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Correlative approach to digitalization and economic growth

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Abstract. *It is known that the evolution of digital technologies, together with a combination of other essential generic technologies, leads to a change in the way we design, produce and market related products and services, as well as in the way how value is generated from them. Digitalization and transformation of the business process to create remarkable customer experience are absolutely necessary for any company that wants to evolve and succeed in the fast-digitizing business environment. The main objective of this research was to discover how digitalization influences economic growth. The databases used were Eurostat and World Bank. We selected 8 main research variables, which were divided into two sets to describe (i) the phenomenon of digitalization by digital skills, mobile subscriptions, enterprises with e-commerce, and (ii) the phenomenon of economic growth by real GDP growth, unit labour cost growth, resource productivity and R&D expenditure of GDP. The research methodology was centred on Canonical Correlation Analysis to reveal the connections within and between the two phenomena. The results revealed, for example: the digitalization set was able to explain 70.33% of economic growth with the correlation of 0.800; the real GDP growth is affected by the share of enterprises involved with e-commerce, unit labour costs and resource productivity are affected by high-level digitalization seen by enterprises conducting data analysis on customers for marketing purposes; and that digital skills and R&D expenditures are positively related.*

Keywords: digitalization, economic growth, canonical correlation analysis.

Introduction

Most economies in developed countries are based on innovation and technology. Technology replaces manual labour in most aspects of life and in most segments of the economy (Connolly-Barker et al., 2020). Life offline is gradually becoming impossible. Digital transformation is the process of discovering new business applications that integrate data (Bimber et al., 2012; Kinnunen and Georgescu, 2020). Digitization influences the development of the digital business.

Digital transformation requires digital business and digitization. Although each business has its own specifics, there are some elements of digital transformation that appear in each case. The main element that changes for the better is the customer experience. It has easier access to information and the final product. Then, operational agility is improved because most

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intermediaries disappear. Digitization also brings transformations in terms of organizational culture and leadership. Of course, this does not mean that all companies that aim to digitize their own processes and services succeed. In fact, studies show that about 70% of digital transformation processes fail (Androniceanu et al., 2020a, Androniceanu et al., 2020). It can be said that two aspects are essential for digitalization: resources (human, material, informational and financial) and the management of organizations/governments that aim for a digital transformation (Kljucnikov et al., 2019). Digitization is necessary and must have a real stake: to solve challenges or problems that a business faces or to serve the unaddressed needs of a category of public or stakeholder in the market.

Digitalization is a process of change, which has a major impact on people and the processes they go through. The digital transformation generates efficiency, speed, productivity, and a reduction in errors - and all these gains are reflected not only in the indicators of economic growth and performance but also in terms of competitiveness, reputation, and brand (Androniceanu et al., 2020b).

In the European economy, digitalization has a major impact (Androniceanu et al., 2019; Kinnunen et al., 2019). That is why European leaders believe that this must be supported. At the extraordinary meeting of the European Council in Brussels on 1-2 October 2020, EU leaders discussed the digital transformation that will take place in Europe. Digitization is a key pillar of the EU's recovery after the COVID-19 crisis (Androniceanu, 2020a; Platt, 2020). It has a key role to play in promoting new forms of growth and strengthening the EU's resilience. Digital technologies are not only changing the way people communicate, but also, more generally, the way they live and work. The situation created by the COVID-19 pandemic has given the EU a new impetus to work to accelerate the technological transition.

The hypothesis from which we start in this research is that digitalization significantly influences economic growth in every European country. That is why we intend to show in this paper what this influence consists of. What impact digitalization has on economic growth in European states (Kosach et al., 2020). Therefore, the research question we start from is: How does digitalization influence economic growth in European countries? From these research perspectives, we analyse digitalization and economic growth in European states using the main component analysis developed by Hotelling (1936) later on.

Literature review

Over time, several definitions of digitalization have been proposed. Scott Brennen and Daniel Kriess (2014) define digitalization through digital communication and the impact of digital media on contemporary social life. Digitalization means to integrate digital technologies in business and to produce added economic value. From another perspective, digitalization means to develop business in a digital environment. It creates the digital form of different things.

Digitization means transforming interactions, communications, business functions, and business models into (more) digital data, which is often reduced to a combination of digital and physical, such as Omni channel customer service, integrated marketing, or the industrialization of production with a mix of autonomy, semi-autonomous and manual operations, electronic services and so on. Digitalization also means that the workforce works differently. The human resources are working by using a large variety of digital tools (Mircica, 2020). The digital systems allow them to work in a different way, more "digital" - common, unitary, remote (Ionescu, 2020).

Digital transformation requires cultural change, because digitalization is more about human resources than digital technology. The transformation process involves and requires

customer-centred organizational changes, supported by management, driven by radical challenges in the culture of organizations and the exploitation of technologies that enable and transform the way employees work (Costea, 2020). Digitalization is the process of converting analogue information into a digital format. In a broader context, digitalization is defined as the social transformation determined by the massive adoption of digital technologies to generate, process and trade information. Digitization determines the creation of common platforms for the development of applications, e-government services, e-commerce, social networks, as well as the availability of online information. Digitalization is difficult to define because it is a term with many variables. Digitization involves the integration of technology in all sectors of a business and results in fundamental changes in the way it operates and in the value it offers to the final consumer (Androniceanu et al., 2020). For every business, digitalization can mean something different, depending on their specificity. For example, in the banking system, digitalization involves both the transposition of data into the virtual environment and the availability to the customer. In contrast, in retail, digitalization means the existence of a virtual sales space. Nations constantly support and take efforts to establish congenial policies towards their sustainability and economic growth (Dvorský et al., 2020a). One of the most important goals of digital transformation is economic growth. Due to digitization, economic growth is achieved, and the competitiveness of goods and services increases (Shpak et al., 2020).

Economic growth is a positive variation in the production of goods and services in an economy (Dvorský et al., 2020b). Many authors examine the influence of selected factors on economic growth. For example, the effect of leaders (Smith, 2020), the legal environment (Virglerova et al., 2020), the socio-cultural changes (Uslu et al., 2020) or the management style (Belas et al., 2020), and so on. The main indicator to measure economic growth is GDP, which we also included in our research. Measuring economic growth is done by calculating GDP growth rates. According to the way of involvement in the economic growth process, there are: (1) direct factors, which include the human factor (labour resources), the material factor (material resources and accumulated production equipment) and the informational-technological factor; (2) indirect factors: the rate of research-development investments, the financial-monetary, the budgetary and fiscal policy of the state, the absorption capacity of the internal market, the ecological policy, the international exchanges, etc (Meyer et al., 2017; Stverkova et al., 2018).

In our research we followed the influence of these factors in relation to digitalization and economic growth. In the literature, special attention is paid to economic growth, because the general well-being of society depends on its level. It is expected that these two concepts of digitization and economic growth will create a new digital economy model. The digital economy is considered to be the fourth industrial revolution, characterized by the ability to transform economies, jobs and even society as a whole, by introducing new technologies and processes (Fila et al., 2020; Ślusarczyk and Ul Haque, 2019; Shpak et al., 2019). The digitalization of economies will help increase access to education, jobs and finance, even if, in the short term, it could lead to a reduction in repetitive and no value-added jobs in almost all economic sectors, whether we are talking about industry, agriculture or services (Androniceanu, 2020b).

From this perspective, in our paper we approached digitalization and economic growth and analyzed the main factors that influence digitalization, economic growth and development through a set of specific variables. The methodology, the main results and discussion are presented in the following sections of our paper.

Methodology

Canonical Correlation Analysis (CCA) introduced by Hotelling (Hotelling, 1936) is a statistical technique used to detect the associations between two sets of variables in a dependent relation. The pairs of canonical variates explain the inter- and intra-set variability. The first canonical correlation has the highest importance. The correlation coefficients are significant when their absolute values are greater than 0.45.

CCA was applied to the set of 27 European state members for 2019 and for 8 indicators in line with previous research (Georgescu and Kinnunen, 2021). In Table 1, the digitalization indicators (V1-V4) are the independent set and the economic growth indicators (V5-V8) are the dependent set.

Table 1. The main research variables

Variable	Variable Label	Source
V1	Digital skills	World Bank
V2	Mobile subscriptions	World Bank
V3	Enterprises with e-commerce	Eurostat
V4	Enterprises with data analysis	Eurostat
V5	Real GDP growth (3yrs avg)	Eurostat
V6	Unit labour cost growth (3yrs avg)	Eurostat
V7	Resource productivity (3yrs avg)	Eurostat
V8	R&D expenditure of GDP (3yrs avg)	Eurostat

Source: Our selection based on Eurostat and World Bank databases.

The goal of CCA is to predict four variables: Real GDP growth (3 years average), Unit labour cost growth (3 years average), Resource productivity (3 years average), and R&D expenditure of GDP (3 years average) based on four independent variables: Digital skills, Mobile subscriptions, Enterprises with e-commerce, and Enterprises with data analysis. We used the data collected from Eurostat and World Bank for the years 2018-2019. Figure 1 describes the distributions of digitalization indicators and their correlation. The statistically significant within-correlations include 0.58 between Enterprises with e-commerce (V3) and Enterprises with data analysis (V4), 0.56 between Digital skills (V1) and the data-analysis activity (V4), and 0.45 between Digital skills (V1) and the e-commerce active (V3).

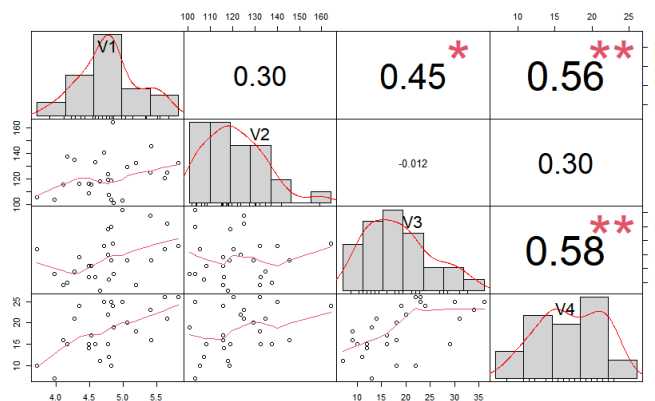


Figure 1. Set 1: Digitalization variables

Source: Authors' own research.

Figure 2 describes the distributions of economic growth indicators from set 2 and the correlations within set 2. The statistically significant within-correlations range from negative -0.56 - -0.44 between the real GDP growth (V5) versus R&D expenditures as a share of GDP (V8) and resource productivity (V7) and from -0.45 - -0.43 between Unit labour cost growth (V6) versus resource productivity (V7) and the growth in unit labour costs (V6); positively statistically significant correlations 0.36-0.37 were detected between real GDP growth (V5) and the growth in unit labour costs (V6) and between Resource productivity (V7) and R&D expenditure of as a share of GDP (V8), respectively.

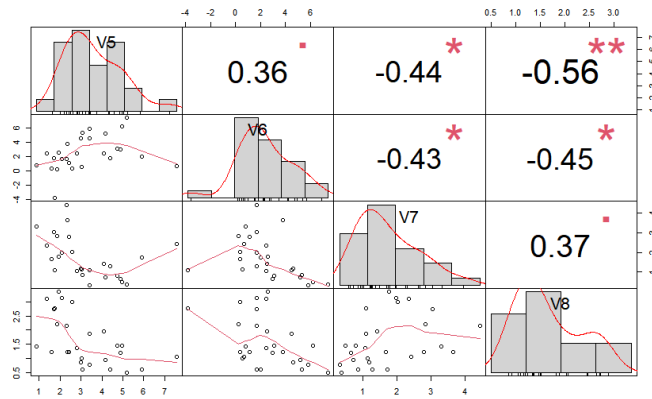


Figure 2. Set 2: Economic growth indicators

The independent set of indicators is denoted by $X = (V_1, \dots, V_4)^T$ and the dependent set $Y = (V_5, \dots, V_8)^T$. There are four pairs of canonical variates in the model. A_i is a linear combination of the elements of set X and B_i is a linear combination of elements of set Y :

$A_1 = a_{11}V_1 + \dots + a_{14}V_4$	
...	
$A_4 = a_{41}V_1 + \dots + a_{44}V_4$	
$B_1 = b_{11}V_5 + \dots + b_{14}V_8$	
...	
$B_4 = b_{41}V_5 + \dots + b_{44}V_8$	

The canonical correlation for the i^{th} canonical pair (A_i, B_i) is $\rho_i^* = \frac{\text{cov}(A_i, B_i)}{\sqrt{\text{var}(A_i) \text{var}(B_i)}}$, $i = 1, \dots, 4$. By means of CCA we will determine the linear combination that maximizes the canonical correlation ρ_i^* for the canonical pairs $(A_i, B_i), i = 1, \dots, 4$.

First, we find out whether there is any relationship between the two sets X and Y . We build a multivariate multiple regression model to predict the economic growth indicators (set Y) from the digitalization indicators (set X). We have five multiple regression equations. Each of the

following four multiple regression equations predicts one Y variable from the four variables in set X :

$V_5 = \beta_{10} + \beta_{11}V_1 + \beta_{12}V_2 + \beta_{13}V_3 + \beta_{14}V_4$ <p style="text-align: center;">...</p> $V_8 = \beta_{40} + \beta_{41}V_1 + \beta_{42}V_2 + \beta_{43}V_3 + \beta_{44}V_4$	
--	--

The null hypothesis that the regression coefficients from above are zero, which is equivalent to testing that the two sets of indicators X and Y are independent:

$H_0 : \beta_{ij} = 0, i, j = 1, \dots, 4$	
--	--

Results and discussions

By means of SPSS 26 we analyze the main findings of CCA.

Pillai's trace test, Hotelling's trace test, and Wilk's lambda criteria are significant, with p - values less than 0.05. The tests in Table 1 prove that there is a statistically significant and positive linear relationship between the dimensions of digitalization and economic growth indicators.

Table 1. Multivariate tests of significance (S = 4, M = -1/2, N = 8 1/2)

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Pillais	1.13306	2.17368	16	88	0.011
Hotellings	2.53494	2.77259	16	70	0.002
Wilks	0.19686	2.5759	16	58.68	0.004
Roys	0.64067				

Source: Authors' own research.

The CCA analysis generated four roots, as seen in Table 2. The eigenvalues are decreasingly ordered.

Table 2. Eigenvalues and canonical correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.	Sq. Cor
1	1.78295	70.33496	70.33496	0.80042	0.64067
2	0.6376	25.15238	95.48734	0.62398	0.38935
3	0.11237	4.43285	99.92019	0.31783	0.10102
4	0.00202	0.07981	100	0.04493	0.00202

Source: Authors' own research.

The eigenvalues are calculated as the ratio between the squared correlation and 1 minus the squared correlation. For instance, the largest eigenvalue 1.78 can be computed as $1.78 = \frac{0.64}{1 - 0.64}$.

Canonical correlations are correlation coefficients of the pairs of canonical variates. The first canonical correlation, 0.80042 is the correlation coefficient between the first pair of

canonical variates. 70.33% of the variation in A_1 is explained by the variation in B_1 . This value is the highest in this model, suggesting that the first canonical correlation is the most significant. In Table 3, we test the null hypothesis that all correlations are equal to 0, equivalent with all pairs of canonical variates are not correlated:

$H_0 : \rho_1^* = \dots = \rho_5^* = 0 .$	
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Since Wilks lambda is significant ($p=0.004 < 0.05$) and the canonical correlations are decreasingly ordered, it follows that $\rho_1^* \neq 0$. Then, we test the hypothesis that the remaining pairs of canonical variates are correlated:

$H_0 : \rho_2^* = \dots = \rho_5^* = 0 .$	
---	--

Since $p=0.167 > 0.05$, the second canonical variate pair is not correlated, $\rho_2^* = 0$. Similarly, the last two tests are not significant, since $p > 0.05$.

Table 3. Dimension reduction analysis

Roots	Wilks L.	F	Hypoth. DF	Error DF	Sig. of F
1 TO 4	0.19686	2.5759	16	58.68	0.004
2 TO 4	0.54786	1.52173	9	48.83	0.167
3 TO 4	0.89717	0.58544	4	42	0.675
4 TO 4	0.99798	0.04451	1	22	0.835

Source: Authors' own research.

The raw and standardized canonical coefficients for the dependent variables are shown in Tables 4 and 5.

Table 4. Raw canonical coefficients for dependent variables

Variable	1	2	3	4
V5	0.54546	-0.01097	-0.3737	-0.44885
V6	-0.07871	0.31843	0.26747	-0.27667
V7	0.24598	-0.54037	0.59055	-0.71615
V8	1.14658	0.82858	0.20551	0.08423

Source: Authors' own research.

The raw canonical coefficients are interpreted as follows. The canonical variates are interpreted as outcome variables, analogous to linear regression. A one-unit increase in variable V5 Real GDP growth leads to a 0.54546 increase in the first variate of economic growth measurement (Table 4). An increase in one standard deviation in variable V5 (Real GDP growth) leads to a 0.86407 standard deviation increase in the first variate of economic growth measurement (Table 5).

Table 5. Standardized canonical coefficients for dependent variables

Variable	1	2	3	4
V5	0.86407	-0.01738	-0.59198	-0.71103
V6	-0.18409	0.74478	0.62558	-0.64711
V7	0.26365	-0.57921	0.63299	-0.76761
V8	1.01943	0.7367	0.18272	0.07489

Source: Authors' own research.

Using the coefficient values in the second column of Table 4, the first canonical variable for economic growth is:

$B_1 = 0.54546V_5 - 0.07871V_6 + 0.24598V_7 + 1.14658V_8$

The size of the coefficients shows the contribution of the variables to the canonical variable.

In Table 6, the first canonical variable for economic growth is strongly dominated by V8 R&D expenditure of GDP, with a correlation coefficient 0.71673. The second canonical variable for economic growth is positively moderately dominated by V6 Unit labour cost growth with a correlation coefficient 0.66056, and negatively moderately dominated by V7 Resource productivity (-0.62367). The third canonical variable for economic growth is negatively dominated by V5 Real GDP growth (-0.74752), and by V7 Resource productivity (0.68916). The fourth canonical variable for economic growth is negatively dominated by V5 Real GDP growth (-0.64767) and V6 Unit labour cost growth (-0.60309). Only absolute value correlations above 0.45 are considered significant.

Table 6. Correlations between dependent and canonical variables

Variable	1	2	3	4
V5	0.1141	0.09335	-0.74752	-0.64767
V6	-0.44341	0.66056	0.05777	-0.60309
V7	0.33803	-0.62367	0.68916	-0.14774
V8	0.71673	0.20146	0.46579	0.47827

Source: Authors' own research.

In Table 7, 20.94% of the variance among the dependent set economic growth is explained by the first dependent canonical variate, while 13.415% is explained by the first covariate canonical variate. Similarly, 21.865% of the variance among economic growth is explained by the second dependent canonical variate, while 8.513% is explained by the second covariate canonical variable. The third dependent canonical variate explains most of the variance among economic growth, 31.35%.

Table 7. Variance in dependent variables explained by canonical variables

CAN. VAR.	Pct Var DEP	Cum Pct DEP	Pct Var COV	Cum Pct COV
1	20.94002	20.94002	13.41562	13.41562
2	21.86516	42.80518	8.51319	21.92881
3	31.35066	74.15584	3.167	25.09581
4	25.84416	100	0.05218	25.14799

Source: Authors' own research.

Next, we determine the raw and standardized canonical coefficients for the covariates (Tables 8 and 9). A one-unit increase in variable V1 (Digital skills) leads to a 0.61405 increase in the first variate of digitalization (Table 8). An increase of one standard deviation in variable V1 (Digital skills) leads to a 0.32048 standard deviation increase in the first variate of digitalization (Table 9). The first canonical variable for digitalization is expressed as:

$$A_1 = 0.61405V_1 - 0.01257V_2 + 0.09374V_3 + 0.01778V_4$$

Table 8. Raw canonical coefficients for covariates

Covariate	1	2	3	4
V1	0.61405	1.15521	1.78175	0.93814
V2	-0.01257	0.03865	-0.00993	-0.06111
V3	0.09374	0.06234	-0.1157	-0.01583
V4	0.01778	-0.22833	0.07184	-0.07351

Source: Authors' own research.

Table 9. Standardized canonical coefficients for covariates

Covariate	1	2	3	4
V1	0.32048	0.60292	0.92992	0.48963
V2	-0.18799	0.57783	-0.14854	-0.91373
V3	0.7489	0.49802	-0.92433	-0.12649
V4	0.09893	-1.27022	0.39968	-0.40895

Source: Authors' own research.

The correlations from Table 10 show the relative contribution of each covariate to each canonical variable.

Table 10. Correlations between covariates and canonical variables

Covariate	1	2	3	4
V1	0.6543	0.29036	0.69533	-0.06403
V2	-0.07226	0.36312	0.25917	-0.89205
V3	0.95121	0.02934	-0.27731	-0.13206
V4	0.65063	-0.47275	0.33921	-0.48797

Source: Authors' own research.

The first canonical variable for digitalization (Table 10) is strongly dominated by V3 (Enterprises with e-commerce) with a correlation coefficient 0.95121. The fourth canonical variable for digitalization is strongly negatively dominated by V2 (Mobile subscriptions) with -0.89205. Only absolute correlation values above 0.45 are considered significant.

In Table 11, 28.21% of the variance among the covariate set digitalization is explained by the first dependent canonical variate, while 44.03% of the variance is explained by the first covariate canonical variate.

Table 11. Variance in covariates explained by canonical variables

CAN. VAR.	Pct Var DEP	Cum Pct DEP	Pct Var COV	Cum Pct COV
1	28.21275	28.21275	44.0364	44.0364
2	4.2879	32.50065	11.01298	55.04937
3	1.87544	34.37609	18.56533	73.6147
4	0.05327	34.42936	26.3853	100

Source: Authors' own research.

Similarly, 4.28% of the variance among digitalization is explained by the second dependent canonical variate, while 11.01% is explained by the second covariate canonical variate.

In Table 12 are shown regression analysis results of the effect of the digitalization indicators on each economic growth indicator. The importance of each covariate is measured by the values of beta.

Table 12. Regression analysis for cells error term

Covariate	B	Beta	Std. Err.	t-Value	Sig. of t	Lower -95%	CL-Upper
Dependent variable: Real GDP growth (V5)							
V1	-0.518406	-0.170797	0.78252	-0.66249	0.515	-2.14124	1.10443
V2	0.008304	0.078373	0.02413	0.34406	0.734	-0.04175	0.05835
V3	0.063589	0.320692	0.05286	1.20302	0.242	-0.04603	0.17321
V4	-0.042147	-0.148015	0.0818	-0.51523	0.612	-0.2118	0.1275
Dependent variable: Unit Labour cost growth (V6)							
V1	0.620998	0.138571	1.00405	0.6185	0.543	-1.46126	2.70326
V2	0.05114	0.32692	0.03097	1.65147	0.113	-0.01308	0.11536
V3	-0.021684	-0.074067	0.06782	-0.31972	0.752	-0.16234	0.11897
V4	-0.227133	-0.540244	0.10496	-2.16399	0.042	-0.44481	-0.00946
Dependent variable: Resource productivity (V7)							
V1	0.107856	0.052517	0.468	0.23046	0.82	-0.86272	1.07843
V2	-0.021664	-0.302202	0.01443	-1.50095	0.148	-0.0516	0.00827
V3	-0.025868	-0.192804	0.03161	-0.81829	0.422	-0.09143	0.03969
V4	0.11779	0.611347	0.04892	2.40763	0.025	0.01633	0.21925
Dependent variable: R&D expenditure of GDP (V8)							
V1	0.694778	0.407838	0.36207	1.91891	0.068	-0.05611	1.44566
V2	-0.004569	-0.076837	0.01117	-0.40917	0.686	-0.02773	0.01859
V3	0.03925	0.352676	0.02446	1.60484	0.123	-0.01147	0.08997
V4	-0.008397	-0.052539	0.03785	-0.22184	0.826	-0.08689	0.0701

Source: Authors' own research.

Based on the results above, we reach the following conclusions:

- The effect of V3 (Enterprises with e-commerce) is more important in absolute value than the effect of V1 (Digital skills) when predicting V5 (Real GDP growth);
- The effect of V4 (Enterprises with data analysis) is more important in absolute value than the effect of V2 (Mobile subscriptions) when predicting V6 (Unit labour cost growth);
- The effect of V4 (Enterprises with data analysis) is more important in absolute value than the effect of V2 (Mobile subscriptions) when predicting V7 (Resource productivity);
- The effect of V1 (Digital skills) is more important in absolute value than the effect of V3 (Enterprises with e-commerce) when predicting V8 (R&D expenditure of GDP).

Conclusion

The connections between economic growth and the level of digitalization were under investigation by canonical correlation analysis, CCA. Figure 3 summarizes the key findings: the first root obtained by CCA explained 70.33% of the variation between the two phenomena with the correlation of 0.800. The (explanatory) set of digitalization explained 28.21% of the first canonical variate, while the canonical explained 20.94% of the (dependent) set of economic growth. The individual variables correlations with the canonical variates were positive except for the unit labour cost growth (and close-to-zero for mobile subscriptions).

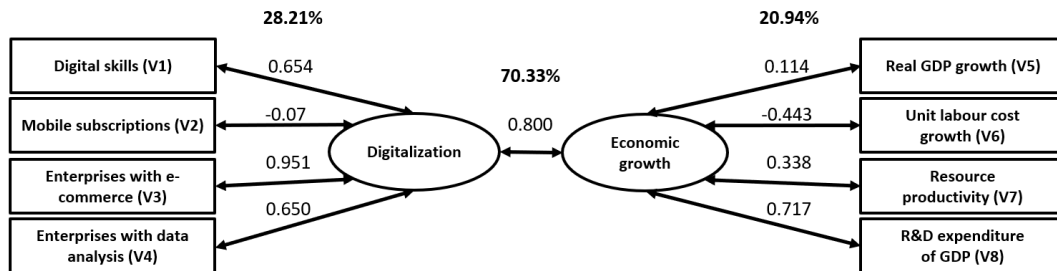


Figure 3. Summary of canonical correlations

Source: Authors' own research.

The regression analysis showed that real GDP growth was mainly dependent on the share of enterprises involved with e-commerce (V3), unit labour costs and resource productivity were mostly affected by enterprises conducting data analysis on customers for marketing purposes (V4), and higher digital skills meant also larger R&D expenditures as a share of GDP.

We note that a short three-year period under analysis limits the generalization of our results and, while applicable to the EU-27 countries, the other digitally developed economic areas, and even more so for less developed, different dependencies may be found. For future research, an extension to time-series analysis is suggested.

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