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On the Pulse of ICT Revolution, Productivity, and Growth: Macedonia versus European Union

Olivera Kostoska[1] and Ilija Hristoski[1]

[1] Faculty of Economics, Marksova 133,
7500 Prilep, Republic of Macedonia
{olivera.kostoska, ilija.hristoski}@uklo.edu.mk

Abstract. Information and Communication Technologies (ICTs) have become more accessible, more powerful and more widespread. Yet, the use of ICTs is not an end in itself. The impact that such technologies have on the economy and society is what ultimately matters. Understanding the economics of ICTs requires a deep and thorough knowledge of how the new technology generates the economic impacts. The ICT revolution holds the transformative potentials, offering many promises and benefits, even while posing severe risks and challenges. Therefore, it is of great importance and still a challenge to measure the capacity of countries to leverage ICTs for increased competitiveness and well-being. Aimed at reaching such a complex task, this paper employs the extensive data compendium of the Networked Readiness Index (NRI) 2015 and a set of supplemental data analysis tools (descriptive statistics, five-number summary statistics and a Box & Whisker plot, Euclidean and statistical distances, hierarchical cluster analysis and a corresponding dendrogram) to estimate both the performance of Macedonia in the NRI and the country's relative position vis-à-vis the EU member states. Looking at the trends since 2012 reveals that Macedonia is one of the ten most improved countries in their overall NRI performance. Nevertheless, the findings suggest that the country is lagging behind the European average in most indicators. The EU member states with the shortest statistical distance from Macedonia are Croatia, Cyprus, Romania, Hungary and Slovenia. Quite the reverse, the Nordics (Finland, Sweden and Denmark) and Western Europe (Luxemburg, Netherlands and UK) are the most 'distant' countries from Macedonia. These latter findings confirm the results obtained by the five-number summary statistics and the hierarchical cluster analysis.

Keywords: ICTs, NRI 2015, productivity, growth, Macedonia, European Union.

1. Introduction

Technology has incredible power to promote economic growth, improve people's life and make opportunities for individuals, companies and nations worldwide. Nowadays, everyone is faced with living an age of unparalleled digital disruption, with huge amounts of technology-driven change, enormous innovation and substantial development in the ways people use technology. The digital economy, which refers to economy empowered by digital technologies, is developing rapidly around the globe. In point of fact, such technologies accounted for more than 21% of gross domestic product (GDP) growth in the most advanced economies of the world in the past five years, while the European Union (EU) digital economy is growing at 12% each year and is now bigger than the Belgian national economy [1]. New digital trends, such as smart grids, mobile web services, cloud computing and social media, are drastically changing the business landscape, redesigning the boundaries of firms, the nature of work and the responsibilities of business leaders. These trends permit more than mere technological innovation. They stimulate innovation in the business models, business networking and transfer of knowledge and access to international markets.

The rising importance of the digital economy is demonstrated in a number of ambitious EU-level policy proposals and targets which have been set in the Digital Agenda for Europe. Launched in 2010, it contains more than 100 actions to ensure that digital technologies are used to stimulate Europe's economy and help the businesses and citizens to get the most out of these technologies. The Digital Agenda is actually one of the seven pillars of the Europe 2020 Strategy, which sets objectives for the growth of the EU by 2020. This Agenda intends to define the key enabling role that the use of ICTs will have to play if Europe wants to succeed in its aspirations for 2020. "The ICT sector is directly responsible for 5% of European GDP, with a market value of € 660 billion annually, but it contributes far more to overall productivity growth (20% directly from the ICT sector and 30% from ICT investments). This is because of the high levels of dynamism and innovation inherent in the sector, and the enabling role the sector plays in changing how other sectors do business. At the same time, the social impact of ICT has become significant – for example, the fact that there are more than 250 million daily internet users in Europe and virtually all Europeans own mobile phones has changed life style" [2].

In fact, ICT has developed into the "general purpose technology" (GPT) to our time, given the essential spillovers to the other economics sectors, their ability to transform the economic activities and business practices, and their role as efficient infrastructure for commercial transactions. Countries with businesses that aggressively incorporate these new technologies in their production processes tend to have enhanced productivity improvements than others. It is noteworthy that all stakeholders (individuals, companies, governments) in the economy are obliged to use these tools in order to create a real information society that ensures maximum productivity gains from ICT adoption [3]. However, the evidence reveals that, so far, the ICT revolution has benefited mostly the rich countries. Unexpectedly, the ICTs have opened up new digital divide which is, more generally, seen as "the gap between nations which can and cannot afford the technology, between the businesses and consumers enjoying the advantages of the Information age and those still awaiting its benefits, as the divide which separates the haves from the have-nots in the sphere of information, or as the exclusion of those who are poor, illiterate, rural or non-English speaking" [4]. Even in the most advanced economies, only certain segments of the population take advantage from ICTs. Progress made in enhancing national competitiveness may generate or deepen domestic inequalities if the unconnected become second-class citizens. In the absence of corrective tools, ICTs may possibly add to a non-inclusive type of growth, thus making the problem worse instead of mitigating it. To attain the ICT revolution and bridge digital divides, the countries are required to develop their ICT ecosystems. This entails long-term, expensive investment in infrastructure and education. "But low-hanging fruits do exist. Governments can create an enabling environment by promoting competition through sound regulation and liberalization" [5]. In general, if employed properly, ICTs can generate economic opportunities and promote social and political inclusion, ultimately contributing to shared prosperity.

Given the transformative power of ICTs and the essential role they have in improving competitiveness, permitting development and bringing progress to all levels of society, measuring the extent to which ICTs are used and understanding the determinants of ICT adoption have become a major concern of researchers around the globe. In 2001, the World Economic Forum embarked on the Global Information Technology Report series and the Networked Readiness Index (NRI). This was essentially a major effort to make conceptual sense of the complex ICT reality, recognizing the common factors that permit countries to implement technology effectively. The past 15 years have provided abundant evidence of these advances. Countries such as Israel, Republic of Korea and Estonia have built their national competitiveness on ICT products and services. In view of that, this paper implements the Networked Readiness Index 2015 to measure the capacity of Macedonia in leveraging ICTs to boost competitiveness and well-being. The country has filed its candidature to become an EU member state. Thus, Macedonia may become a full member at some point and must then abide by the EU's overall goals. This provides a sense of the challenges it currently faces, and makes the case to estimate the relative position of Macedonia and its 'distance' from the EU member states in the context of NRI variables. The rest of the paper is organized as follows. Section 2 reviews some evidence on the impact of ICT on economic growth and productivity. Section 3 introduces description of data and the methodology applied. Section 4 discusses the main empirical findings. Section 5 concludes and recommends.

2. From the Solow Paradox to the ICT-driven Productivity Resurgence: an Overview of Literature

ICTs have radically changed societies in the last quarter of the century prompting unexpected qualitative and quantitative changes. In the course of mid 80s and early 90s, a strong effort was made to measure the impact of ICTs on growth. The discussion was inspired by the so-called Solow paradox or productivity paradox, when, in 1987, Nobel Prize–winning economist Robert Solow noted, "you can see the computer age everywhere but in the productivity statistics" [6]. While until the early and mid-1990's the effects of ICT revolution on growth were not yet fully visible or measurable, by the end of the nineties, the academic literature agreed on the significance of ICT for the U.S. growth revival observed from 1995 to 2000. The deferral in recognizing the importance of ICT in accounting for labor productivity growth can give prominence to different factors, such as: a lack of precise quantitative measures for the output and value created by ICT; obstacles to measure productivity in the service sector, which is a heavy user of ICT; and finally, the total effect of ICT diffusion and use on GDP growth is expected to be proportional to the ICT capital stock existing in the economy [7]. What the growth accounting literature suggests is that rapid technological progress in the ICT-producing sector, especially semiconductors, after 1994 led to a rapid drop in quality-adjusted prices for ICT goods. These trends have been mirrored by the total factor productivity (TFP) growth in the ICT-producing sectors and ICT capital deepening in other sectors. This led to productivity growth. Given that the outstanding performance of the U.S. was not shared by the EU, interest emerged in finding the reasons for this divergence and trying to understand if the U.S.-EU productivity gap was in a way attributable to ICTs.

Oliner and Sichel (2000) find that the use of information technology (including computer hardware, software and communication equipment) made a relatively small contribution to output and productivity growth through the early 1990s. This contribution seems to have surged in the second half of the decade. The authors estimate that “the use of information technology and the production of computers accounted for about two thirds of the 1 percentage point step-up in productivity growth between the first and second halves of the decade”. Thus, they conclude that information technology has been crucial for the increased productivity performance of the U.S. economy [8]. To assess the robustness of the earlier evidence on the role of information technology, the authors extend the growth-accounting results. Yet again, the data confirm a substantial pickup in labor productivity growth and show that, both the use of information technology and efficiency gains related to production of information technology were the critical factors behind the observed resurgence [9].

In a similar effort, Schreyer (2000) examines the ICT contribution to economic growth along with labor and multi-factor productivity. The paper provides an international perspective displaying results for the G7 countries. The findings suggest that ICT capital goods have been important contributors to economic growth for all seven countries, even though the role of ICT has been particularly emphasized in the U.S. [10]. Furthermore, Colecchia and Schreyer (2002) compare the impact of ICT capital accumulation on output growth in Australia, Canada, Finland, France, Germany, Italy, Japan, United Kingdom and United States. The authors draw attention to the fact that “despite differences between countries, the United States has not been alone in benefiting from the positive effects of ICT capital investment on economic growth nor was the United States the sole country to experience an acceleration of these effects. ICT diffusion and ICT usage play a key role and depend on the right framework conditions, not necessarily on the existence of a large ICT-producing sector” [11].

The substantial role that information technology played in the U.S. productivity revival has been additionally confirmed by Jorgenson et al. (2002) [12] and Daveri (2003). The latter stated that the limited growth-improving effects from information technologies in countries other than the U.S. have happened in the IT-producing sectors, while the IT-using industries have contributed bulk of the productivity gains in the U.S [13].

Oulton (2001) employs a growth accounting approach to the UK and tries to measure the contribution of ICT to the growth of both aggregate output and aggregate input. Additionally, US price indices (adjusted for exchange rate changes) are used as deflators for ICT. The findings suggest that, from 1989 to 1998, the growth of ICT output contributed about a fifth of overall GDP growth. Since 1989, 55% of capital deepening has been contributed by ICT capital, and 90% since 1994. In essence, the UK performance in the second half of nineties resembles that of the U.S. in some respects. Both countries experienced acceleration in the rate of output growth accompanied by an upsurge in the contribution of ICT capital deepening. But, “despite the ICT adjustments, the UK growth rate of labour productivity weakens after 1994. Part of this is due to a fall in the contribution of non-ICT capital but part to a slowdown in total factor productivity (TFP) growth. By contrast, the US labour productivity acceleration has been accompanied by a rise in TFP growth (in both the ICT and non-ICT sectors of the economy). Overall, TFP growth has increased in the United States by about one half a percentage point, whereas it has fallen in the United Kingdom by about three quarters of a percentage point" [14].

A recent study summarizing the work in this area is that of van Ark et al. (2008). The analysis divides Europe's growth performance relative to the U.S. into three periods: 1950-1973 (labor productivity growth in the EU came with catching-up in terms of per capita income levels with the U.S. The key factors behind this period of catch-up were technology imitation and the new institutions); 1973-1995 (the "golden age" of post-World War II growth came to an end rather abruptly in the early 1970s, followed by a period of substantially slower growth lasting almost two decades on both continents); and 1995-2006 (the pattern of productivity growth between Europe and U.S. changed radically. The U.S. average annual labor productivity growth accelerated, while that of the EU declined. By 2004, GDP per hour worked in the EU was about 10 percentage points below the U.S. level). The authors indicate that the European productivity slump is attributable to the slower emergence of the knowledge economy in Europe compared to the U.S. They consider different reasons, which are not mutually exclusive, such as: lower growth contributions from investment in information and communication technology in Europe, the relatively small share of technology-producing industries in Europe and the slower multifactor productivity growth that can be observed as a proxy for advances in technology and innovation. The paper underlines that market service sectors are crucial in accounting for the productivity growth divergence between the two regions. Hence, the authors argue that improved productivity growth in European market services is needed so as to evade a further widening of the productivity gap [15].

3. Methodology and Data

Since 2001, the Global Information Technology Report series published by the World Economic Forum in partnership with Cornell University and INSEAD has measured the drivers of ICT revolution by means of Networked Readiness Index (NRI). In essence, the Index measures the propensity and readiness for countries to exploit the opportunities offered by ICTs. The networked readiness framework relies on several principles, such as [5]: a) a high-quality regulatory and business environment is essential to fully leverage ICTs and produce impact; b) ICT readiness (ICT affordability, skills and infrastructure) is a prerequisite to generate impact; c) fully-leveraging ICTs involves a society-wide efforts; d) the impact that ICTs have on society and economy is something that ultimately matters; e) the set of drivers (environment, readiness and usage) interact and reinforce each other to construct a virtuous cycle; f) the networked readiness framework should deliver a clear policy guidance. Such framework underpins the Networked Readiness Index and has been intended to provide direction for policymakers on the factors they need to consider for taking maximum advantage of ICTs in their growth strategies. Recently, the debate has moved from the point of ensuring access to the issue of how to make the best use of ICTs so that business innovation, governance, social cohesion and citizens' political participation may improve. Given this shift in emphasis, the Impact subindex was added to the NRI framework in 2012 [16]. Technically, the NRI 2015 is a composite indicator made up of 4 main subindexes, 10 pillars and 53 individual indicators distributed across the different pillars (Fig. 1). The computation of the Index is based on successive aggregation of scores from the most disaggregated level (i.e. the indicator level) to the highest level (i.e. overall NRI score).

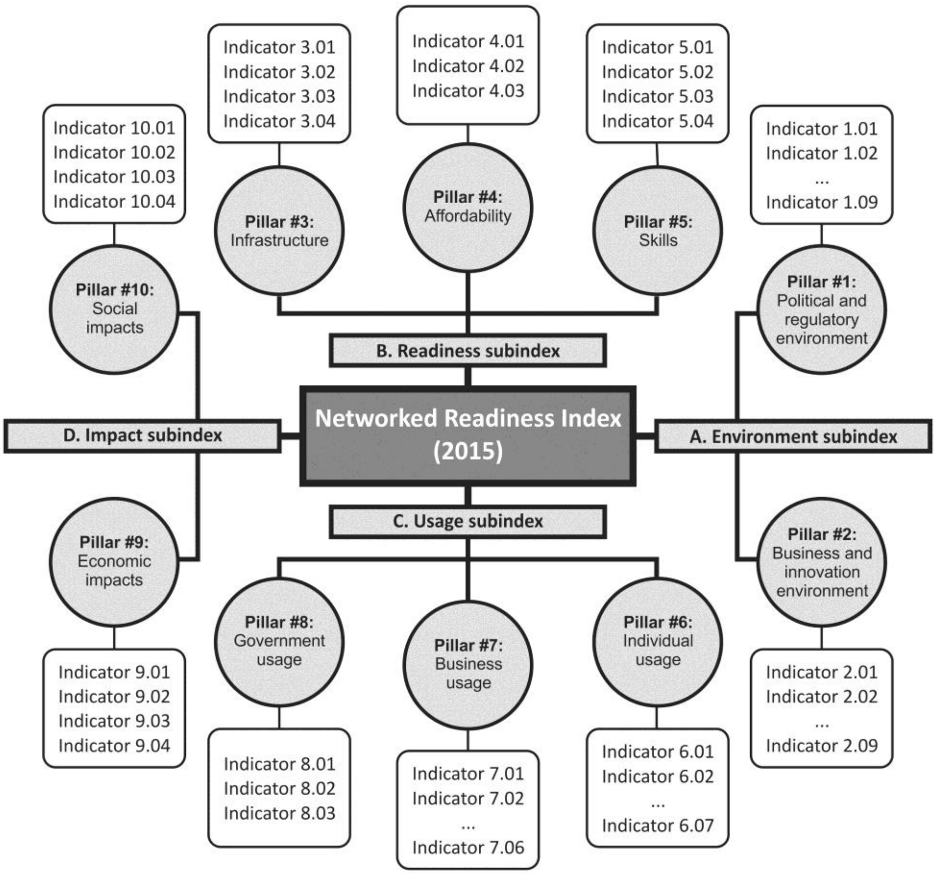


Fig. 1. The complex structure of the Networked Readiness Index 2015
(Source: World Economic Forum, 2015; authors' original representation)

This paper uses the relevant data[1] provided by the Global Information Technology Report 2015 as a secondary data source to carry out two types of analyses by means of the NRI ranks and values. The first one refers to a descriptive analysis of the NRI scores for Macedonia in order to assess the country's overall position and performance on a global scale, while the second estimates the NRI performance of Macedonia vis-à-

[1] The dataset on the NRI indicator values and ranks is publicly available, and can be freely accessed at http://www3.weforum.org/docs/WEF_NRI_2012-2015_Historical_Dataset.xlsx.

vis the EU-28 member states. Based on descriptive statistical methods, the latter opts to evaluate the percentage change (as a measure of deviation) between NRI 2015 indicator values for Macedonia with reference to the EU-28 mean values. With the aim of visualizing the best and worst performers and the interquartile range (from the 75th downto the 25th percentile) by NRI pillars, we further implement a five-number summary statistics accompanied by a corresponding Box & Whisker plot. Moreover, the article uses both the Euclidean and statistical distances, as well as the hierarchical cluster analysis approach to measure the country's 'distance' from each EU member state within the multi-dimensional dataspace.

Given that the measurement scales of the indicator values differ in the original dataset, we conduct, prior to introducing the concept of distance, a Min-Max scaling (i.e. normalization) data pre-processing technique to a number[2] of NRI indicator values in order to convert the input data into a unified range of values on a 1-7 scale (the lowest and the highest score possible). As an alternative approach to Z-score normalization/standardization, the Min-Max normalization scales the data $a[i]$ within an array to new values $a'[i]$, that belong to a fixed, pre-defined bounded range $[x, y]$, as in (1). For those NRI indicators[3] set to obtain worse outcomes at higher values and vice versa, the Min-Max formulation translates into (2), so that we could still preserve the lowest ($x = 1$) and the highest value ($y = 7$). This approach generally produces smaller standard deviations in the array, which can suppress the effects of outliers. As such, the scaling is intended for use in the concept of distance, particularly when the x and y range of data is known *a priori*.

$$a'[i] = \frac{(y-x)}{\left(\max_i(a[i]) - \min_i(a[i])\right)} \times \left(a[i] - \min_i(a[i])\right) + x \quad (1)$$

$$a'[i] = \frac{(x-y)}{\left(\max_i(a[i]) - \min_i(a[i])\right)} \times \left(a[i] - \min_i(a[i])\right) + y \quad (2)$$

[2] These include: Tertiary education gross enrollment rate, % (2.07); Electricity production, kWh/capita (3.01); Mobile network coverage, % pop. (3.02); Int'l Internet bandwidth, kb/s per user (3.03); Secure Internet servers/million pop. (3.04); Internet & telephony competition, 0–2 (best) (4.03); Secondary education gross enrollment rate, % (5.03); Adult literacy rate, % (5.04); Mobile phone subscriptions/100 pop. (6.01); Individuals using Internet, % (6.02); Households w/ personal computer, % (6.03); Households w/ Internet access, % (6.04); Fixed broadband Internet subs/100 pop. (6.05); Mobile broadband subs/100 pop. (6.06); PCT patents, applications/million pop. (7.03); Government Online Service Index, 0–1 (best) (8.02); ICT PCT patents, applications/million pop. (9.02); Knowledge-intensive jobs, % workforce (9.04); and E-Participation Index, 0–1 (best) (10.04).

[3] These include: Software piracy rate, % software installed (1.07); No. procedures to enforce a contract (1.08); No. days to enforce a contract (1.09); Total tax rate, % profits (2.03); No. days to start a business (2.04); No. procedures to start a business (2.05); Prepaid mobile cellular tariffs, PPP $/min. (4.01); Fixed broadband Internet tariffs, PPP $/month (4.02).

The Euclidean distance, D_{ij}, is a well-known measure of distance between two observations, *i* and *j*, in a *p*-dimensional dataspace. Assuming that *i* represents the Republic of Macedonia, *j* (j = 1, …, 28) – the EU member states, p_k (k = 1, 2, …, 53) – NRI 2015 indicators, x_{ik} (k = 1, 2, …, 53) – the indicator values for Macedonia, and x_{jk} (j = 1, …, 28; k = 1, 2, …, 53) – the indicator values for each EU country, the Euclidean distance is given by (3).

$$D_{ij} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk} \right)^2} \tag{3}$$

The statistical distance, SD_{ij}, is obtained from Euclidean distance, once the latter is adjusted to take into account the variance of the variables, s_k^2 , as in (4).

$$SD_{ij} = \sqrt{\sum_{k=1}^{p} \left(\frac{\left(x_{ik} - x_{jk} \right)}{s_k} \right)^2} \tag{4}$$

In (4), s_k stands for a standard deviation of the variable p_k (k = 1, 2, …, 53).

Hierarchical cluster analysis (HCA) is one of the most commonly used exploratory techniques for identifying data structures. As with other clustering algorithms, HCA separates the groups (clusters) of similar cases/observations, based upon their scores on a set of Interval/Ratio-level measures. By virtue of clustering variables together in a manner somewhat similar to the factor analysis, HCA produces a series of models with cluster solutions generally ranging from 1 (all cases are classified into a single cluster) to N (all cases belong to an individual cluster). In fact, hierarchical cluster analysis is an agglomerative method where all cases start in their own distinct cluster. The two ‘closest’ (most similar) clusters are then combined - a step that repeats until all cases are placed into a minimally specified number of clusters (ultimately, into a single cluster). At the end, the optimal number of clusters is specified out of all cluster solutions.

Given that the number of clusters is not predefined, we consider this kind of multivariate statistical analysis the most appropriate to conduct here. Our goal is to provide clusters of countries that reliably distinguish from each other in terms of their intrinsic characteristics vis-à-vis all 53 NRI indicator values, which represent Interval-level measures on a 1-7 scale.

The HCA analysis conducted here includes five different cluster solutions (N = 2 to N = 6 clusters). This is because we keep in mind that there is always a trade-off between the number of clusters and their sizes, i.e. the more the clusters are, each of them contains more homogeneous, yet smaller group of countries.

When it comes to clustering methods, we have opted for the Ward’s method. The latter assumes the concept of distance as that of all clusters relative to the grand average of the sample. Thanks to the use of F value (like ANOVA) that maximizes the significance of differences between clusters, the Ward's method has the highest statistical power among other clustering methods. The downside is that this method is prone to outliers and generally tends to produce relatively small clusters of approximately equal size, which is not always a desirable feature.

Finally, we have opted for the Squared Euclidian Distance measure, which is the most commonly used measure for scale data, primarily for its ability to increase the importance of large distances, while gravely weakening the position of the small ones.

4. Empirical Findings

The NRI 2015 covers 143 economies, which jointly account for 98.4% of world GDP. Not surprisingly, advanced economies perform better in leveraging ICTs than developing ones. In essence, the position of countries in the NRI mirrors their performance on the development ladder, i.e. a higher level of income is usually related to a higher NRI score. Singapore tops the 2015 rankings, while seven of the top ten economies are European. “In Europe, Northern and Western Europe are home to some of the best connected and most innovation-driven economies in the world. In particular, the Nordics - Finland (2nd), Sweden (3rd), Norway (5th), Denmark (15th), and Iceland (19th) – continue to perform well in the NRI. Indeed, these five countries have featured in the top 20 of every edition since 2012” [5]. Similarly, the Western European economies enjoy a strong group performance, viz. the Netherlands, Switzerland, UK and Luxemburg all appear in the top ten. Owing to the strong performance of Estonia and the steady growth of Latvia, which is catching up to Lithuania, the Baltic States are gradually but surely bridging the gap with the Nordics. These countries are running away from what was once a rather homogenous group of Eastern European Countries that have joined the EU since 2004, i.e. the others are either stable or losing the ground [5]. In essence, the Global Information Technology Report 2015 provides data to represent a profile for each of the 143 economies covered in the Report.

4.1. Profile of Macedonia in the various NRI dimensions

Looking at the trends since 2012 reveals that Republic of Macedonia is one of the ten most improved countries[4] in their overall NRI performance [5]. With 0.51 points up, the country has improved its NRI score between 2012 and 2015 along with the obvious progress seen in the rankings (Fig. 2).

The impressive percentage increase (43.14%) in the value of the 4th NRI pillar (Affordability) between 2012 and 2015 has largely contributed to such positive trends (Fig. 3). This exceptional improvement is essentially attributable to the strong performance of two indicators, i.e. 4.03: Internet & telephony competition [values are in range 0 to 2 (best)] and 4.01: Prepaid mobile cellular tariffs, PPP $/min. Taking the value of 1 and 117th position (out of 142 economies) in 2012, the former indicator has received the best value and climbed to the first place (out of 143) in 2015. The latter

[4] In order of score differences, these include: Armenia, Georgia, United Arab Emirates, Kazakhstan, Russian Federation, El Salvador, Macedonia, Mauritius, Kyrgyz Republic and Latvia.

exhibits a less impressive but still solid performance both in the value and rank (0.58 and 125, respectively in 2012; 0.15 and 40, respectively in 2015).

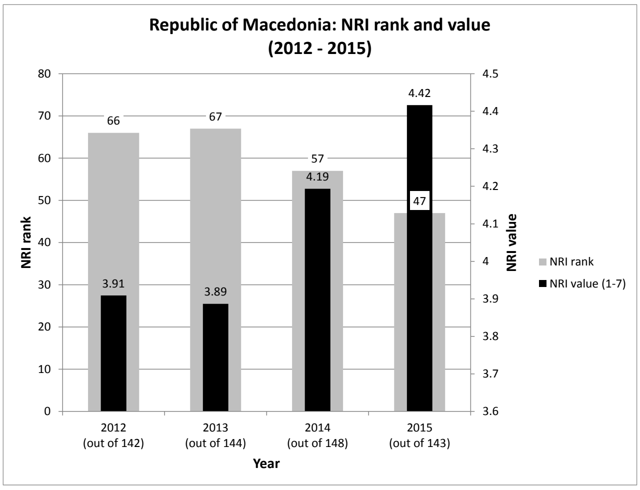


Fig. 2. Republic of Macedonia: NRI rank and value, 2012-2015 (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' original representation)

The percentage increase (17.87%) in the value of the 6th NRI pillar (Individual usage) is also worth paying attention to (Fig. 3). Hereby, the most interesting features reveal the indicator related to the use of virtual social networks [measured on a 1-to-7 (best) scale]. Beginning with the 47th place in 2012 (value = 5.7), the country has gradually moved up to 12th position in 2015 (value = 6.4).

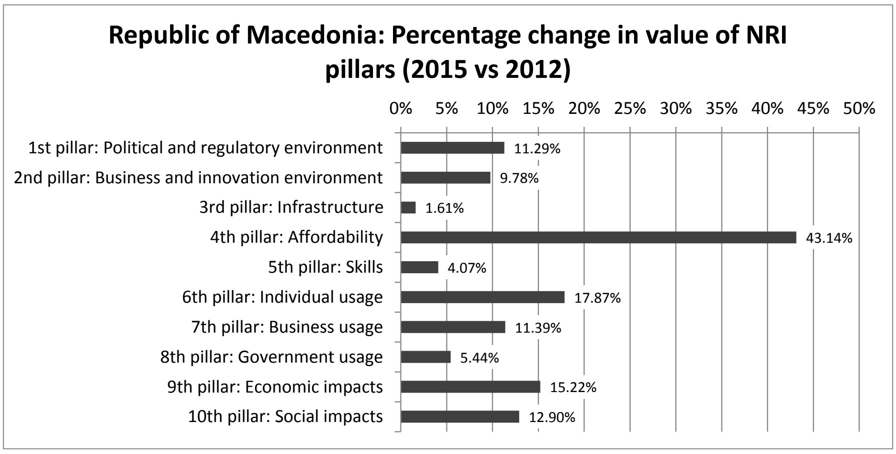


Fig. 3. Republic of Macedonia: Percentage change in value of NRI pillars (2015 vs 2012) (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

4.2. Macedonia versus EU: performance in the NRI 2015

This part first discusses and compares the values of each NRI indicator for Macedonia with reference to the EU mean values, i.e. the percentage change as a measure of deviation between the respective variables (Fig. 4).

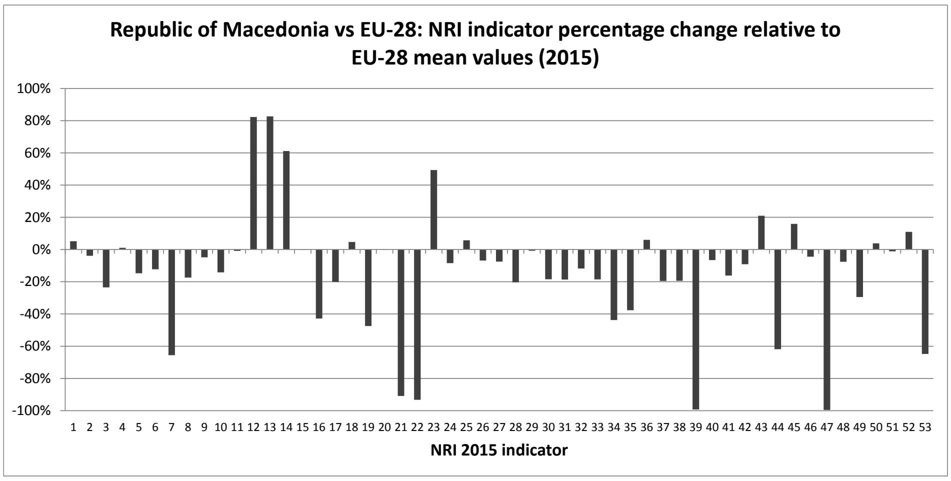


Fig. 4. NRI indicators: deviation between Macedonia and the EU-28 mean values (2015) (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

The findings suggest that Macedonia is lagging behind the corresponding EU mean values in most indicators (39 out of 53). Thus far, the largest gap (–99.55%) is observed in the NRI indicator 9.02 (ICT PCT patents, applications/million pop.) that belongs to the 9th pillar (Economic impacts). This pillar aims to measure the effect of ICTs on the economy through technological and non-technological innovations in a country and the overall shift of an economy toward more knowledge-intensive activities [5]. The NRI indicator 7.03 (PCT patents, applications/million pop.) is the second where Macedonia is performing worse (–99.27%) than the European average. It is noteworthy that this indicator belongs to the 7th pillar (Business usage), which captures the extent to which businesses in a country use the Internet for business-to-business and business-to-consumer operations, as well as their efforts to integrate ICTs in their operations. It also measures the capacity of firms to come up with new technologies by taking into account the number of patent applications under the Patent Cooperation Treaty (PCT) [5]. In essence, there is a body of theoretical work that has sought to explain the motives why broadband infrastructures could have an impact on productivity (levels and growth). That is to say, the high-speed Internet, via broadband infrastructures, produces cheaper and faster exchange of information between economic agents (both within and across organizations) [7]. This makes a sense to place special emphasis on another critical example of a major deviation (–90.85%) from the EU mean value, viz. the NRI indicator 3.03 (Int'l Internet bandwidth, kb/s per user) that belongs to the 3rd pillar (Infrastructure). This last pillar actually captures the state of a country's ICT infrastructure, as well as infrastructure that matters for ICT development: mobile network coverage international Internet bandwidth, secure Internet servers, and electricity production [5]. All the same, the results also show that Macedonia outperforms the EU average in a very few instances of indicators. The greatest difference is actually observed in two NRI variables with relative change of +82.72% (2.04: No. days to start a business) and +82.32% (2.05: No. procedures to start a business).

In order to divide among the best- and worst-performing countries and to identify the interquartile range, we look at the distribution of NRI values for Macedonia and each EU country by individual NRI pillars (Fig. 5). The five-number summary stipulates that both Macedonia and the rest of European Union are outperformed at all pillars by the Western European countries (Austria, Netherlands and Luxembourg), Nordics (Sweden, Finland and Denmark) and Estonia. On the other hand, the country is better placed than the worst-performing economies (Bulgaria, Italy, Slovak Republic, Romania and Greece) and consistently below the median in all cases except the 4th pillar (Affordability) where it lies above the third quartile. In point of fact, this pillar assesses the affordability of ICTs in a country through measures of mobile telephony usage costs and broadband Internet subscription costs, as well as the state of liberalization in 17 categories of ICT services, because more intense competition tends to reduce retail prices in the long run [5].

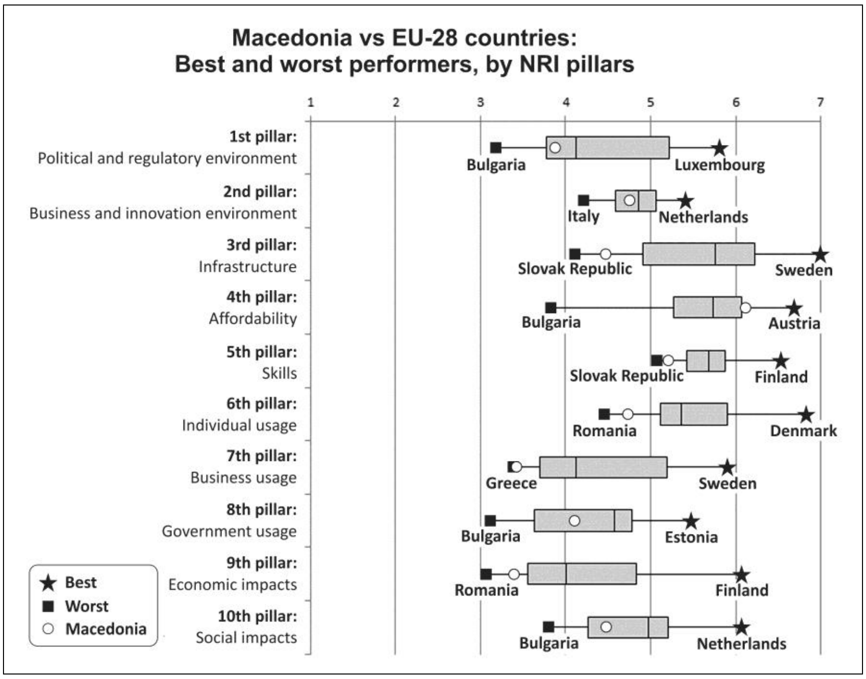
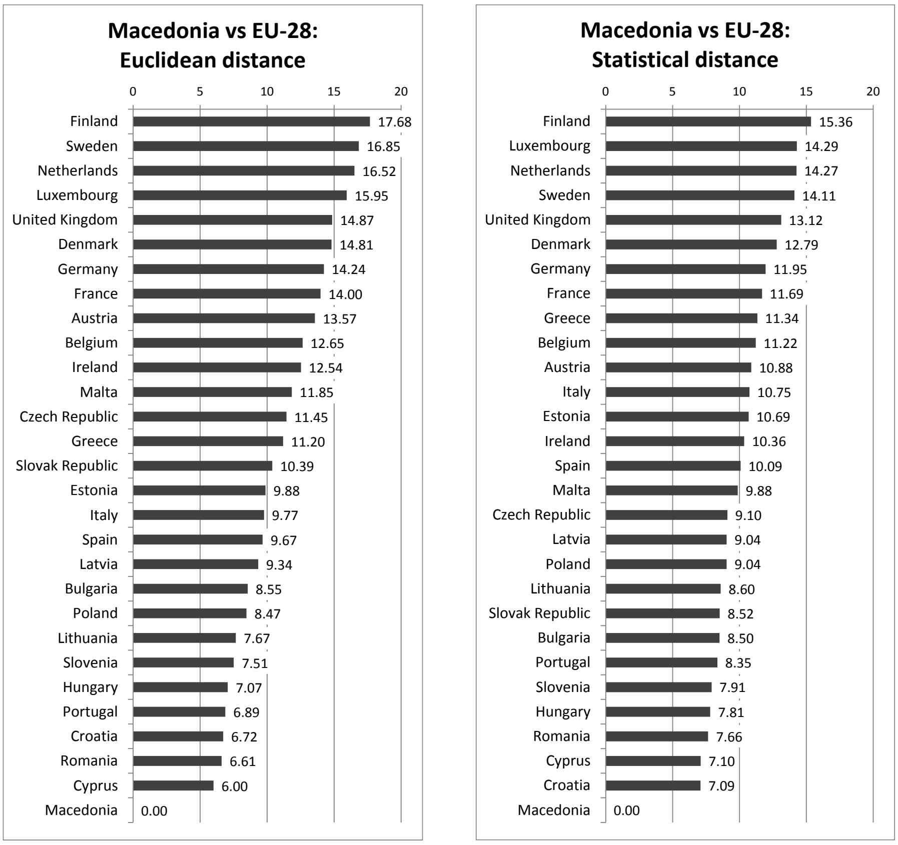


Fig. 5. Box and Whisker plot resembling the five-number summary of the EU-28 member states + Republic of Macedonia, to point out the best and worst performers, by NRI pillars (2015) (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

Next to the previous descriptive measures, the paper further examines the ‘distance’ between Macedonia and each EU country within the normalized NRI space. For that reason, we use two distance measures, viz. the Euclidean distance and the statistical distance (Fig. 6). The findings point to a slight difference between the two types of distance. The EU countries with the shortest statistical distance from Macedonia are Croatia, Cyprus, Romania, Hungary and Slovenia. Quite the opposite, the Nordics (Finland, Sweden and Denmark) and the Western Europe (Luxemburg, Netherlands and UK) are the most ‘distant’ countries from Macedonia. These findings confirm yet again the results already obtained by the five-number summary statistics.



(a) Euclidean distance (b) Statistical distance

Fig. 6. Euclidean and statistical ‘distance’ between Macedonia and each EU-28 country (2015) (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors’ calculations)

The previous findings have finally been completed by the hierarchical clustering analysis approach. Fig. 7 clearly shows that countries fall into different groups, which include diverse number of clusters (2-6). It is noteworthy that the group consisting of N = 4 clusters reflects entirely the grouping of the EU-28 member states relative to Macedonia with respect to the Euclidean distances, i.e. cluster #4 corresponds to TOP 2 EU-28 countries, followed by those of cluster #1. The same as Macedonia, EU-28 countries, positioned in the bottom half of the Fig. 6 (a), belong to the cluster #2. Table 1 reveals the grouping with four clusters and the member countries thereof. Finally, the dendrogram presented in Fig. 8 depicts the overall picture of the hierarchical clustering analysis.

Cluster Membership

Case	6 Clusters	5 Clusters	4 Clusters	3 Clusters	2 Clusters
1:Austria	1	1	1	1	1
2:Belgium	1	1	1	1	1
3:Bulgaria	2	2	2	2	2
4:Croatia	2	2	2	2	2
5:Cyprus	2	2	2	2	2
6:Czech Republic	3	3	3	3	2
7:Denmark	1	1	1	1	1
8:Estonia	4	4	2	2	2
9:Finland	5	5	4	1	1
10:France	1	1	1	1	1
11:Germany	1	1	1	1	1
12:Greece	2	2	2	2	2
13:Hungary	2	2	2	2	2
14:Ireland	1	1	1	1	1
15:Italy	2	2	2	2	2
16:Latvia	4	4	2	2	2
17:Lithuania	4	4	2	2	2
18:Luxembourg	1	1	1	1	1
19:Macedonia	2	2	2	2	2
20:Malta	6	4	2	2	2
21:Netherlands	1	1	1	1	1
22:Poland	2	2	2	2	2
23:Portugal	4	4	2	2	2
24:Romania	2	2	2	2	2
25:Slovak Republic	3	3	3	3	2
26:Slovenia	2	2	2	2	2
27:Spain	2	2	2	2	2
28:Sweden	5	5	4	1	1
29:United Kingdom	1	1	1	1	1

Fig. 7. Cluster membership of the EU-28 countries + Macedonia according to the Ward's clustering method and squared Euclidean distance measure (2015)
(Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

Table 1. The membership of EU-28 countries + Macedonia in the solution that relies on four clusters (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

Cluster	Country
#1	Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, United Kingdom
#2	Bulgaria, Croatia, Cyprus, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Macedonia, Malta, Poland, Portugal, Romania, Slovenia, Spain
#3	Czech Republic, Slovak Republic
#4	Finland, Sweden

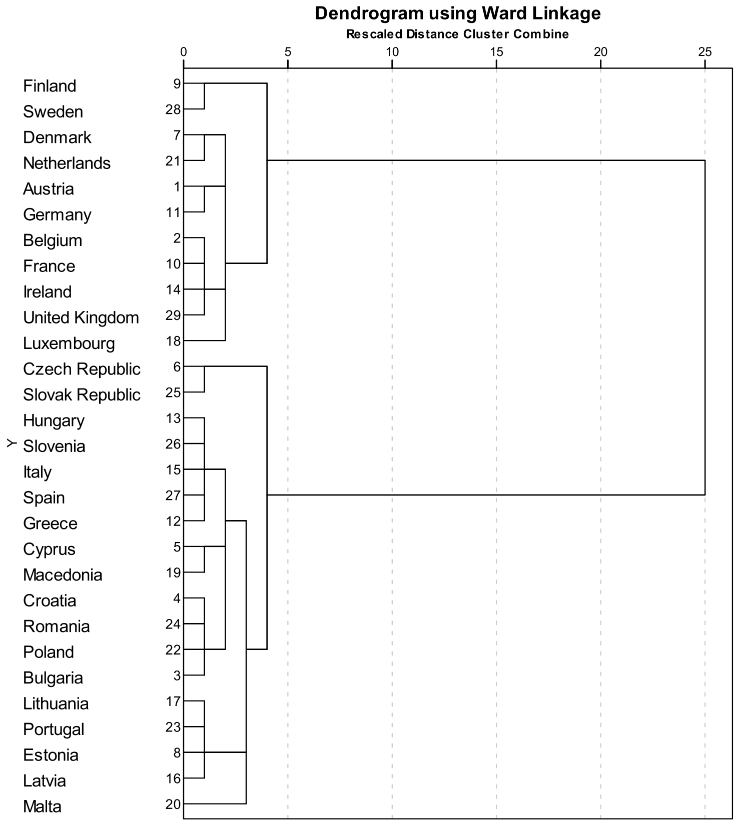


Fig. 8. Dendrogram depicting the cluster membership of the EU-28 countries + Macedonia according to the Ward's clustering method and squared Euclidean distance measure (2015) (Source: The NRI Historical Dataset, 2012-2015 World Economic Forum; authors' calculations)

5. Conclusions and Recommendations

As a general purpose technology, ICTs have an influence that extends well beyond the productivity gains. Those technologies act as a vector of economic and social transformation by enhancing connectivity, improving access to basic services, generating employment and business opportunities and shifting the ways people interact, communicate and engage among themselves and with their governments. With the Networked Readiness Index 2015 and a set of supplemental data analysis tools, this paper tries to assess both the ability of Macedonia to leverage ICTs for increased competitiveness and the country's relative position vis-à-vis the EU member states. In an effort to accomplish such a complex task, our empirical analysis aims to provide guidance to decision makers for those areas where policy interventions may possibly boost the impact of ICTs on productivity and growth. Apart from the market failures, worth paying is the evidence that ICTs investment respond more rapidly to demand shocks than other forms of capital. This implies that programs triggering ICTs investment may be beneficial for counter-cyclical policies, and this may prove to be especially important in terms of economic crisis. Though this paper does not explicitly cover the most appropriate types of policy interventions, a number of indications can be drawn from the empirical research conducted here.

Namely, the results of the Networked Readiness Index reveal that Macedonia is one of the ten most improved countries in their overall NRI performance. The awe-inspiring percentage increase (43.14%) in the value of the 4th NRI pillar (Affordability) between 2012 and 2015 has largely contributed to such positive trends. The percentage increase (17.87%) in the value of the 6th NRI pillar (Individual usage) is also worth revealing. All the same, the findings suggest that Macedonia is lagging behind the European average in most NRI indicators (39 out of 53). Thus far, the largest gap is observed in the effects of ICTs on the economy through technological and non-technological innovations in a country (economic impacts), as measured by the number of patent applications in ICT-related technologies. Similarly, Macedonian companies are falling significantly behind their EU peers in the capacity to innovate (reflected by the PCT patent applications per million populations). Another example of a major deviation from the European average is the NRI indicator (Int'l Internet bandwidth, kb/s per user) that belongs to the Infrastructure pillar. Improvements hereby are of critical importance as they can give rise to development of new products and processes and to new business models (so that broadband infrastructure can be interpreted as an investment promoting the GPT features of ICT). Furthermore, the five-number summary specifies that both Macedonia and the rest of European Union are outperformed at all NRI pillars by the Western Europe (Austria, Netherlands and Luxembourg), Nordics (Sweden, Finland and Denmark) and Estonia. Hitherto, Macedonia performs better than Bulgaria, Italy, Slovak Republic, Romania and Greece and is consistently below the median in all cases except the 4th pillar (Affordability) where it lies above the third quartile. These findings are confirmed once again in our research efforts to examine the 'distance' between Macedonia and each EU country within the normalized NRI space. The findings point to a minor difference between the two distances, viz. the Euclidean and the statistical distance. That is to say, Nordics and the Western European countries (Luxemburg, Netherlands and UK) are the most 'distant' from Macedonia, while Croatia, Cyprus, Romania, Hungary and Slovenia are those EU member states, which exhibit the shortest statistical distance from the country. The previous results have been reaffirmed by the hierarchical cluster analysis. In view of the Euclidean distance, the grouping of countries in four clusters has proven to match the exact ordering of the EU-28 countries.

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