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# The Analysis of the Digital Economy and Society Index in the EU

**Andriy Stavytskyy**

Department of Economic Cybernetics,
Taras Shevchenko National University of Kyiv
Vasylkivska str. 90-a,
Kyiv 03022, Ukraine
E-mail: a.stavytskyy@gmail.com

**Ganna Kharlamova**

Department of Economic Cybernetics,
Taras Shevchenko National University of Kyiv
Vasylkivska str. 90-a,
Kyiv 03022, Ukraine
E-mail: akharlamchek@gmail.com

**Eduard Alexandru Stoica**

Faculty of Economic Sciences,
Lucian Blaga University of Sibiu
Dumbravii 17,
Sibiu 550324, Romania
E-mail: eduard.stoica@ulbsibiu.ro

**Abstract:** *The paper analyzes the Digital Economy and Society Index (DESI), which characterizes the development of digital economy. Based on the data of 28 European countries for 2013–2018, using the panel regression, we studied the influence of the consumption index growth by the purchasing power parity and unemployment among the active population on the structural units of DESI. It is shown that a 1% increase in the consumption index results in about 0.2 increase in the DESI, and an increase in unemployment by 1% leads to about 0.2 DESI decline. It is also shown that the 98% value of DESI is actually determined by its previous trends, and therefore it is impossible to increase this index rapidly. Some reflections and conclusions are made on the perspective of the developing states, i.e., Ukraine, that is not yet assessed in DESI ranking.*

**Keywords:** *consumption, DESI, index, panel regression, unemployment*

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## 1. Introduction

Social development to new technologies and globalization processes push the economy to be changed. These days, the main focus is on digitizing. The term 'digital economy' was first used by Nicholas Negroponte (1995) from the Massachusetts University. Then, the 2017 World Economic Forum saw the future of the economy in its informatization.The Forum set targets for the implementation of the 'digital economy and society' in order to accelerate the progress. Thus, the Digital Economy and Society Index (hereafter DESI) was introduced to determine the stage of the state's or other specific economic entity's development in this area (Moroz, 2017). The DESI index characterizes the progress of 28 European countries in the development of the digital economy and society (European Commission, 2018). This indicator allows the analysis of the state development in accordance with the efficiency of its transition to digital economy; the justification of areas where such changes should be the first priority; the assessment of the dynamics of changes in space and time; and the clusterization of states in accordance to the indicators. It should be noted that in addition to DESI, there is the I-DESI (The International DESI), which differs in several indicators from the European one, but allows at least to approximate the level of development of the EU countries with other (DESI, 2018).

The index has been analysed by numerous scholars, in particular by Stoica and Bogoslov (2017). The basis of the research was to compare the values of the index or its components in different countries, or the definition of the index value for a particular country (Pilinski, 2015). However, until now, the assessment of the relationship between the value of the index and the main macroeconomic factors in the country is still lacking. It leads to a discussion—is digitalization a source or a consequence of sustainable development at the level of the state? On the one hand, the level of economy determines opportunities for innovations, but, on the other hand, even the richest countries cannot implement digital technologies without the appropriate knowledge and skills base. Thus, this research is an attempt to add to this discourse by the modelling results. The primary goal of the paper is to estimate and analyse the impact of economic conditions in EU countries on the level of digital development. The sub-goal is to check the difference between EU and non-EU states in providing new technologies.

The article is structurally composed in the following content parts: (1) a review of the literature on the subject of research; (2) the methodology for analysis, which includes data collection, its verification, modelling of panel regression;

(3) the analysis of the results with assumptions how to implement it in practice; and (4) the findings and conclusion.

## 2. Literature review

The transformation of the technological structure of modern economy has led to the emergence of a digital economy, which opens up significant opportunities and, at the same time, creates some threats (Kolomiets, 2017). The consequence of this process is the qualitative transformation of economic relations. The attention is increasingly paid to the development of digital economy and its conceptualization as a basis for political decisions. The World Economic Forum has launched the research on digital economy as a leading area for the future development of society:

> *Digitization transforms business models, political landscape and social norms. The purpose of the System Initiative of the World Economic Forum 'Forming the Future of the Digital Economy and Society' is to contribute to the development of a common digital environment that creates trust, which is the driving force of integration, economic development and social progress.* (Giannone & Santaniello, 2018)

In general, digital economy is not only the relationships that are mediated by the internet, cellular communication, ICT. It changes business interaction; destroys a long chain of mediators; accelerates the progress of various transactions (loans, leases, sales, taxes, settlements, etc.); overcomes barriers to market access, eliminates spatial constraints and creates alternative commercial platforms; provides competitive advantages to companies regardless of their size; allows to create the effect of scale and realize its positive spillover impact, reducing costs. There are new business practices that are reflected in the emergence of the gig-economy, freelance, crowdfunding, crowdinvesting, crowdsourcing, crowdcasting, and crowdlending (Seagate, 2017).

Not only the economic and social ratings and indices are gaining a special significance, but also indices that cover some aspects of the digital economy development, such as indices of the information society. For example, the Digital Economy and Society Index (DESI) was designed in the European Union in 2015 for the purpose of identifying priority investment areas for the creation of the digital market and helping the EU countries to improve digital

productivity (Stoica & Bogoslov, 2017). For the fourth consecutive year, the Huawei company explores the trends of digital economy by its global network interaction index (Global Connectivity Index, or GCI). They note that the growth of the index indicates an increase in the levels of competitiveness, innovation and productivity in the national economy. The next widely known attempt in the scientific literature is the Digitization Index (DiGiX) that assesses the factors, agents' behaviour and institutions that enable a country to fully leverage Information and Communication Technologies (ICTs) for increased competitiveness and wellbeing (Camara & Tuesta, 2017). It is a composite index that summarizes 100 relevant digital performance indicators of a state. The DiGiX is structured around six principal dimensions: infrastructure, households' adoption, enterprises' adoption, costs, regulation and contents. Each dimension is in turn divided into a number of individual indicators, adding up to 21 in total.

Given that the issues of the digital economy and the indices and ratings themselves have a very shallow retrospective, the forecasting of its dynamics and comparative analysis of the countries' success according to these indicators is highly impossible (Boneva & Dzhambazova, 2017). The same applies to the analysis of the factors influencing the development of the digital economy and its KPIs (Burger-Helmchen & Meghisan-Toma, 2018). Yet, if we go deeper in the scientific literature, including browsing in the Google Scholar, the number of papers on this subject is increasing. Still, the mathematically reasonable approach to the issue is still not sufficiently widespread (Haltiwanger & Jarmin, 2000) and the same could be said about the extensive review by the geography for the analysis (Corrocher & Ordanini, 2002). For example, the work by Nagy (2019) relies on cross-country analysis to determine the significant differences between Ukraine and Hungary in terms of access to the internet and device usage including smartphones, computers and tablets. The results show a certain lag in Ukraine, which is not surprising. Ershova *et al*. (2018) proposed the digital economy development assessment as a tool for managing the digital transformation processes at the national, regional and sectoral levels. Their methodology includes a system of indicators, measurement tools and evaluation criteria that allows assessing the current situation under the conditions and effects of digital transformation. Taking into account the novelty of the issue, the scientific world has not yet come to a comprehensive understanding of representative indicators of the digital economy—along with the indices, various sets of factors that may reflect the evolution of the situation are used. As an example, to conduct a comparison of the digital economy development level of the so-called "old" members of the European Union, Ziemkiewicz (2018) used ten diagnostic variables which were provided by Eurostat. The taxonomic

measure of development proposed by Zdzisław Hellwig was applied to compare the countries. However, despite the fact that creating the digital economy is often pointed out as a potential chance for less developed countries to close their development gap to the best-developed economies, the research confirmed the traditional disparities between the "old" European Member States.

Thus, the analysis of literature on the subject provides grounds for formulating the novelty of our study in terms of assessing the DESI as a dependent variable to the mathematically grounded study of the impact and consequences of socio-economic development in the EU. Afterwards, we tried to spread the results on the state that is not under the DESI assessment yet—Ukraine—and appreciated some researchers' attempts to assess an index like DESI for this state to test the hypothesis.

## 3. Methodology

The index consists of five main indicators, which are subdivided into three levels. Five indicators are located at the first level, namely Connectivity, Human Capital, Use of Internet, Integration of Digital Technology, and Public Digital Performances. At the second and third level, these five indicators are specified and divided into 13 subgroups of the second level and 34 subgroups of the third level (DESI, 2018; see Annex).

After determining the indicators of the second and third levels and bringing them into a comparative form through the coefficients provided by the calculation methodology, there are 5 indicators of the first level, each of them corresponds to a specific weighting factor. After that, the final result of the index is calculated using the formula:

$$DESI = \sum_{i=1}^{5} a_i w_i$$

Where $a_i$ is the value of the $i$ -the indicator of the first level, $w_i$ – the appropriate weighting factor (Table 1). Thus, the index DESI is calculated.

According to the European Commission (Fig. 1), nine countries of the EU (Denmark, Sweden, Finland, the Netherlands, Luxembourg, Ireland, Great Britain, Belgium, and Estonia) have the highest rates. The average result is assessed for Spain, Austria, Malta, Lithuania, Germany, Slovenia, Portugal,

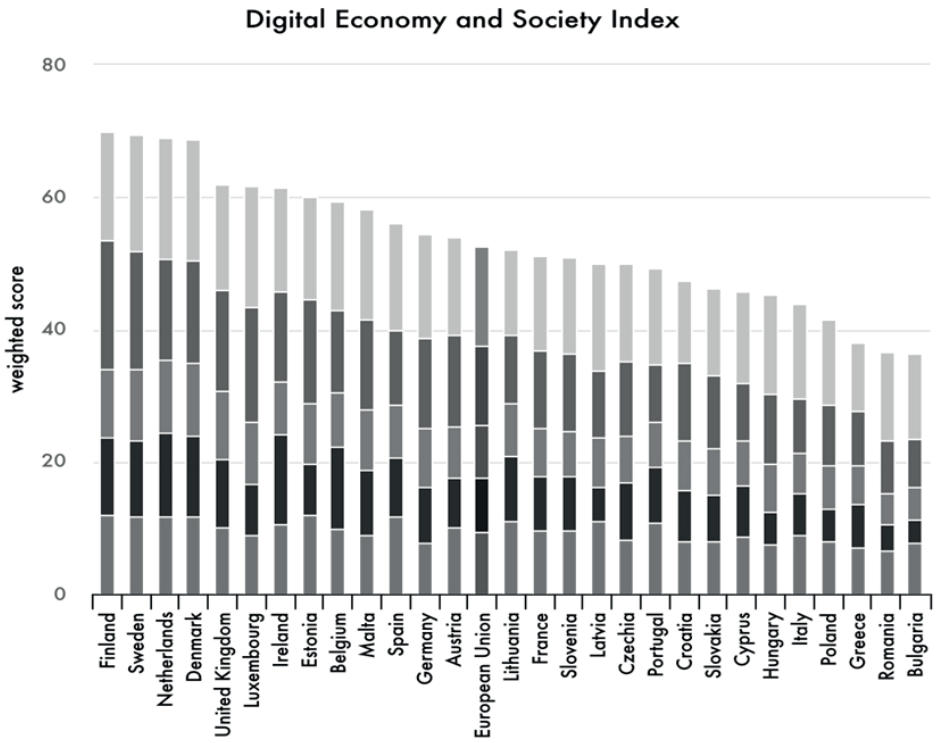
Czech Republic, France, and Latvia. The lowest result was shown by Slovakia, Cyprus, Croatia, Hungary, Poland, Italy, Bulgaria, Greece, and Romania. Overall, the countries have maintained their positions compared with 2017.

*Table 1. Weights of the first level*

| I level | Coefficients |
|---|---|
| 1. Connectivity | 0.25 |
| 2. Human Capital | 0.25 |
| 3. Use of Internet | 0.15 |
| 4. Integration of Digital Technologies | 0.20 |
| 5. Public Digital Services | 0.15 |

*Source: Digital Economy and Society Index (DESI)*

*Figure 1. Digital Economy and Society Index by main dimensions*




*Source: DESI Composite Index, 2017*

## 4. Data

A significant part of the study is to consider the impact of macroeconomic indicators on the DESI index. In this case, we can formulate a few hypotheses:

> *Hypothesis 1*. A higher level of economic development of the country leads to an increase in the digitization of the country.
> *Hypothesis 2*. Given high unemployment, the country has incentives for digitization.
> *Hypothesis 3*. The level of the country's digital development is determined primarily by its previous development. So, it is impossible to obtain a high level of digital development very quickly.

To test the hypotheses we compiled the data of structural units of the DESI index for 28 countries of the European Union for the years 2014–2018 (European Commission, 2018):

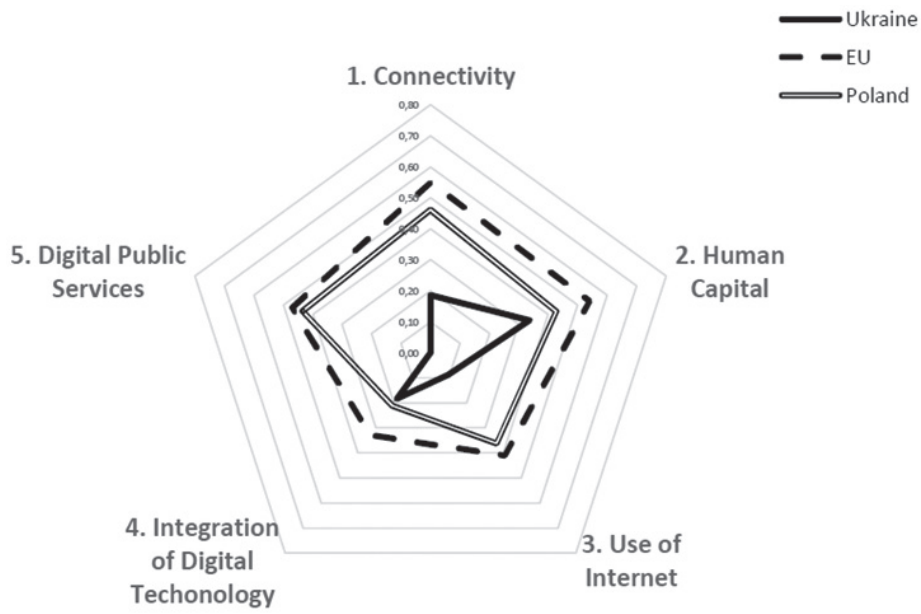
- Connectivity
- Human Capital
- Use of the Internet
- Integration of Digital Technology
- Digital Public Services

In addition, we needed indicators that allowed us to assess the development of the economy and society. In particular, we took per capita GDP for the years 2013–2017. In order not to receive substantially different results for countries, as there is more than a twofold difference at some levels of life in the European Union countries, the analysis used real per capita expenditures based on purchasing power parity (volume indices of real expenditure per capita in PPP (EU28 = 100)).

The unemployment rate among the active population was used (percentage of the active population) for the analyses of socio-economic factors' impact on digitalization, since it represents those unemployed people who, after retraining, may increase the level of digitization of the economy. All data are annual and sourced from Eurostat for 2013–2017.

United Europe requires inclusion data of all countries within the continent. But some states cannot provide clear parameters for the calculation of DESI, therefore such countries were omitted. For example, for Ukraine, a separate assessment for this state was not carried out. Nevertheless, according to Pilinski *et al*. (2015), the DESI index in Ukraine lags behind the European indicators by 2–4 times (Fig. 2).

*Figure 2. Index of DESI by its groups for Ukraine, Poland and average for EU countries*




*Source: DESI, 2015*

## 5. Models

A panel regression model was constructed for 28 European Union countries in the form:

$$y_{it} = \beta_{0i} + \beta_1 x_{j1t-1} + \beta_2 x_{j2t-1} + \varepsilon_{it} \ ,$$

where

$y_{it}$ – i-th component of DESI;

$x_{i1t}$ – index of consumption per capita (according to purchasing power parity);

$x_{i2t}$ - the percentage of unemployed among the active population in the j-th country;

$\varepsilon_{it}$ – residuals.

Construction of the correct model required the verification of all rows to stationarity. In our case, all components of the DESI index, per capita consumption (weighted for purchasing power parity) and the unemployment rate among the active population are trend-stationary processes according to the Levin, Lin and Chu *t*-test. The relevant statistics are given in Table. 2.

*Table 2. Testing the data for stationarity by method Levin, Lin and Chu t-test*

| Variable | Statistic | Prob. |
|---|---|---|
| Connectivity | -66.8627 | 0.0000 |
| Human Capital | -52.3810 | 0.0000 |
| Use of Internet | -25.6594 | 0.0000 |
| Integration of Digital Technology | -176.255 | 0.0000 |
| Digital Public Services | -2.37330 | 0.0088 |
| DESI | -27.7961 | 0.0000 |
| Consumption per capita | -96.0677 | 0.0000 |
| Unemployment | -15.2064 | 0.0000 |

*Source: Authors' calculation*

Lagrange Multiplier Test for Random Effects showed that for all five components, we need to use different combinations of effects, as shown in Table 3.

*Table 3. The presence of fixed and random effects in regression*

| Variable | Cross-section | Time Periods |
|---|---|---|
| Connectivity | Random | Random |
| Human Capital | Random | Fixed |
| Use of the Internet | None | None |
| Integration of Digital Technology | Random | Fixed |
| Digital Public Services | Random | Random |

*Source: Authors' calculation*

According to these values, the corresponding regressions were estimated. To test the hypothesis as to the speed of digital development of the country, a model of panel auto-regression was constructed:

$$desi_{jt} = \beta_0 + \beta_1 desi_{jt-1} + \varepsilon_{jt}$$

where
$desi_{jt}$ – DESI in j-thstate in period t;
$\beta_0, \beta_1$ – coefficients;
$\varepsilon_{jt}$ – residuals.

## 6. Results & discussion

A summary table of estimates for all regressions is given in Tables 4 and 5.

*Table 4. Regression results*

| Dependent variable | Independent variables | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|---|
| Connectivity | C | 14.26300 | 1.162673 | 12.26742 | 0.0000 |
| | GDPPC_1 | 0.022085 | 0.008314 | 2.656408 | 0.0088 |
| | U_1 | -0.288374 | 0.049833 | -5.786765 | 0.0000 |
| Human Capital | C | 12.07324 | 0.641849 | 18.81009 | 0.0000 |
| | GDPPC_1 | 0.016747 | 0.005168 | 3.240740 | 0.0015 |
| | U_1 | -0.080590 | 0.026558 | -3.034494 | 0.0029 |
| Use of Internet | C | 6.721762 | 0.453451 | 14.82357 | 0.0000 |
| | GDPPC_1 | 0.012566 | 0.003039 | 4.134123 | 0.0001 |
| | U_1 | -0.079929 | 0.025404 | -3.146291 | 0.0020 |
| Integration of Digital Technology | C | 4.473813 | 0.943633 | 4.741052 | 0.0000 |
| | GDPPC_1 | 0.020630 | 0.007264 | 2.839914 | 0.0052 |
| | U_1 | 0.051131* | 0.044770 | 1.142093 | 0.2555 |
| Digital Public Services | C | 11.54411 | 1.139329 | 10.13237 | 0.0000 |
| | GDPPC_1 | -0.007076* | 0.008877 | -0.797100 | 0.4268 |
| | U_1 | -0.328448 | 0.033763 | -9.727959 | 0.0000 |

*Source: Authors' assessment*
** non-significant at 5% level*

*Table 5. Regression results*

| **Dependent variable** | **Connec-tivity** | **Human Capital** | **Use of Internet** | **Integration of Digital Technology** | **Digital Public Services** |
|---|---|---|---|---|---|
| R-squared | 0.286444 | 0.792568 | 0.215934 | 0.691039 | 0.420503 |
| Adjusted R-squared | 0.276027 | 0.783210 | 0.204488 | 0.677101 | 0.412043 |
| F-statistic | 27.49804 | 84.69563 | 18.86507 | 49.57909 | 49.70592 |
| Prob(F-statistic) | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |

*Source: Authors' assessment*

On the basis of the tables above, we can conclude that all considered models are adequate, and the absolute majority of coefficients are significant. The obtained values show that there is a certain positive impact of the state development level on the structural parts of DESI. In particular, a 1-point increase in costs per capita (according to PPP), which, depending on the country ranges from 0.6 to 2%, leads to a one-year increase in Connectivity by 0.022, Human Capital—by 0.117, Use of Internet—by 0.013, Integration of Digital Technology—by 0.021. There was no significant impact on Digital Public Services.

The level of unemployment, on the contrary, hinders the digital development of the economy. In particular, the increase in the unemployment rate among the active population by 1% leads to a decrease in Connectivity by 0.288, Human Capital—by 0.081, Use of Internet –by 0.080, Digital Public Services—by 0.328. There is no significant impact on the Integration of Digital Technology indicator.

So, we see that the growth of the DESI index has certain limitations. For example, if most European countries increase by 1–3% annually, and unemployment does not have a tendency to decrease, we can expect an annual increase of DESI by 0.2–0.5. The analysed indicators point to rather similar trends. Although, if Connectivity and Integration of Digital Technology respond to economic growth at the level of 0.051–0.22, then the use of the Internet—only at 0.013. This can be explained by the fact that in European countries the use of the internet is already so widespread that any expansion of it is extremely difficult to implement. At the same time, the development of human potential is responding at a much faster pace—0.117 for every percentage of growth. This can be explained by the fact that wealthier people have opportunities to improve education, receive additional information, opportunities, and to increase the payments of digital economy services.

It can be noted that, in general, the effect of expanding consumption in European countries will have a rather limited effect. For example, the states that are DESI outsiders can significantly improve their structure due to economic growth, but actually, the ceiling has already been achieved in the wealthy countries.

Nonetheless, the countries still have a significant potential for development by fighting unemployment, in particular, through the conversion of the unemployed to the digital services sector. This effect will intensify because the new generation will find it much easier to adapt to the new economy, and, therefore, the states will receive an additional bonus for technological development. Moreover, the greatest effect in the coming years should be connected with the part of Digital Public Services, i.e., the development of e-government, the introduction of

direct democracy, and the creation of the most transparent conditions for the functioning of economic and political agents.

Under the analysis of panel regression, where DESI – dependent variable, sample 2015–2018 (28 cross-sections totalling 112 panel balanced observations), the following results were obtained (Table 6).

*Table 6. Panel model regression results*

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.896825 | 0.092549 | 9.690297 | 0.0000 |
| DESI(-1) | 0.976739 | 0.009059 | 107.8186 | 0.0000 |
| R-squared | 0.990626 | Mean dependent var | | 10.64589 |
| Adjusted R-squared | 0.990541 | S.D. dependent var | | 2.147049 |
| S.E. of regression | 0.208816 | Akaike info criterion | | -0.277026 |
| Sum squared resid | 4.796475 | Schwarz criterion | | -0.228482 |
| Log-likelihood | 17.51347 | Hannan-Quinn criteria | | -0.257330 |
| F-statistic | 11624.85 | Durbin-Watson stat | | 2.120622 |
| Prob(F-statistic) | 0.000000 | | | |

*Source: Authors' assessment*

This model clearly indicates that the change in the DESI indicator by almost 98% depends on its previous value. This means that it is difficult to increase this indicator for all countries rapidly.

Thus, we received answers to the above hypotheses' testing (Table 7).

*Table 7. Results of hypothesis testing*

| Hypothesis | Testing results |
|---|---|
| Hypothesis 1. A higher level of economic development of the country leads to an increase in the digitization of the country. | This hypothesis is confirmed in 4 models out of 5. In general, a more prosperous society leads to more advanced digital services. |
| Hypothesis 2. Given high unemployment, the country has incentives for digitization. | This hypothesis has also been confirmed in 4 models out of 5. This means that European countries with high unemployment have all the grounds for increasing DESI in the near future. |

| Hypothesis | Testing results |
|---|---|
| Hypothesis 3. The level of the country's digital development is determined primarily by its previous development. So, it is impossible to obtain a high level of digital development very quickly. | This hypothesis is confirmed. In fact, the current value of DESI at 97.7% is determined by its previous value. In other words, the acceleration of digital development is possible only for extraordinary success in the growth of the economy or the fight against unemployment. Since in developed countries large variations in these indicators are impossible, the digitization of the economy will develop at approximately the same pace. |

*Source: Authors' compilation*

## 7. Conclusions

Thus, the DESI index is a European indicator that determines the level of development of the digital economy and society itself and consists of 34 indicators, which are divided into 5 groups and 3 levels. For calculation of the final result, each group has its own weight coefficient, which acts as a multiplier of the final function.

The study tested three hypotheses. The analysis confirmed that a more prosperous society leads to more advanced digital services. Each additional 1% increase in consumption leads to an increase in DESI by 0.2. The second hypothesis tested the impact of unemployment on DESI. The study showed that the European countries with high unemployment rate could increase DESI in the near future through fighting unemployment. The third hypothesis explored whether it is possible to rapidly increase the level of DESI. The research showed that the current value of DESI at almost 98% is determined by its previous trends, i.e., it is impossible to have a rapid break in the development of the digital economy.

This leads to rather depressing conclusions about poor and underdeveloped countries, i.e., Ukraine. This country has a rather low level of DESI. Therefore, it should undertake a lot of steps to increase it, as there is no doubt that the future is in digital economy and society. However, the study shows that an increase in DESI is not possible rapidly and intensively. According to some estimates, the value of DESI in Ukraine was 6.35 in 2018, which is, for example, twice as less than in the United Kingdom. Ukraine should have an annual growth of 3% and an annual drop in unemployment rate at the

minimum of 0.5% and, even in this case, it would take the country at least ten years to achieve such a level.

Dr. **Andriy Stavytskyy** is an associate professor in economic cybernetics, a trainer, facilitator of the British Council Higher Education Leadership Development Programme (2016/2018), national expert on Higher Education Reform in Ukraine within the Bologna Process, an Erasmus professor with an experience of lecturing and training work at the universities of Lithuania and Turkey, a coordinator of ECTS of Taras Shevchenko National University of Kyiv (since 2011), and tutor of the course 'Economics' (in English), at the Edinburgh Business School.

Dr. **Ganna Kharlamova** is an associate professor at the Economic Cybernetics Department, Faculty of Economics; a team member for the Tempus project 'Improving the Efficiency of Student Services' 530534-TEMPUS-1-2012-1-UK-TEMPUS-SMGR (2013/2014); a certified coach in soft skills development of students, university staff and managers (UK, 2014); an Erasmus professor with an experience in lecturing and training work at the universities of Romania and Turkey; a team leader of TSNUK in the Higher Education Leadership Development Programme (2-year project) within the frameworks of the project 'Skills Plus Portal for Leadership (SPPL)' under the guidance of the British Council in Ukraine. Kharlamova is co-director and member of the organizing committee of a few NATO ARWs, ASIs, and a coach and successful grant programme applicant for the NATO grant for the provision of educational services in English-language training within the framework of the NATO-Ukraine professional development of civilian personnel security and defence sector (2015–2018), NATO ARWs. Kharlamova is the executive editor of .

Dr. **Eduard Alexandru Stoica**, PhD, is an associate professor at the Faculty of Economic Sciences of the University Lucian Blaga of Sibiu, Romania. His research is on the border between cybernetics (by creating an adaptive feedback model), e-business (through the model's connection with e-marketing, e-commerce and e-government) and software engineering (by projecting and implementing software instruments). His research activity includes Romanian grants and European projects. He is also assistant editor-in-chief for *Revista Economica*.

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## Annex. Structure of DESI

| Dimension | Sub-dimension | Indicator |
|---|---|---|
| 1 Connectivity | 1a Fixed Broadband | 1a1 Fixed Broadband Coverage |
| | | 1a2 Fixed Broadband Take-up |
| | 1b Mobile Broadband | 1b1 Mobile Broadband Take-up |
| | | 1b2 4G coverage |
| | | 1b3 Spectrum |
| | 1c Speed | 1c1 NGA Coverage |
| | | 1c2 Subscriptions to Fast Broadband |
| | 1d Affordability | 1d1 Fixed Broadband Price |
| 2 Digital Skills | 2a Basic Skills and Usage | 2a1 Internet Users |
| | | 2a2 At Least Basic Digital Skills |
| | 2b Advanced skills and Development | 2b1 ICT Specialists |
| | | 2b2 STEM Graduates |
| 3 Use of Internet | 3a Content | 3a1 News |
| | | 3a2 Music, Videos and Games |
| | | 3a3 Video on Demand |
| | 3b Communication | 3b1 Video Calls |
| | | 3b2 Social Networks |
| | 3c Transactions | 3c1 Banking |
| | | 3c2 Shopping |
| 4 Integration of Digital Technology | 4a Business digitisation | 4a1 Electronic Information Sharing |
| | | 4a2 RFID |
| | | 4a3 Social Media |
| | | 4a4 eInvoices |
| | | 4a5 Cloud |
| | 4b eCommerce | 4b1 SMEs Selling Online |
| | | 4b2 eCommerce Turnover |
| | | 4b3 Selling Online Cross-border |
| 5 Digital Public Services | 5a eGovernment | 5a1 eGovernment Users |
| | | 5a2 Pre-filled Forms |
| | | 5a3 Online Service Completion |
| | | 5a4 Open Data |