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USING DATA ENVELOPMENT ANALYSIS TO EVALUATE THE EFFICIENCY OF EUROPEAN UNION COUNTRIES IN INFORMATION TECHNOLOGIES[1]

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ABSTRACT

In an environment where international competitive conditions are becoming increasingly difficult in parallel with the changes in science and technology, the importance of developments in information technologies is increasing day by day. This study aims to specify the relative efficiency of European Union countries in the field of information technologies using Data Envelopment Analysis. In this direction, four inputs and four outputs are determined. According to both the CCR and BCC models, Austria, Croatia, Czechia, France, Germany, Lithuania, Poland, Slovakia, Slovenia, and Spain are the countries that cannot show 100% performance in obtaining information technology outputs with the information technology inputs determined in the study. While Belgium and Poland are effective in the BCC analysis, they are not effective in the CCR analysis. In this case, Belgium and Poland are technically effective in BCC analysis, but can not achieve scale efficiency. Input and output rates of inefficient countries are interpreted by comparing them with best practice benchmarks.

Keywords: *Data Envelopment Analysis, Effectiveness, European Union Countries, Information Technologies.*

JEL Codes: *C60, N14, O30.*

1. INTRODUCTION

One of the most important elements of long-term development is science and technology. Information societies are the basis of rapidly developing technology. Science and technology are recognized as the most important driving force for economic development and growth. Developed countries are aware that being leader in many fields in the international arena and playing an effective

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role in solving economic problems can only be possible by having effective science and technology policy and opportunities. Countries should develop their science and technology infrastructures and invest in human resources in this field to ensure international competitive advantage and sustainable growth. In addition, the development of production technology, research and development (RveD) activities, innovation activities, high-tech product production and their effects on efficient production processes are very important for economic growth and competitiveness.

The globalization of economic life and the increase in information intensity in economic activities are the major factors affecting the creation of a knowledge economy. The economies of countries that are internationally competitive, technologically advanced and provide a high standard of living for their citizens are generally information-based economies (Yaylalı, Oktay, Akan, & Kaynak, 2007, s. 2). Accordingly, in today's world where data is the most important resource and information transfer and processing are becoming increasingly important, the economies of countries that can catch up with technology and innovation are in an advantageous position in issues such as growth, employment, foreign trade and competition. Technological developments and innovation are the main source of a country's technological capability. In order to produce technology, specialised employees are needed. Innovations made by countries in the field of science and technology have become an indicator of the level of development of countries. As a result of countries establishing and following certain science and technology policies, technological research is transferred to industry and thus countries develop continuously within a certain system. Today, science and technology policies is one of the principal factors affecting the economic performance of a country.

In the following parts of the study, after reviewing the literature, the selection of variables, data envelopment analysis and the findings obtained from the analysis are given. Then comes the conclusion and discussion section.

2. LITERATURE REVIEW

There are many studies in the literature where data envelopment analysis is used for effectiveness evaluation. This section includes studies in the literature on European Union (EU) countries, information technologies and Data Envelopment Analysis (DEA) that are taken as references when conducting this study.

According to their study Shafer and Byrd (2000), Data Envelopment Analysis (DEA) is used to evaluate the efficiency of IT investments. For this purpose, the information system budget as a percentage of shots, the total processor value of an organisation as a percentage of sales and the percentage of the information system budget allocated to training were determined as three inputs. The outputs are five year compound annual revenue growth and five year compound annual income growth. At the end of the study, DEA produced a measure of efficiency for each organisation evaluated and provided information on how the inputs and outputs of inefficient DMUs can be adjusted to be considered efficient.

In their study, Yaylalı et al. (2007) aimed to measure the knowledge economy performances of 27 European Union member countries and Turkey. Information, communication and technology expenditures; public research and development expenditures; research and development expenditures of enterprises; the number of graduates of science and engineering departments; the portion of public education expenditures in GDP; and the human development index were determined as inputs. The proportion of high technology products in exports, the number of patents affiliated with the American Patent Institute, the ratio of employees in knowledge-intensive services to total employment, number of mobile phone subscriptions per hundred people, the percentage of businesses with internet access, and the number of Internet users are determined as outputs. Efficiency values are found by applying CCR and BCC models and interpreted for European Union countries and Turkey.

Liu, Gong, Zhu, and Titah, (2022) investigated the relationship between information technology (IT) and performance. For this purpose, they worked on two-stage network DEA models and took multiple inputs and outputs into account. In the study, they examined the relationship between information system performance and IT inputs according to regions and sectors with a sample of 86 companies from different continents.

Another study analysing the environmental efficiency of European Union countries with DEA is written by Aceituno, Orzaez, Cepeda, Nieto, and Ramos (2023). In the data analysis, economic, environmental, electricity generation data, vehicle capacity and industrial production rate of distinct countries are regarded to calculate environmental efficiency. The study concluded that 12 out of 27 member countries have high environmental efficiency in proportion, while for the others it could be improved by applying a series of adjustments.

Erdin and Çağlar (2023) used data envelopment analysis to compute the efficiency levels of OECD countries in the field of national innovation. The subcategory indexes of the Global Innovation Index are taken as inputs and outputs of the research. In the study the data is obtained from the published data on the Global Innovation Index website. In this study, it is figured that nine OECD countries have scale efficiency. While Switzerland ranks first with the highest innovation performance, the country that ranks last in scale efficiency is Mexico.

In their study, Xu, Mei, Sun, Zhang, and Liang (2023) measure sustainable innovation efficiency in 27 EU countries from 2000 to 2017 by considering industrial waste and total energy consumption with data envelopment analysis (DEA). The imports of high-technology products, research and development expenditure, researchers in this field are considered as the input indicators; while journal articles in scientific and technical field, patent applications and GDP per person are considered as the output indicators. In the study it is determined that eight countries have an efficiency value of 1. It is stated that resources in technological innovation need to be used logically so as to rise the desired outputs and decrease the undesired outputs.

Many studies have been made on the European Union countries. In this study, via the inputs and outputs determined for information technologies, it is investigated which countries are efficient and in which areas the inefficient countries should make improvements. The analysis is made with the most recent data available and it is thought to contribute to the literature.

3. METHODOLOGY

Data envelopment analysis (DEA) is chosen as main method to examine the efficiency of European Union countries in information technologies. This analysis a non-parametric method based on linear programming. By comparing units with deterministic inputs and outputs, the most efficient production units are determined and inefficient units are evaluated.

3.1. Selection of the Variables

The inputs and outputs determined in the study in which the relative efficiency of 27 member countries of the European Union (EU) in the field of information technologies is analysed by Data Envelopment Analysis(DEA) is shown in Table 1.

Table 1. Inputs and Outputs in DEA

Inputs	Outputs
I1: The number of researchers (thousand full-time equivalents)	**O1:** Employed ICT specialists (%of enterprises)
I2: Government budget allocations for RveD (per inhabitant)	**O2:** High-tech exports (%of total exports)
I3: Training to ICT specialists (%of enterprises)	**O3:** The top 10% most cited publications (%of total publications)
I4: PhD students by field of science and technology (%of total PhD students)	**O4:** PCT patent applications per billion GDP (in PPS)

The data analized in the study are taken from the European Statistical Office (Eurostat, 2023) database and the European Innovation Scoreboard (European Commission, 2023). The first input is the number of researchers (thousand full-time equivalents) in 2021(Eurostat - online data code: rd_p_persocc). What is meant by researchers here is a subcategory of RveD personnel and professionals who are involved in the considering or invention of new information, products, processes,techniques and systems, and in the administration of the projects interested. Statistics on RveD personnel are collected by the Organisation for Economic Co-operation and Development (OECD). The second input is Government Budget Allocations for RveD(GBARD) (€ per inhabitant) in 2022 (Eurostat - online data code: GBA_NABSFIN07). RveD is at the centre of many European and national level policies aimed at improving the competitiveness of EU’s economies and the wellfare of its citizens, and is a cross-cutting issue related to the European Commission's political priorities. The statistics on GBARD in the European Union provide with data measuring government support for RveD activities. The third input is training to Information and Communication Technology (ICT) specialists (%of enterprises) in 2022 (Eurostat - online data codes: isoc_ske_itspe and isoc_ske_itrcrs and isoc_ske_itts). Training is crucial for staff to develop or equip themselves with ICT skills and ICT training is related for all personnel. The rapid advancement of information and communication technology (ICT) creates a constant demand for training ICT specialists to adapt to their work environment. The fourth input is PhD students by field of science and technology (%of total PhD students) in 2020 (Eurostat - online data code: educ_uoe_enrt03). The research potential of a country is related to its human resources, which consist of qualified, highly equipped and expert employees living in that country. The number of PhDs in science and technology is seen as a more decisive measure of potential research. In study, the ratio of PhD students in science and technology to total PhD students is identified as the final input.

As for outputs, the first output is Employed ICT specialists (%of enterprises) in 2022 (Eurostat - online data codes: isoc_ske_itspe and isoc_ske_itrcrs and isoc_ske_itts). The continuing and extensive use of Information and Communication Technology (ICT), which has become the most important and key element of business life, has also increased the demand for experts working in this field. Eurostat defines ICT specialists as "employees who have the skills to develop, operate and maintain ICT systems and for whom ICT forms the main part of their work". Professional ICT expertise is necessary for the successful use of ICT in business activities and electronically conducted trading business (e-trade). The second output is high-tech exports (%of total exports) in 2021 (Eurostat - online data codes: isoc_ske_itspe and isoc_ske_itrcrs and isoc_ske_itts) .In addition to the fact that the most developing manufacturers in the field of international trade are high-tech industries, their development also affects the increase in performance on other sectors. The list of products categorised as high-tech products according to the OECD definition includes technical products whose manufacture requires a high intensity of RveD. High-technology wares are examined in nine groups in accordance with the Standard International Trade Classification (SITC-Rev. 4): Aerospace, electronic-telecommunications, computer and office machines, electrical machines, pharmacy, scientific instruments, chemistry, non-electrical machines and armament. The third output is the primary 10% most cited publications (%of entire publications) in 2020 (European Commission, 2023). Scientific publications that are among the top 10% of the most cited publications in global as a percentage of total scientific writings in the country are taken by considering the scope of Scopus publication data. It is considered as a measure of the quality of the research system, conceding that highly cited publications are of higher quality. The fourth output is PCT (Patent Cooperation Treaty) patent applications per billion GDP (Gross Domestic Product) (in PPS- Purchasing Power Standard) in 2019 (European Commission, 2023). The number of patent application under the PCT, at international stage, divided by the Gross Domestic Product in Purchasing Power Standard. The number of patents is a measure of the ratio of new product innovation. One of the component that will provide competitive advantage for companies will be their new product development capacity.

3.2. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is presented by Charnes, Cooper and Rhodes (1978) as a method of measuring efficiency using multiple inputs and outputs. In the study, Farrell's efficiency measurement studies in 1957 are also used and the organisations or entities to be measured are called decision-making units (DMUs). Cooper, Seiford and Tone (2007) explained DEA as a non-parametric and linear method, which is used to compare the relative efficiency of multiple similar samples of decision-making units (DMUs) with multiple inputs and outputs.

After the identification and selection of DMUs in DEA, inputs and outputs are determined. Although there are different ideas for the number of units that should be admitted in the analysis, such as the number of DMUs needs to be at least two times (Golany & Roll, 1989, s. 239) or three times (Paradi, Yang, & Zhu, 2011, s. 325) the total number of inputs and outputs. Cook et al (2014, s. 2) state that such directions are not compulsory and don't have statistical support but are seted for convenience (Erdin & Çağlar, 2023, s. 437). The expressiveness and goal of the analysis builds on the inputs and outputs chosen in the model. Deciding on the correct input and output units for DMUs is not only very critical but also difficult. In this sense inputs and outputs should be reasonably related (Thanassoulis, Dyson, & Foster, 1987, s. 399).

Data Envelopment Analysis is an approach of measuring comparative or relative efficiency, since its measurement by DEA is made with reference to some units that are compared with each other. The efficiency score is generally given as a number between 0-1% or 0-100%. A DMU with a score less than 100% or 1 is considered inefficient relative to other units (Cvetkoska, 2011, s. 422). While efficient units are those with the finest greatest performance in the study, inefficient units can develop into efficient by decreasing inputs or increasing outputs. DEA not only calculates efficiency scores but also sets input and output targets for inefficient units to become efficient. Using output targets, potential improvement ratio (PIR) can be calculated by the following formula:

$$PIR = \frac{Target\ Value - Actual\ Value}{Actual\ Value} * 100$$

The PIR for the inputs of study can be computed as well in same A potential improvement ratio present the rate of improvement (decrease or increase) that need to be reached relating to input or output for an inefficient unit to become efficient (Erdin and Çağlar, 2023, s. 437).

DEA attempts to define the performance of the DMUs in two forms, input-oriented, which aims to least possible inputs for a given level of output, and output-oriented, which aims to maximize outputs for a given input level (Castellano, Gabriella De, & Punzo, 2023, s. 146). Efficiency may also stand on returns to scale, which are constant or variable. Two major DEA models are advanced according to the type of returns to scale (Hsieh & Lin, 2010, s. 15). The first model was developed by Charnes, Cooper and Rhodes (1978) and named as CCR with their names. This model is developed under the assumption of constant returns to scale (CRS). What does this mean that any change in the level of input should make a proportional difference in output and there is not any scale effect (Castellano et al., 2023, s. 146). The second model is introduced by Banker, Charnes and Cooper (1984) and named as BCC with their names as well. As an extension of the CCR model, they developed a model assess the productivity of decision units under the assumption of variable returns to scale (VRS). This implies that DMUs may have different productivity at various scales. In another words, the fertility of diverse production technologies may vary based on the scale at which the DMUs operate (Castellano et al., 2023, s. 146).

Since the target of this study is to determine the relative efficiency of the European Union countries in the field of information technology and to maximise the output of inefficient countries in this field, this study uses two basic output-oriented models. Accordingly, efficiency levels are computed using the following linear programming models in Table 2 (Cooper, Seiford, & Zhu, 2011, s. 13; Sherman & Zhu, 2006, s. 115; Zhu, 2009, s. 15).

Table 2. Output-Oriented CCR and BCC Envelopment Models

Output-Oriented CCR Envelopment Model	**Output-Oriented BCC Envelopment Model**
$\boldsymbol{max\varphi + \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)}$	$max\varphi + \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$
subject to	subject to
$\boldsymbol{\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{i0} \quad i = 1,2,\ldots,m}$	$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{i0} \quad i = 1,2,\ldots,m$
$\boldsymbol{\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \varphi y_{r0} \; r = 1,2,\ldots,s}$	$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \varphi y_{r0} \quad r = 1,2,\ldots,s$
$\boldsymbol{\lambda_j \geq 0 \quad j = 1,2,\ldots,n}$	$\sum_{j=1}^{n} \lambda_j = 1 \quad \lambda_j \geq 0 \; j = 1,2,\ldots,n$

In Table 2, n represents the number of DMUs; m represents number of inputs; s represents number of outputs. DMUj consumes amount xij of input i and produces amount yrj of output r. Whereas s_i^- represents input slack, s_r^+ represents output slack. λ_j represents the relative weight of DMU j.

4. RESULTS

Data Envelopment Analysis is used to measure the relative effectiveness of decision-making units that are similar to each other or operate for a similar purpose. For this reason, in the study, the relative effectiveness of 27 member countries of the European Union in information technologies is examined by output-oriented CCR and BCC models by using DEAP (Data Envelopment Analysis Program) Version 2.1. The reason for using output-oriented models is to demonstrate the capacity of countries to maximise information technologies outputs at the level of resources they have. The determined input and output set and the data obtained for the member countries of the European Union are shown in Table 3.

Table 3. DMUs, Input and Output Data

		Inputs				Outputs			
No	**DMU**	**I1**	**I2**	**I3**	**I4**	**O1**	**O2**	**O3**	**O4**
1	Austria	55.052	433.1	13.8	37.7	23.2	14	1031.6	4.52
2	Belgium	76.3	305	19.8	41.7	32.7	17	1190.9	3.05
3	Bulgaria	16.2	27.3	6.1	27	15.9	6.4	244.4	0.51
4	Croatia	9.5	113.8	9.4	40.1	17.1	7.4	481.6	0.57
5	Cyprus	1.6	127.4	13.9	33.5	24.5	4.8	1043	0.71
6	Czechia	48.1	151.2	10.5	46.4	19.6	18.3	515.2	0.72
7	Denmark	45	529.1	21.1	38.2	34.2	12.1	1223.5	6.17
8	Estonia	5.4	189.3	10.4	45.2	17.2	12.8	880.1	1.33
9	Finland	43.554	434.1	15.9	36.3	28.9	6.8	1179.8	6.94
10	France	340	263.7	8.8	48.8	17.6	17.2	886.5	3.14
11	Germany	459.5	517.6	13.5	41.2	22.2	15	1040.5	5.9
12	Greece	44.3	151.2	9.1	31.8	20.5	4.8	923	0.61
13	Hungary	43.3	62	9	31.8	30.6	15	589.4	1.09
14	Ireland	23	195.7	9	43.3	30.4	43.4	1125.1	1.49
15	Italy	172.7	214.4	9.1	50.1	13.4	7.7	1217.7	2.08
16	Latvia	4.5	49.6	7.7	38.9	18.7	9.6	499.9	0.73
17	Lithuania	11	78.2	7.8	43.1	17.2	8	586	0.55
18	Luxembourg	2.194	661.6	13.4	60.8	23.1	5.4	1278.3	1.66
19	Malta	1.044	71.2	18.3	28	33.5	24.3	877.2	1.33
20	Netherlands	106.1	440.7	20.8	31	30.8	21.7	1394.2	4.89
21	Poland	135.7	69.4	10	35.9	30.9	8.8	546.3	0.48
22	Portugal	56.2	77.4	9.2	34.2	20	4.7	875.7	1.01
23	Romania	19.1	17.6	5.4	36.5	11.5	9	627.7	0.14
24	Slovakia	17.5	70.2	8	35.9	17.7	8.2	445.3	0.51
25	Slovenia	11.1	149.1	13.7	36.3	20.6	7.1	789.9	1.58
26	Spain	154.1	167.7	9.1	33.6	16.3	6.8	915.5	1.37
27	Sweden	100.1	391.6	13.4	43	23	11.4	1167.9	9

The output-oriented CCR model efficiency scores, output-oriented BCC model efficiency scores, scale efficiency (SE) scores and scale characteristics (SC) for the 27 members of the European Union are presented in Table 4. Scale efficiency is computed by dividing the efficiency value obtained from the CCR model by the efficiency value obtained from the BBC model (CCR/BCC). It is seen that different efficiency results close to each other are obtained with CCR and BCC models. As expected, BCC efficiency values are higher than CCR efficiency values and BCC model evaluates more countries as efficient. While the CCR model evaluates the member countries of the European Union according to the constant return scale, the BCC model also takes into account the increasing return and decreasing return scale situations; therefore the BCC efficiency scores are calculated higher than the CCR efficiency scores. However, the difference is very small (Keçek, 2010, s. 111).

Table 4. The Efficiency Scores of EU Countries

No	DMU	CCR	BCC	SE	SC
1	Austria	0.885	0.888	0.996	Increasing
2	Belgium	0.856	1	0.856	Decreasing
3	Bulgaria	1	1	1	Effective
4	Croatia	0.71	0.713	0.995	Decreasing
5	Cyprus	1	1	1	Effective
6	Czechia	0.551	0.633	0.87	Decreasing
7	Denmark	1	1	1	Effective
8	Estonia	1	1	1	Effective
9	Finland	1	1	1	Effective
10	France	0.905	0.963	0.94	Increasing
11	Germany	0.875	0.875	1	Effective
12	Greece	1	1	1	Effective
13	Hungary	1	1	1	Effective
14	Ireland	1	1	1	Effective
15	Italy	1	1	1	Effective
16	Latvia	1	1	1	Effective
17	Lithuania	0.861	0.863	0.997	Increasing
18	Luxembourg	1	1	1	Effective
19	Malta	1	1	1	Effective
20	Netherlands	1	1	1	Effective
21	Poland	0.909	1	0.909	Decreasing
22	Portugal	1	1	1	Effective
23	Romania	1	1	1	Effective
24	Slovakia	0.773	0.782	0.989	Increasing
25	Slovenia	0.841	0.843	0.998	Decreasing
26	Spain	0.972	0.999	0.973	Increasing
27	Sweden	1	1	1	Effective

According to the CCR model, Austria, Belgium, Croatia, Czechia, France, Germany, Lithuania, Poland, Slovakia, Slovenia, Slovenia and Spain with efficiency values below 1, are the countries that cannot perform 100% in obtaining information technology inputs and information technology outputs determined in the study. Apart from these countries, other member countries of the European Union have obtained information technology outputs with 100% efficiency from information technology inputs.

According to the BCC model, Austria, Croatia, Czechia, France, Germany, Lithuania, Slovakia, Slovenia and Spain which have efficiency values below 1, are the countries that cannot perform 100%

in ontaining the information technology outputs determined with the information technology inputs determined in the study.

Belgium and Poland are effictive according to BCC analysis, but not in CCR analysis. This shows that Belgium and Poland are technically efficient in the BCC analysis, but they cannot achieve scale efficiency. Therefore, considering the total effectiveness, it shows that it is not considered effective. In this context, it can be interpreted that Belgium and Poland are locally effective but not effective in total.

In order to achieve efficiency, both CCR and BCC efficiency values should be equal to 1. While potential increase is expected in the information technology performance of Austria, France, Lithuania, Slovakia and Spain, which are countries that cannot achieve efficiency; a decrease is expected in the information technology performance of Belgium, Croatia, Czechia, Poland and Slovenia.

For an ineffective country, improvement methods can be explored through a better understanding of how its performance compares with best practice benchmarks. A reference country with the most similar mix of inputs and outputs to the target country may provide useful information. So that European Union Countries that are not effective can make improvement input and output factors. The comparison results; reference unit groups and obtained coefficients for ineffective countries shown in Table 5. In addition, when the outputs of the analysis are reviewed, it is noted that there are no benchmark values proposed for Belgium.

Table 5. DMUs, Coefficients and Reference Groups

No	DMU	Obtained Coefficients and Reference Groups
1	Austria	14(0.218) 12(0.116) 20(0.117) 9(0.397) 27(0.152)
4	Croatia	14(0.294) 19(0.124) 16(0.582)
6	Czechia	19(0.161) 13(0.401) 14(0.438)
10	France	23(0.440) 14(0.236) 27(0.314) 15(0.010)
11	Germany	12(0.012) 14(0.209) 20(0.144) 27(0.635)
17	Lithuania	5(0.039) 8(0.013) 16(0.551) 23(0.192) 14(0.205)
21	Poland	13(0.892) 19(0.108)
24	Slovakia	13(0.214) 3(0.170) 19(0.010) 14(0.147) 16(0.459)
25	Slovenia	19(0.168) 9(0.108) 5(0.495) 27(0.046) 16(0.183)
26	Spain	3(0.005) 14(0.024) 12(0.772) 27(0.094) 23(0.104)

As can be seen from Table 5, the country most frequently cited as a reference by 8 countries is Ireland, country number 14, followed by Sweden and Malta, which are cited 5 times each. Subsequently Latvia by 4 countries; Romania, Hungary and Greece by 3 countriess; Netherlands, Finland, Cyprus and Bulgaria by 2 countries; Estonia and Italy by 1 country are taken as reference.

Target values can be calculated with the help of reference groups, and coefficients for the input and output factors of ineffective countries.

Target value for the employed ICT specialist (%of enterprises) for Austria is calculated as follow:

$TV\text{-}O1_{Austria} = O1_{Ireland}(0.218) + O1_{Greece}(0.116) + O1_{Netherlands}(0.117) + O1_{Finland}(0.397) + O1_{Sweden}(0.152)$

$$=30.4\ (0.218) + 20.5\ (0.116) + 30.8\ (0.117) + 28.9\ (0.397) + 23\ (0.152) = 27.58$$

Austria should increase employed ICT specialist (%of enterprises) from 23.2 to 27.58. Potential improvement ratio (PIR) of employed ICT specialist (%of enterprises) of Austria can be calculated as follow

$$PIR = \frac{Target\ Value - Actual\ Value}{Actual\ Value} * 100$$

$$PIR = ((27.58 - 23.2) / 23.2) * 100 = 19$$

Thus, it can be interpreted that Austria needs to improve the number of ICT specialists (%of enterprises) about 19%. Target values and improvement ratios are calculated similarly for other output factors and presented in Table 6.

Table 6. Output Targets and Potential Improvements for Ineffective Countries

		O1	O2	O3	O4
Austria	Output Value	23.20	14.00	1031.60	4.52
	Target Value	27.58	16.99	1161.36	5.09
	Potential Improvement Ratio	19%	21%	13%	13%
Croatia	Output Value	17.10	7.40	481.60	0.57
	Target Value	23.98	21.36	730.49	1.03
	Potential Improvement Ratio	40%	189%	52%	80%
Czechia	Output Value	19.60	18.30	515.20	0.72
	Target Value	30.98	28.94	870.37	1.30
	Potential Improvement Ratio	58%	58%	69%	81%
France	Output Value	17.60	17.20	886.50	3.14
	Target Value	19.59	17.86	920.61	3.26
	Potential Improvement Ratio	11%	4%	4%	4%
Germany	Output Value	22.20	15.00	1040.50	5.90
	Target Value	25.64	19.49	1188.60	6.74
	Potential Improvement Ratio	15%	30%	14%	14%
Lithuania	Output Value	17.20	8.00	586.00	0.55
	Target Value	19.92	16.27	678.73	0.78
	Potential Improvement Ratio	16%	103%	16%	42%
Poland	Output Value	30.90	8.80	546.30	0.48
	Target Value	30.91	16.00	620.48	1.12
	Potential Improvement Ratio	0%	82%	14%	132%
Slovakia	Output Value	17.70	8.20	445.30	0.51
	Target Value	19.88	13.98	518.25	0.79
	Potential Improvement Ratio	12%	70%	16%	55%
Slovenia	Output Value	20.60	7.10	789.90	1.58
	Target Value	25.36	9.47	936.28	1.87

	Potential Improvement Ratio	23%	33%	19%	18%
Spain	Output Value	16.30	6.80	915.50	1.37
	Target Value	19.99	6.79	915.84	1.37
	Potential Improvement Ratio	23%	0%	0%	0%

The countries in Table 6 can become effective in terms of information technologies by reaching the given output target values. As a percentage value, PIR indicates how much a country needs to increase their outputs (as a proportion). For Austria it can be say that; should increase the ratio of ICT specialists number (%of enterprises) from 23.2 to 27.58 about 19% and the ratio of high-tech exports (%of total exports) from 14 to 16.99 about 21%. It also should increase the number top 10% most cited publications (%of total publications) from 1031.6 to 1161.36 about 13% and lastly PCT patent applications per billion GDP (in PPS) should increase from 4.52 to 5.09 about 13%. Similar interpretations can be made for other countries by using the results in Table 5. The target values of outputs presented provide a benchmark for ineffective countries. Focusing on these weaknesses should be a policy priority, as the higher a country's PIR in innovation outputs, the weaker its performance in related outputs. The highest PIR value is for Croatia's high-tech exports (%of total exports) output with 189 per cent. It can be concluded that Croatia is the weakest country in the output of high-tech exports and to be effective, it needs to increase the value of this output from 7.40 to 21.36.

When Table 6 is evaluated as a whole, Czechia is the country that should increase the number of ICT specialists in enterprises the most (with 58% PIR) and Croatia (with 189%PIR) is the country that should increase its high-tech exports the most. Whereas Czechia (with 68% PIR) the country that needs to increase the most cited publications worldwide, Poland (with 132% PIR) is the country that needs to increase the number of patents the most.

5. DISCUSSION AND CONCLUSION

Within the framework of economic globalisation, information technology is a major factor in increasing the enlargement and rivalry of business. The investments in science, innovation, technology, research and development constitute an important policy for the EU. Science and technology policies and resources should be directed to utilise development in strategic areas with high innovation capacity.

This study aims to measure the relative efficiency of the information technologies in countries by using Data Envelopment Analysis under the output oriented CCR and BCC framework. In this way, efficient countries are identified and information is given on how inefficient countries can reach their targets. The European Union countries are considered for this analysis. The EU is a large and diverse economic and political unit consisting of various countries and cultures. The study differs from previous studies with the inputs and outputs it considers and is important in terms of revealing the efficiency of the European Union countries in information technologies.

DEAP (Data Envelopment Analysis Program) Version 2.1 is used in the study application and the obtained results are tabulated and explained. According to both the output oriented CCR and BCC models, Austria, Croatia, Czechia, France, Germany, Lithuania, Poland, Slovakia, Slovenia, and Spain which have efficiency values below 1 are the countries that cannot show 100% performance in obtaining information technology outputs with the information technology inputs determined in the study. While Belgium and Poland are effective in the BCC analysis, they are not effective in the CCR analysis. In this case, Belgium and Poland are technically effective in BCC analysis, but can not achieve scale efficiency. For ineffective countries, comparing their activities with best practice benchmarks is important for improvements and inefficient units can become efficient by decreasing inputs or increasing outputs. The Potential improvement ratio, which gives the rate of improvement that needs to be reached in the relevant input or output in order for an inefficient unit to become efficient, in this study demonstrates how much a country should increase its outputs (as proportion). Accordingly, when PIR values are compared, Czechia needs to increase the number of ICT specialists in enterprises the most; Croatia needs to increase high technology exports the most; Czechia needs to increase the number of most cited publications worldwide the most; and Poland needs to increase the number of patents the most.

There are studies in which DEA is used to compare the efficiencies of European countries and different inputs and outputs are considered. However, unlike the studies in which different samples are examined at different times, it is thought that conducting the analysis with the most recent data available is contribute to the literature.

In light of the results obtained from the study, policy makers can offer clear policies that enable the production of more output using less input and improve the output with the developments in information technologies. In this sense, the development of technology increases efficiency and ensures more effective use of resources. The analysis is made with the most recent data available and it is thought to contribute to the literature. In addition, it can be considered as a preliminary study for more comprehensive future studies.

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