The Penetration of ICT into the Economy-Technical Infrastructure in the V4 Countries

Petr Doucek, Martina Kuncová, Lea Nedomova

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Petr Doucek[1], Martina Kuncová[1], Lea Nedomová[1]

[1] University of Economics, Prague, W Churchill sq. 4, Prague, Czech Republic
doucek@vse.cz, martina.kuncova@vse.cz, nedomova@vse.cz

Abstract. This article deals with the integration of information technology tools and services into the economies of European countries and compares the degrees to which ICT has penetrated into their economies and societies. Our evaluation of the penetration of ICT into economies within this article works primarily from the standpoint of infrastructure-services penetration. These services are today typically expressed through computer-network connection speeds. For our comparison of the nations of Europe, and of the V4 nations, we utilized public, open data for 2010–2014 provided by various institutions. These include primarily Eurostat, the Office of the European Union, the World Bank, and the Czech Statistical Office. In terms of methodology, the multi-criteria TOPSIS analysis method is used for comparison. A comparison of the penetration of technological infrastructure into the V4 countries between 2010 and 2014 and a comparison of them with the EU average is provided at the end of the article.

Keywords: Economics, ICT, Technical Infrastructure, V4 Countries

1 Introduction

The political, economic, and cultural processes of EU member countries are supported significantly through the introduction of information and communication technologies (ICT). These processes, predicted in the 1960s by visionaries such as Peter Drucker in his book The Age of Discontinuity [1], count upon the “economy of goods being replaced by the knowledge economy,” and they shape not only relationships in societies with advanced economies, but also relationships between these and the other parts of the world. The importance of ICT for society’s functioning is today considerable, and thus its overall impacts on the economy and societal processes are also important. The philosophy and ideas of information society per se are further developed in e.g. the conception of Frank Webster [2], who delimits information society from the standpoint of five basic categories — technological, economical, professional, territorial, and cultural. Thus it is hardly surprising that, in today’s relatively technically — even technocratically — oriented society, the strongest emphasis is placed on the first two dimensions:

- technological (the use of various information technologies, the level of internet deployment, the number of citizens who use ICT for various activities in their daily lives etc.) and
- economical (more precisely stated, economical and managerial — the percentage of profit or GDP invested or spent on ICT, the support for a given type of process via ICT, etc.) e.g. for the general level of the economy of the Czech Republic [3].

Due to this article's limited scope, we cannot discuss the entire broad spectrum of the literature here.

2 Problem Formulation

The foundation for the measurement of a society's ICT penetration, and thus its ICT deployment, and for the consequent growth of its competitive abilities lies in the European concept of indicators for **a society's technological maturity in ICT**. The indicators concerning ICT services are then derived from these.

In our article we focus on primary indicators — that is, on technological-infrastructure indicators. For the purposes of our analyses, we have included among the European states the 28 member states of the European Union, as well as Norway and Iceland, and we have also included for comparison the average of the EU countries (only 27 states, as Croatia only acceded in 2013, and from the standpoint of the years observed, it is not included in the EU average). The article itself then answers the following question:

- From the technological-indicator standpoint, what was the place of the V4 countries (the Czech Republic, Slovakia, Poland, and Hungary) among the countries of Europe, and what was the development of the Czech Republic's standing in the observed period, 2010–2014?

3 Methods and Data Collection

3.1 Selected indicators

We included three subcategories within the category of technological indicators: indicators connected with broadband, indicators focused on the use of the internet in households, and indicators focused on internet users. For all of these, the data is expressed as a percentage of households/inhabitants of the given country that meet the given criterion. The foundation for our monitoring of technological maturity and of the penetration of ICT into an economy is various devices' connection speeds for computer networks and their data-transfer bandwidth. These factors are monitored both via purely technological aspects such as the speed of connections to networks and from the angle of who is utilizing these connections (households and individuals). The monitored indicators are provided in Table 1 through Table 3 below.

Table 1. Indicators for the monitoring of the speeds of connections to computer networks

Indicator ID	Indicator name
BB_FCOV	Coverage of the type broadband — landline.
BB_SPEED2	Broadband-type connection speed over 2 Mbps from all broadband-type landline connections.
BB_SPEED10	Broadband-type connection speed over 10 Mbps from all broadband-type landline connections.
BB_SPEED30	Broadband-type connection speed over 30 Mbps from all broadband-type landline connections.
BB_SPEED100	Broadband-type connection speed over 100 Mbps from all broadband-type landline connections.

Source: the authors

Tab. 2 Indicators for the monitoring of household connections

Indicator ID	Indicator name
H_IACC	Households with an internet connection.
H_BROAD	Households with a broadband internet connection.
H_BBFIX	Households with a landline-broadband internet connection.
H_BBMOB	Households with a mobile-broadband internet connection.

Source: the authors

Tab. 3 Indicators for the monitoring of individuals' connections

Indicator ID	Indicator name
I_IUPORT and I_IUMD	Persons utilizing portable devices (laptops or PCs) over mobile WiFi or a cellular network for access to the internet at home or at work or outside of both of these localities.
I_IUSE	Internet access at least once per week (including daily access).
I_IDAY	Daily internet access.
I_IUX	Never utilizes the internet.

Source: the authors

For all of the selected criteria, "cardinal" information is available, i.e. quantitative information, which simplifies the selection of a method (since for qualitative data it would be necessary to either use methods suitable for this type of data or choose an adequate transformation). Since these are all percentages, i.e. values from the same numeric scale and with the same units, one might think to simply sum the values for each country for all criteria. This could however provide an advantage or a disadvantage in certain situations (for extreme values). We thus opted for a method that also takes into account the data's variability within a single criterion: the TOPSIS method. Before taking a look at it, let us first describe our method for filling in missing data. As mentioned above, these are the percentages of a given country's inhabitants who meet the required characteristic. The data is available for multiple years; it typically changes less than ten percentage points per year, and usually with a growth trend that is nearly linear.

3.2 Data Collection

For the empirical estimation of digital competitiveness, a robust data set must be used. The data for our analysis was obtained from the Eurostat database [4]. This article works with the versions of the individual indicators as of the 18th of January, 2016.

3.3 Topsis Method

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) was first used in 1981 [5]. In literature, a variety of comparisons and evaluations using TOPSIS is mentioned - for example evaluation of companies [6-8], comparison of the electricity production methods [9], comparison of countries from various points of view [10] including ICT [11-12], comparison of industries in achieving the sustainability of internet of things [13].

The basic idea behind this method is the expectation that the best variant has the smallest distance from the ideal variant and the largest from the base variant, and meanwhile the ideal variant reaches the best values under each criterion (this is typically a hypothetical variant) and the base variant on the other hand reaches the worst values under each criterion. The formulas listed below are derived under the assumption that all criteria are of a maximalization type (i.e. a higher value is preferred). Minimalization criteria must be converted to maximalization criteria, for example by subtracting the data from the highest possible value for the given criterion. For calculations the data must be normalized, i.e. all criteria must be converted to the same scale (0:1). This normalization adjusts extreme values.

The normalized criteria matrix can thus be constructed based on the relationship

$$r_{ij} = \frac{y_{ij}}{\sqrt{\left(\sum_{i=1}^{p}\left(y_{ij}\right)^2\right)}}, \quad i = 1, 2, \dots, p, \;\; j = 1, 2, \dots, k, \tag{1}$$

where

r_{ij} – indicates the normalized value for the i-th variant and the j-th criterion and

y_{ij} – the original criterion value for the i-th variant and the j-th criterion after conversion of the criteria into maximalization criteria.

In the next step, the weighted criteria matrix **W** = (w_{ij}) needs to be constructed based on the relationship

$$w_{ij} = v_j \cdot r_{ij} \tag{2}$$

where v_j indicates the weight for the criterion j. We then use the matrix **W** to determine the theoretical ideal (H) and base (D) variant, where $H_j = max_i\, w_{ij},\ \ j = 1, 2, \dots, k$ (k gives the number of criteria) and $D_j = min_i\, w_{ij},\ \ j = 1, 2, \dots, k$.

For each variant there follows a calculation of the distance from the ideal variant $d_i^+ = \sqrt{\sum_{j=1}^{n}\left(w_{ij} - H_j\right)^2}$ and from the base variant $d_i^- = \sqrt{\sum_{j=1}^{n}\left(w_{ij} - D_j\right)^2}$. Then in the last step we calculate the so-called relative indicator of the distance from the base variant $c_i = \frac{d_i^-}{d_i^+ + d_i^-}$

The variants are then organized by descending value of c_i. Based on the c_i values obtained, the countries are classified into 8 clusters. The breadth of the intervals is identical for all clusters and all comparisons, with the exceptions of clusters 1 and 8. Cluster 1 (c_i from 0.75 to 1) contains the best-rated countries (due to the nature of the TOPSIS method, the c_i coefficient is in the 0–1 range, and meanwhile a value of 1 can only be reached if a set were to contain only one single variant that reaches the best values based on all criteria, which did not happen for the countries observed), and cluster 8, meanwhile, contains the worst-rated countries (c_i is in the 0–0.15 range). The remaining clusters, meanwhile, have a breadth of 0.1 — i.e. for cluster two, c_i is in the interval from 0.15 to 0.25. The calculations and analyses themselves are then performed in two programs: MS Excel and Sanna.

4 Results and Discussion

4.1 Results of empirical analysis

This part of the contribution presents the development of the state of ICT penetration in the Czech Republic and a comparison of it with the other countries of Europe. The development of ICT service utilization in Czech society, in accord with the methods typically used in the European Union, is tracked every year via national statistical research. The problem of long-term tracking of ICT utilization lies in the fact that the services being monitored gradually change over time, and thus the data sample is not identical for all periods. We can cite as an example here the deployment of ADSL technology, which nearly no-one was using 10 years ago.

Technological indicators — infrastructure services

From Table 4 and Figure 1 below, we can see the development of the penetration of infrastructure services into the economies of European countries. From the comparison between the years 2010 and 2014, we see that for most of the countries, a tangible increase in the penetration of infrastructure services occurred.

Table 4. Technological indicators — results

Order in 2014 (in 2010)	Countries	Resulting relative rating		Cluster	
		2014	2010	2014	2010
1 (1)	Sweden	0,70174	0,60548	2	3
2 (4)	Finland	0,63374	0,50410	3	4
3 (19)	Latvia	0,56105	0,32338	3	6
4 (3)	Norway	0,54560	0,50748	4	4
5 (11)	Belgium	0,51229	0,41664	4	5
6 (8)	Netherlands	0,50934	0,43378	4	5
7 (2)	Iceland	0,50077	0,56768	4	3
8 (7)	Denmark	0,46286	0,44007	4	5
9 (14)	Great Britain	0,43774	0,35570	5	5
10 (10)	Estonia	0,43365	0,42508	5	5
11 (5)	Romania	0,43294	0,48738	5	4
12 (9)	Luxembourg	0,42407	0,42815	5	5
13 (15)	Germany	0,42328	0,35552	5	5
14 (24)	Ireland	0,42057	0,26781	5	6
15 (18)	Portugal	0,41618	0,32727	5	6
16 (22)	Spain	0,40928	0,29225	5	6
17 (12)	Austria	0,40431	0,38881	5	5
18 (13)	France	0,38512	0,36115	5	5
19 (16)	Slovakia	0,37449	0,35218	5	5
20 (20)	**EU27**	**0,37269**	**0,31341**	**5**	**6**
21 (23)	Hungary	0,37246	0,27902	5	6
22 (6)	Lithuania	0,36429	0,44817	5	5
23 (25)	Malta	0,35728	0,24146	5	7
24 (17)	Slovenia	0,31095	0,33009	6	6
25 (26)	**Czech Republic**	**0,30705**	**0,22290**	**6**	**7**
26 (27)	Poland	0,30538	0,21585	6	7
27 (21)	Bulgaria	0,29184	0,29705	6	6
28 (28)	Croatia	0,29119	0,21096	6	7
29 (29)	Italy	0,20841	0,20165	7	7
30 (30)	Greece	0,17323	0,18633	7	7
31 (31)	Cyprus	0,16770	0,14919	7	8

Source: the authors

The division of the countries of Europe into individual clusters can be seen in the following Fig. 1.

With our evaluation we see that a blanket shift towards an increase in the level of the technological indicators is occurring. While in 2010 none of the countries observed had reached an index value on the level of the second cluster and only two countries (Sweden and Iceland) were on the level of the third cluster, for 2014 there is one country (Sweden) on the level of the second cluster and two countries on the level of the third cluster (Finland and Latvia). Likewise the EU27 European Union average shifted from the sixth cluster to the fifth cluster. We identified the weakest infrastructure, meanwhile, in the countries of the seventh cluster, among which are classified Italy, Greece, and Cyprus — which in 2010 was even placed in cluster eight.

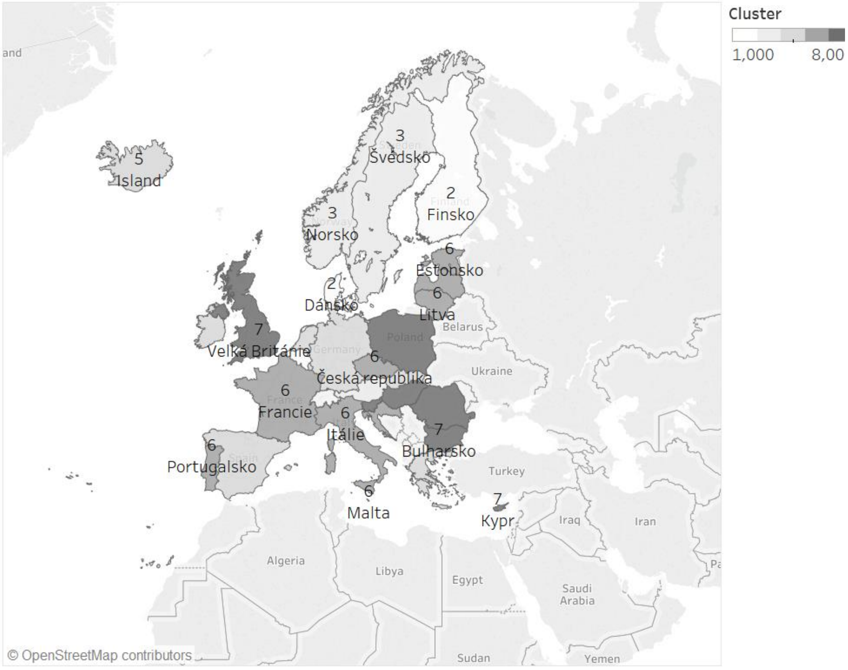

Fig. 1. Geographical distribution of countries in individual clusters in the Technological Indicators group Source: for data [4]; for figure the authors

Out of the individual countries, the largest leap was made by Latvia (from 19th to 3rd place in the country ranking). In the opinion of this study's authors, this is caused by the significant growth in the options for an internet connection for businesses and citizens and in connection speed. A trend can also be inferred from the growth in the absolute value of ICT investments in Latvia, which grew by 66 percentage points between 2010 and 2013. Meanwhile in Lithuania (where a significant rating drop occurred), investments into ICT essentially stagnated.

Comparison for the V4 countries

In the V4 countries, the best technological-indicator values are displayed by Slovakia, which maintained its position in the fifth cluster and fares best in this rating out of the V4. It is followed with a minimal gap by Hungary, which still belonged to the sixth cluster in 2010, but in 2014 had shifted to the fifth cluster. And wedged between these two nations we find the average for the EU27 states, which also shifted from the sixth to the fifth cluster. The remaining two nations — the Czech Republic and Poland — were placed in the sixth cluster in 2014, while in 2010 they both belonged to cluster seven.

In general we can state that the level of infrastructure services both in the V4 countries and for the average of the EU27 states is growing.

Figure 2 below goes on to depict the percentage of use for individual infrastructure indicators in the countries of the V4.

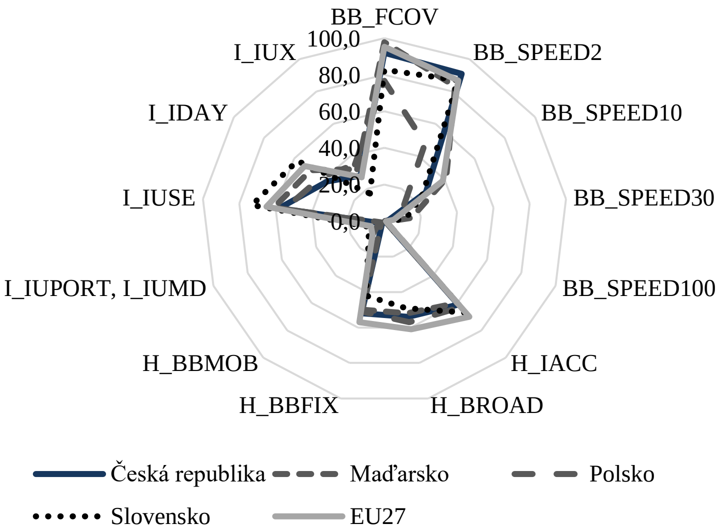

Fig. 2. Technological indicators in the V4 and EU27 countries in 2010

Source: for data [4]; for figure the authors

From the figure we can see that in 2010 the most common data transfer method in the economies of these countries was a landline broadband connection (BB_FCOV), and a speed of 2 Mbps (BBSPEED2) dominated in this connection. Speeds of 10 Mbps and higher were utilized only marginally. In the observed countries, roughly 70% of households were connected to the internet in this period, and the majority connection method was a broadband-speed landline. Roughly 80% of users had internet access at least once a week, and roughly 70% of them accessed the internet daily.

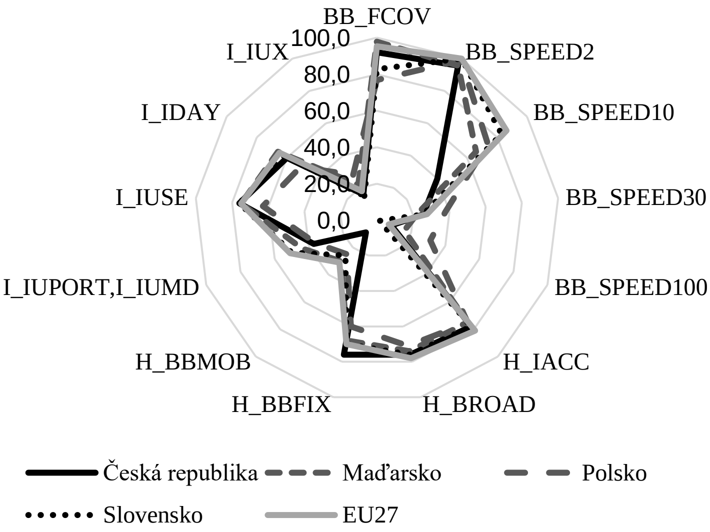

Fig. 3. Technological indicators in the V4 and EU27 countries in 2014

Source: for data [4]; for figure the authors

The most visible change in infrastructure between 2010 and 2014 was a change in internet connection speed. Especially in Slovakia, and to some extent in Hungary and Poland, an expansion of internet connections with a speed of 10 Mbps occurred, and in Poland, connections with a 100 Mbps speed saw growth — here we can assume that this concerns the investment into infrastructure connected with the organizing of the European soccer championship on 2012. The number of households with an internet connection also increased, as did their connection over broadband — roughly by ten percentage points. The number of daily internet users also grew in a very similar way.

5 Conclusions

Our analysis of the penetration of ICT technological indicators into the economy has shown that the general trend in European countries in the observed period, 2010–2014, is towards a growth in ICT penetration. This is also the expected development for the overall penetration of ICT into daily life.

From the analysis performed it is clear that the greatest utilization of broadband technology is in the Scandinavian countries, among which Latvia is wedged in third place. On the other end of the European spectrum we find the countries of Europe's South: Bulgaria, Croatia, Italy, Greece, and then in last place Cyprus. From the standpoint of the V4 countries, Slovakia fares best in terms of the level of penetration of technologies into the economy; it is the only one of them to lie above the EU average. Along with Hungary, it is placed within the fifth cluster. Poland, along with the Czech Republic, is placed in cluster six. From this we can see that during the period studied, a certain qualitative shift occurred in all of these countries with the exception of Slovakia. But at the same time it is clear that the V4 is among the regions where ICT infrastructure is not very well-developed. Thus it must be assumed that if we wish to become the equals of the advanced nations of Europe, we will need to make massive investments into this area in the coming years.

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