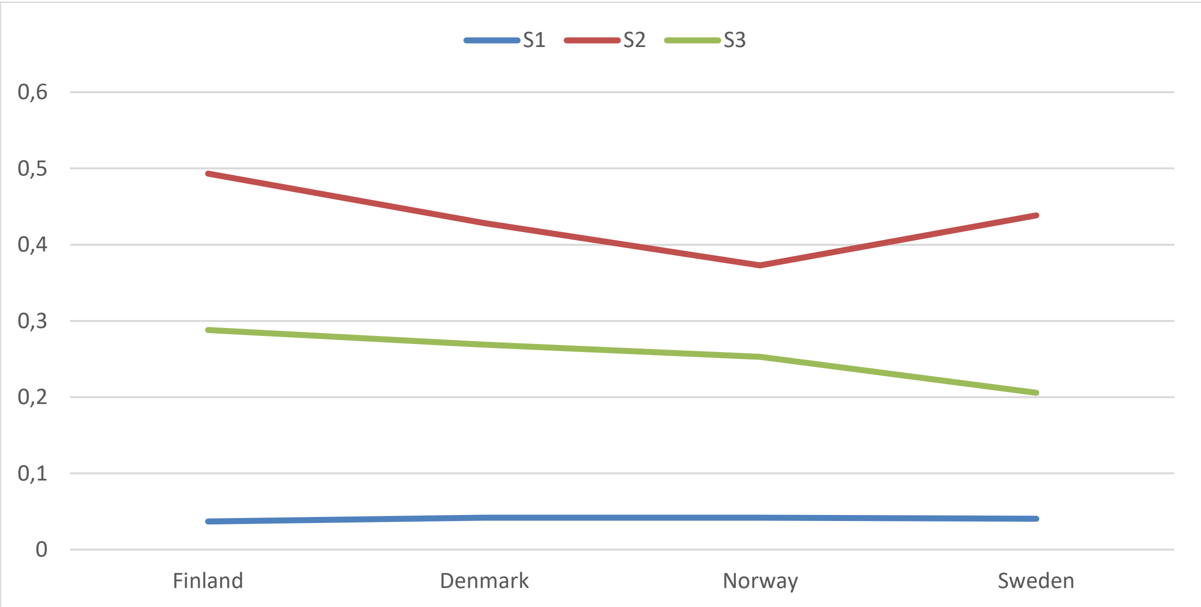
Figure 2
Entropy values of IDI indicator – ICT usage sub-index for Scandinavian countries



Source: Author's 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 included 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 inhabitants 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: Author's work

The reference values of the sub-indices indicators, their entropy weights and the differences 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 per cent, 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			
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	40	-43.89	-3.89
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			
Fixed (wired)-broadband subscriptions per 100 inhabitants	A3	33.33	32.145	1.185	40	39.86	0.14
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			
Secondary gross enrolment ratio	S2	33.33	35.247	-1.917	20	10.02	9.98
Tertiary, gross enrolment ratio	S3	33.33	26.505	6.825			

Source: Author's 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 (no.) 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 analysed. 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-indeks	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: Author's 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 analysed 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.

Conclusion

This paper describes the methods of calculating the ICT Development Index (IDI) for four countries in 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 with high ICT implementation and potential. Finland is fifteenth in order among all European countries with regard to 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; Koivusilta et al., 2007; *OECD Regional Well-Being - How Is Life?*, n.d.). 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 centres. 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, n.d.).

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.

Forecasts show 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, which makes sense to analyze. 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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