Determinants of Digitalization in Developed Countries

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Abstract
The work proposes to clarify the definition of the term "digitalization" and identify the determinants of digitalization using analytics and econometric analysis. To do this, first, a definition is formulated on the basis of separate copyright interpretations of the term "digitalization," which together reflects specific aspects of this phenomenon. The question of which factors are decisive in developed countries in the context of the emergence and development of digitalization is then explored.
Based on the proposed hypotheses of the study and the construction of the econometric model, the following answers to the questions raised were obtained and substantiated. First, digitalization has a positive impact on the well-being of developed countries. Secondly, at the moment, ordinary users demand such determinants of digitalization as information and communication technologies and the availability of public services in electronic format. The results obtained provide empirical confirmation of the process of transformation of information technologies at present.

Keywords
Developed countries, GDP, information and communications technology, public online-services, digitalization potential

1. Introduction

Every year, the topic of digitalization, especially during the pandemic, becomes more and more relevant. The development of digital technologies and their implementation in public life requires new research to understand how this phenomenon affects the economy in general through particular ones. For example, in particular, attention to it has increased from corporate, budgetary organizations, as well as government agencies during the outbreak of the coronavirus pandemic. In addition, according to Google statistics, ordinary people are also interested in digitalization. The popularity of search queries containing the keywords "digit" or "digitalization" has remained quite high for several years.

Although scientists and experts put a lot of effort to promote the proper attitude to digitalization, there is still no unified approach to its definition or aspects of its use for today. However, there exist strong associations with gadgets, which became the part of our lives, – personal computers, smartphones, electronic watches and so on. This is not surprising because more than three quarters of American households are using one of the main digital technology gadgets, such as was mentioned above. At that time, the speed of digital technology evolution and distribution within the last 150 years is absolutely impressing. While telephone needed 75 years to reach 100 million users, the internet reached the same result for only 7 years [1]. The reason for such high tempo of technology diffusion is mainly explained by the reduction of costs on their use. The change in the international call costs from 1930 is the best illustration for this fact (Figure 1) [2].

Thus, the facts mentioned above point out the availability of a standard set of digital technology, which are not only the catalysator of digitalization promotion and further evolution of more complex

technology, but also support significant technological transformations related to numerous spheres of our life. All this indicates the relevance of this study.
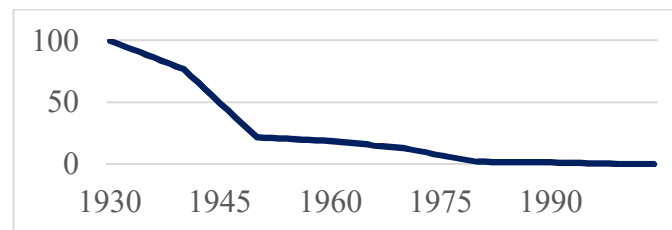

Figure 1: International calling costs from New York to London (relative to 1930), %

2. Use of digital technology

In terms of social relations invention of smartphone and cheap mobile internet caused a boom of social networks and messengers, which rapidly became a part of our everyday life and, hence, turned upside down our beliefs about sociocultural interaction.

Business made its contribution to digitalization, too. The internet expansion served as one of the major factors of its active evolution lately. First of all, the new trend of e-commerce was born. It allows customers to purchase goods at lower prices in comparison with classic retailers not even leaving their house. At the same time, sellers get the opportunity to save significant amounts of money on keeping offline stores. Secondly, now it is much easier for entrepreneurs to advertise their goods and services and look for clients through the new channels – websites and pages in social networks. This kind of approach reduced entering barriers into creation of their own business for novice entrepreneurs and cut marketing expenses for existing companies. An illustrative example is the largest online-retailer Amazon. This company, which not only realized its potential thanks to digitalization, but, in many ways, is at the forefront of its development, investing tens of billions of dollars in research and innovative developments [3].

Despite the fact that creation of all developments related to digitalization and its evolution became real owing to the work of scientists, further implementation of digital technology and advanced methods of collection and processing information allowed to boost science at a new level. First computers in universities simplified the process of research a lot: many operations were automatized, and calculations accelerated. Moreover, growth of the internet network opened an access to vast variety of data sources and databases and gave an opportunity of cooperation and experience sharing with abroad colleagues. To add more, the sphere of education was affected by the colossal breakthrough: it became able to get all necessary knowledge studying via open online courses from world leading universities.

Let us restate that many types of digital technology are a part of our everyday life, and scientists and developers all over the world hold even more researches and experiments. Yet, only now we start to assimilate it and identify the process of digitalization as a part of something great and very meaningful, namely, the Fourth Industrial Revolution. A lot is told about it by famous economist, founder and president of the World Economic Forum Klaus Schwab in his eponymous book.

Nevertheless, for the purpose of further active and sustainable growth of national and world economies it is necessary to understand what factors play the key role in establishment of main driver of these transformations – digitalization. In next section we analyze the literature in order to get basic concepts of terminology and digitalization determinants.

3. Literature review, terminology and problem statement

Literature review related to digitalization allowed to point out several features in formulation of this concept. On the one hand, when we talk about digital transformation, we often think that we are talking about the usual digitization of information. On the other hand, if we are talking about the application of digital technologies (blockchain, big data processing, artificial intelligence, etc.) to a specific subject area – finance, sociology, medicine, etc. [4], then we are talking about the development of the digitalization process [5]. Sometimes we consider the process of digitalization through the prism of

destabilizing structures that are currently used by non-digital tools in socio-technical systems [6]. Thus, we will clarify the definition of the term "digitalization" taking into account the wording of different authors. Digitalization is a dynamic process in which, on the basis of digital technologies, the transformation of existing socio-technical systems is carried out with the simultaneous creation of new or transformation of existing value systems for all members of society – individuals, organizations, businesses, and the state by involving them in this process through interaction.

It follows that as a result of the digitalization process, the use of new digital tools either focuses on solving certain groups of research tasks [4, 7, 8], or develops at the level of macro relations in a rather theoretical framework without using any data [5, 9, 10], or discover digitalization on a scale of particular countries [11, 12]. However, the problem of evaluating the impact of digitalization on the economies of developed countries is still, largely, unsolved. This study is going to fulfill this blank via construction of econometrics model in the next section.

To sum up, the search for determinants – factors of influence on the development of digitalization- is the goal of this study. At the same time, the object of our research is the independent reality of digitalization, and the subject is the determinants of this fact. Since the developed countries, as a rule, are the main engines of technological progress of mankind and transformations in various spheres of the economy as a result of previous industrial revolutions, we address our research to the developed countries. Work in a such context gives an opportunity to examine precisely original determinants.

The goals of the research are following:
- To specify the definition of the term "digitalization" on the base of other authors' definitions;
- To identify the determinants of digitalization based on econometric analysis.

4. Data and methodology

Let us take into consideration the fact that availability of digital technology played a crucial role in their establishment and dynamic increment of digitalization potential. Hence, it is logical to make the following assumptions. Imagine that the "starter pack" of digital technology is rather costly, or the access to it is associated with a range of special restrictions, such as signing of non-disclosure of information agreement or use of this technology within a strictly stated regulation. Presumably, that kind of approach would leave the access to digital technology among the small group of interested parties – scientists, military and large transnational corporations, – rather than allow distributing them broadly. Taking into account that determinant (after the Greek "determi nans, ntis" – defining) is a factor that conditions different actions or phenomena (in particular, digitalization), the preceding argument is considered to be necessary and sufficient for highlighting availability as one of the determinants of digitalization.

For detecting the other determinants of digitalization, it is needed to clarify some key ideas of the research. The group of developed countries might vary depending on selection criteria and methodology. Therefore, in order to avoid disagreement, within the framework of this study, developed countries are understood to be those who are given the appropriate status in the latest version of the UN report World Economic Situation and Prospects 2018 (Table 1)

With many massive and widespread phenomena, it often happens that terms related to them begin to be actively used by native speakers in everyday life. However, the use of such neologisms does not always occur consciously, with an understanding of the meaning of the word. Especially, this applies to those phenomena that have recently appeared, and digitalization in this case is no exception. Let's figure out what this broad concept implies.

The Cambridge Dictionary defines the word "digital" as "describing information about an object recorded or transmitted by computer technology" [12]. Their colleagues from Merriam-Webster interpret the term "digitalization" in a similar way: "the process of converting something into digital form" [13]. In the book Digitalization in Open Economies [14], Michael Vogelsang also emphasizes that digitalization means "expressing information in the form of strings of zeros and ones," the so-called binary or binary code.

Table 1

The list of developed countries regarding un world economic situation and prospects

Australia	Cyprus	Germany	Japan	New Zealand	Slovenia
Austria	Czech Republic	Greece	Latvia	Norway	Spain
Belgium	Denmark	Hungary	Lithuania	Poland	Sweden
Bulgaria	Estonia	Iceland	Luxembourg	Portugal	Switzerland
Canada	Finland	Ireland	Malta	Romania	United Kingdom
Croatia	France	Italy	Netherlands	Slovakia	United States

These definitions cannot be considered completely incorrect, but they refer to a completely different term, which is very consonant with digitalization (digitization) and is largely associated with it - digitization (digitization). Yes, data digitization is an integral part of digital transformation, but it is far from all digitalization. Unfortunately, not everyone fully understands this difference, from where confusion arises. Many authors investigating the phenomenon of digitalization note this in their works and, as a rule, make all the necessary explanations at the beginning of the articles so that the reader is not confused about the terminology used [15, 5]. Review the major versions and make a comprehensive definition.

Parviainen et al. [16] on the basis of the studied literature give several versions of the wording at once:

1. "Changes associated with the application of digital technologies in all aspects of human society";

2. "The ability to transfer existing products or services to digital counterparts, thus creating advantages over material objects";

3. "Adapting or increasing the use of digital or computer technologies by an organization, industry, state, etc."

Hagberg et al. [4] draw attention to the fact that, using the term "digitalization," we should mean by it a dynamic and open to change concept that continues its development, rather than something formed and completed. Moreover, it is accompanied by a wide involvement of people and organizations in the process of its formation through daily procedures of social interaction.

And finally, Yoo et al. [5, C.7] see digitalization through the prism of destructive transformations of existing sociotechnical structures, which were previously provided with non-digital means. In other words, the authors say that technological changes alone are not enough, since not all inventions have an equally significant influence on the further vector of development of society and are able to create or significantly change an established system of values. As an example, the introduction of digital switching by telecom companies in the 1970s and a digital camera are compared. Both technologies made a significant contribution to the evolution of technological progress, but, obviously, only one of them was able to change the appearance of modern society.

Given all the features of digitalization on which researchers emphasized, we can conclude that that digitalization is a dynamic, open process during which the fundamental transformation of existing sociotechnical structures takes place with the simultaneous creation or change of an established value system by increasing the use of digital technologies by all members of society - individuals, organizations, the state - and their active involvement in this process through daily interaction.

Thus, digitalization is a new, non-standard and rather large-scale phenomenon, and it is understood intuitively that this topic should be studied comprehensively. However, the number of problems arises in attempts to build a correct model evaluating the impact of digitalization on economic development.

In our study, we will take GDP per capita as an endogenous variable (in constant 2011 prices in international dollars. The choice of this variable is explained by the presence of the impact of any technological revolution on economic growth. This indicator serves as a rather adequate proxy of economic development because it expresses the average amount of goods and services per one citizen. Therefore, the higher the indicator the better. Furthermore, the values in international dollars allow comparing standards of living among different countries due to adjustment of real GDP per capita for purchasing power parity.

When choosing regressors, we followed the following arguments. On the one hand, the use of expanded massive of separate regressors in the model would lead to its overload: loss of degrees of freedom and, as a consequence, significant deformation of the coefficients estimates. On the other hand, selection of some limited set of regressors would make the model unrealistic. The optimal solution to this problem is the use of indices related to digitalization as regressors. In that case, the exogenous variables cover the wide range of aspects of digitalization not overloading the model. Undoubtedly, this is an advantage of exploiting such approach.

Also it is important to mention that the indices are constructed for various purposes by different organizations. That is why some of the sub-indices might be identical or contain similar indicators in them. It might directly lead to appearance of multicollinearity in the model and biased evaluation of coefficients. To avoid this issue, the selected indices were adjusted in a way that no correlating patterns were left in these indices. The methodology of indices calculation maintained.

Thus, the following digitalization indices are set up as the model regressors.

The first is ICT Development Index (IDI) without sub-index ICT Skills. We refused to take into account the sub-index of skills in the field of ICT in our study. Despite the fact that this skill is important, however, the informatization of society covers all areas of human activity for a long time. Therefore, the study of this factor in the context of this study will be incorrect.

The second is Online Service Index (OSI), the sub-index of E-Government Development Index (EGDI) that reflects the quality of access to public online-services (websites and Internet portals of ministries, social and health organizations etc.). Two other sub-indices of EGDI: Human Capital Index (HCI) and Telecommunication Infrastructure Index (TII) were dropped because the parameters coincident to TII were accounted in IDI, while HCI parameters were accounted in GII.

The third factor is the Global Innovation Index (GII) with four sub-indices - "Human Capital", "Business Complexity", "Knowledge and Technology Output" and "Creative Output". In our view, the adjusted GII almost fully reflects the potential for digitalization of the economy. At the same time, we take into account human capital, its efficiency and the effect of innovation. But to assess the net effect of this potential, we do not take into account the factors of influence of state and market institutions. Since the selected indicators are independently published by different responsible organizations, they may not coincide with each other. Thus, the data were collected in the most possible coinciding periods: 2008, 2010, 2012 and 2017. In total, the group has 144 observations "country-year".

The model is formalized as follows:

$$\ln(GDP\ per\ capital^{2011}_{PPP})_{it} = \beta_0 + \beta_1 OSI_{it} + \beta_2 IDI\_adj_{it} + \beta_3 GII\_adj_{it} + \varepsilon_{it}, \qquad (1)$$

where the coefficients of all regressors are assumed to be positive and reflect a certain side of the formation of digital techniques in their micro - and macro-interaction with humans. The experience of technological breakthroughs during the period of industrial revolutions justifies our assumption about the positive impact on the standard of living of this symbiosis. We formulate hypotheses:

H1: The OSI coefficient is positive ($\beta\_1 > 0$).

The easier access to public services in a country, the higher the standard of living of the population.

H2: The coefficient IDI_adj is positive ($\beta\_2 > 0$).

A well-developed ICT base in the country contributes to the automation of production processes, which in turn has a positive impact on increasing labor productivity.

H3: The coefficient of GII_adj is positive ($\beta\_3 > 0$).

Each of sub-indices in GII adjusted reflect different features of digital technology evolution and its synergy with a human. Based on the accepted theoretical assumptions and their analysis, we can conclude that such a combination influences positively on standards of living.

5. Empirical results and discussion

The absolute values of each indicator vary depending on the methodology as follows: OSI - from 0 to 1, IDI - from 0 to 10, GII - from 0 to 100. Their relative value is in the range from 0% to 100%. Since multiplication by 100 and 10 of the OSI and GII indicators, respectively, does not affect the estimates of the coefficients, we apply this operation for convenience.

Table 2
Descriptive Statistics

	(1) Mean	(2) Std. Dev.	(3) Min	(4) Max
OSI	66.46	18.06	28.89	100.00
IDI_adj	52.68	9.32	30.52	71.04
GII_adj	44.04	8.12	28.35	64.60
No. of obs.	144			

No. of countries: 36. Periods: 2008, 2010, 2012, 2017.

Analysis of descriptive statistics of regressors (Table 2) shows us not the most ideal results on the achievements in the field of digitalization on the part of some developed countries. The average value is close to the 50th percentile, 2 of the top 3 indicators have values no higher than 75%, and, in addition, the gap between leaders (max) and supporters (min) is quite noticeable. All of that demonstrates the existing improvement potential, which is only to be unleashed.

Although the matching patterns were removed from the selected indices as far as possible, the presence of a statistically significant correlation between the regressors is revealed by the correlation matrix (Table 3). In our case, this value is at the level of 1%, which is somewhat alarming. However, existing correlation of different degree between exogenous variables does not signal about the obligatory presence of multicollinearity. Let us make coefficients estimation and some necessary tests in Stata to prove that.

Table 3
Correlation matrix of regressors

	OSI	IDI_adj	GII_adj
OSI	1		
IDI_adj	0.568***	1	
GII_adj	0.604***	0.770***	1

*$p<0.10$, **$p<0.05$, ***$p<0.01$

Besides the main model, the LSDV model (Least Squared Dummy Variable), which is similar to Fixed Effects, was built and estimated in order to run tests for multicollinearity and evaluate some parameters that Stata calculates incorrectly for panel data models, for example, R2 adjusted (Table 4).

Low values of VIF for the each regressor (Table 5) confirm that the minimal existing multicollinearity the model does not significantly affect the estimates of the coefficients. Therefore, the expected conclusions derived from this simulation may well be considered relevant (empirical rule: if VIF < 10, then the presence of multicollinearity in the model is not a serious problem).

The P-value of the F-statistic is below 0.05 and all the coefficients that are significant at the 10% level (one of them at the 1% level) demonstrate the overall quality of the model. At the same time, it can be noted that the hypothesis of positive coefficients with OSI and IDI _ adj is not rejected. Because improving the infrastructure of information and communication technologies and the availability of public services online undoubtedly have a positive impact on improving the social well-being of developed countries.

Table 4
Results of model coefficients estimation

	(1) Panel FE		(2) LSDV	
OSI	0.0010*	(0.0543)	0.0010*	(0.0543)
IDI_adj	0.0045***	(0.0110)	0.0045***	(0.0110)
GII_adj	-0.0027*	(0.0015)	-0.0027*	(0.0015)
R2 overall	0.3298			
R2 between	0.5273			
R2 within	0.2108			
R2_adj			0.9730	
F-statistics	9.3487		136.5403	
p-value(F)	0.0000		0.0000	

Standard errors are represented in parentheses
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

The hypothesis that the coefficient of GII_adj is positive is rejected. This can be explained as follows. Our assumption of a positive relationship between the development of technology and knowledge and living standards suggested achieving economic growth in the long term and did not take into account the fact that any technological innovations and the associated retraining of specialists have the practice of paying off not at the time of innovation, but after some time. This phenomenon is known in economic theory as an investment lag.

Table 5
VIF values for regressors

Regressor	VIF
OSI	3.81
IDI_adj	4.20
GII_adj	5.59
Average	4.53

In summary, digitalization has a positive impact on the well-being of developed countries, but at the moment, the key drivers of digitalization growth are simpler and more understandable information and communication technologies and the availability of public services in electronic form.

6. Conclusion

By the end of the study the following results are obtained. The decisive factors of emergence and evolution of such a large-scale phenomenon as digitalization were considered. The accent of the research was made on developed countries for the purpose of detecting the most important pure determinants of digitalization. The definition of the term "digitalization" was specified and improved on the basis of other authors' works in a way that it reflects all the aspects of this phenomenon. It was shown that in modern science digitalization is examined in a framework of practical works with differentiation into levels "individual – company – industry – country", and in a framework of theoretical and methodological works.

At the stage of analytics and econometric analysis, the goals of the study were achieved: the concept of digitalization was clarified and the desired determinants of digitalization were determined. Based on the simulation results, you can draw the following conclusion: Developed countries are currently undergoing a transformation of information technology and acquiring the necessary knowledge to manage it. However, this stage is accompanied by certain investments that have not yet paid off. Therefore, the result of our study demonstrates the fact that progress in these areas of processes, caused by a one-time increase in the GII _ adj indicator (adjusted Global Innovation Index), which takes into

account human capital and its effectiveness in conjunction with the introduction of innovation, leads to a slight decrease in real gross domestic product per capita by 0.27%.

At the same time, this decline is offset by successes in other areas. Thus, the specific growth of the OSI (Online Service Index), reflecting the quality of access to public online services and the IDI _ adj (adjusted ICT Development Index), reflecting the level of development of the ICT base of the country, lead to a cumulative growth of real GDP per capita by almost 0.55%. Clearly, this is more than enough to cover the undisclosed potential of progressive innovation.

Thus, digitalization positively affects the well-being of developed countries, but at the moment, simpler and more understandable technologies for common users are a key driver of growth in the framework of digitalization.

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