MODELS OF EVALUATION AND ANALYSIS OF THE DIGITAL TECHNOLOGIES IMPACT ON THE COUNTRIES ECONOMY

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Digital Technologies

Humanity lives in a time of exciting technological innovation. Digital technologies facilitate transformational changes. New technologies are changing product markets, factors of production, business, and work. Recent advances in artificial intelligence and related innovations are expanding the boundaries of the digital revolution. Thanks to technology, our world can become more equal, peaceful, and fair.

At the same time, technology can threaten privacy, undermine security and exacerbate inequality. Like previous generations, humanity will have to make a choice about how to use new technologies and control their development.

New technologies have great prospects. They create new paths and opportunities for a more prosperous future. But they also pose new challenges to the world economy. Although digital technologies have impressed with the brilliance and skill of their applications, they have not yet fully yielded the expected dividends in higher productivity growth. Indeed, aggregate productivity growth has slowed over the past few decades in many countries. Accordingly, economic growth tends to decrease. One important reason for these results is that national authorities and institutions have been slow to adapt to the unfolding changes. So, while digital technologies provide significant productivity gains, they also create new challenges as production processes, sources of competitive advantage, and market structures change.

The purpose of the work is to build a complex of economic and mathematical models that allow evaluation, analysis, and forecast of the impact of digital technologies on the economy of countries.

Conceptual research scheme

Stage 1

- Highlighting key indicators of economic and digital development
- Collection and analysis of statistical data
- Assessment of the economic situation in the studied countries

Stage 2

- Construction and analysis of Panel Data models

Stage 3

- Implementing Cluster Analysis

Stage 4

- Construction and analysis of multiple linear regression and forecast development

Economic Development Indicators

- GDP per capita(Y_1)
- unemployment rate(Y_2)
- GNI per capita (Y_3)

Digital Development Indicators

- Global E-Government Index (X_1)
- E-participation index (X_2)
- Online Service Index (X_3)
- Human Capital Index (X_4)
- Telecommunication Infrastructure Index (X_5)
- Internet users,‰ (X_6)

Data were taken for 70 countries from 2012 to 2020

Panel Data

A feature of models built on the basis of panel data is the ability to analyze and study both spatial data and time series. The advantages of such models are the ability to take into account and analyze the individual characteristics of economic units, and effectively eliminate the heterogeneity of objects based on short series, which cannot be done when building standard regression models.

Panel data models were built and the influence of factor variables (e-government development index, e-participation index, online services development index, human capital index, telecommunications infrastructure index, percentage of Internet users) on the GDP per capita of countries was analyzed.

```
> m.pooled <- plm(Y1 ~ X1 + X2 + X3 + X4 +X5 + X6, data = h, model = "pooling")
> summary(m.pooled)
Pooling Model

Call:
plm(formula = Y1 ~ X1 + X2 + X3 + X4 + X5 + X6, data = h, model = "pooling")

Balanced Panel: n = 70, T = 9, N = 630

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-50362.03 -10342.01   -822.41   7378.23  70776.76

Coefficients:
               Estimate  Std. Error t-value  Pr(>|t|)
(Intercept) -2.2057e+04  4.3732e+03 -5.0436 6.001e-07 ***
X1           8.3767e+07  3.8536e+07  2.1737  0.030104 *
X2          -2.8245e+04  5.8094e+03 -4.8621 1.472e-06 ***
X3          -2.7897e+07  1.2846e+07 -2.1717  0.030256 *
X4          -2.7931e+07  1.2846e+07 -2.1744  0.030053 *
X5          -2.7854e+07  1.2845e+07 -2.1685  0.030496 *
X6           2.1336e+02  7.4363e+01  2.8692  0.004255 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    3.4245e+11
Residual Sum of Squares: 1.5174e+11
R-Squared:      0.55691
Adj. R-Squared: 0.55264
F-statistic: 130.504 on 6 and 623 DF, p-value: < 2.22e-16
```

In the combined regression model, the coefficient of determination is greater than 0.5, which indicates that all input elements significantly (according to the Chaddock scale) explain the fate of the variation of the resulting indicator. Fisher's test indicates that the models are adequate and significant. Comparing the Student's test, it can be concluded that in the models with random effects and fixed effects, Y1 (GDP per capita) is significantly influenced by X2 (index of electronic participation), in the combined regression model, all indicators are significantly influenced, X2 (e-participation index) and X6 (percentage of Internet users) have a particularly strong influence .

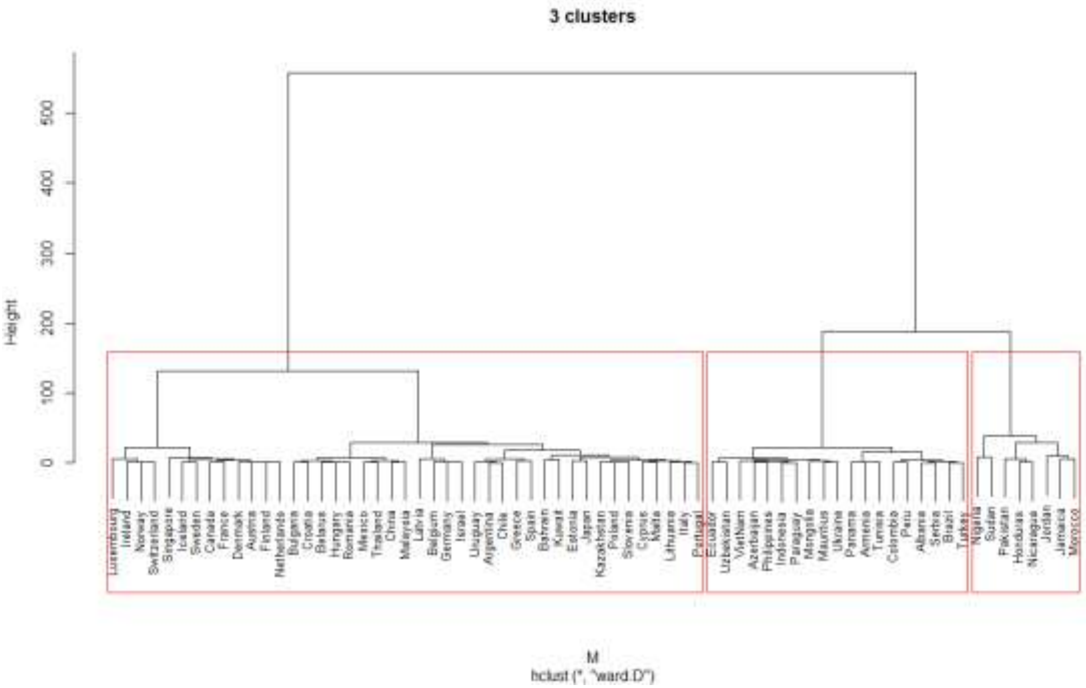
Comparing the Student's test, it can be concluded that in models with random effects and fixed effects, Y2 (unemployment rate) is significantly influenced by X2 (index of electronic participation), in the combined regression model all indicators do not have a significant impact on the resulting indicator.

In the combined regression model for Y3, the coefficient of determination is slightly less than 0.7, which indicates that all input elements significantly (according to the Chaddock scale) explain the share of variation in the resulting indicator. Fisher's test indicates that the model is adequate and significant. Comparing Studen's test, it can be concluded that in all models, Y3 (GNP per capita) is significantly influenced by X2 (index of electronic participation) and X6 (percentage of Internet users).

Cluster Analysis

he initial data for cluster analysis was taken for 2020. The *dplyr* library (R programming language) was used. To determine the optimal number of clusters, the *Nbclust* procedure was used, which includes 30 different indices for finding the optimal number of clusters, and gives the result voted for by the majority of methods.

Now we implement a hierarchical cluster analysis using Ward's method. Let's build a dendrogram and see all the possible clusters that can be found in our data




```
> fviz_nbclust(res)
Among all indices:
===================
* 2 proposed  0 as the best number of clusters
* 1 proposed  1 as the best number of clusters
* 6 proposed  2 as the best number of clusters
* 12 proposed  3 as the best number of clusters
* 3 proposed  4 as the best number of clusters
* 2 proposed  8 as the best number of clusters

Conclusion
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* According to the majority rule, the best number of clusters is  3 .
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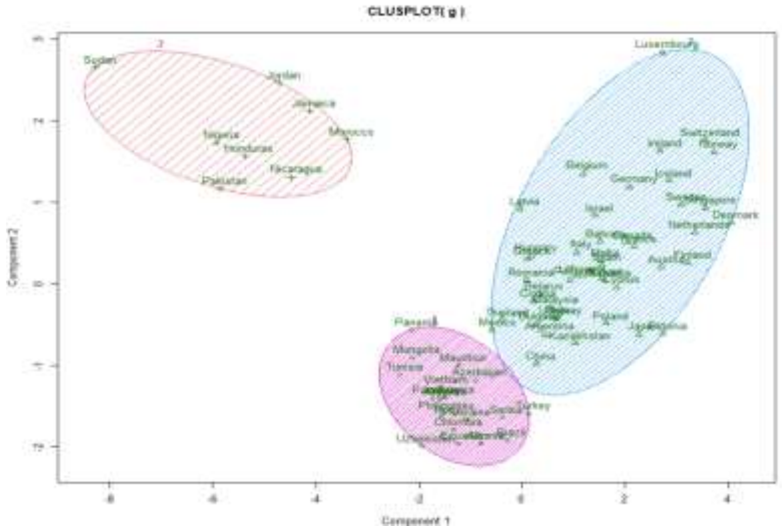
Thus, countries can be divided into 3 groups:

cluster No. 1 - with an average level of development of digital technologies and the economy (Turkey, Brazil, Panama, Mauritius, Colombia, Serbia, Peru, Azerbaijan, Paraguay, Albania, Ecuador, Armenia, Indonesia, Mongolia, Tunisia, Ukraine, the Philippines, Uzbekistan, Vietnam);

cluster No. 2 - with a high level of development of digital technologies and the economy (Luxembourg, Norway, Ireland, Switzerland, Denmark, Singapore, Sweden, the Netherlands, Canada, Finland, Iceland, Austria, Germany, Belgium, France, Israel, Italy, Cyprus, Spain, Malta, Slovenia, Portugal, Greece, Estonia, Bahrain, Lithuania, Poland, Hungary, Latvia, Croatia, Chile, Uruguay, Romania, Malaysia, Kazakhstan, Mexico, Bulgaria, Argentina, China, Belarus, Thailand, Japan, Kuwait);

cluster No. 3 – with a low level of development of digital technologies and economy (Jamaica, Jordan, Morocco, Nigeria, Honduras, Sudan, Nicaragua, Pakistan).

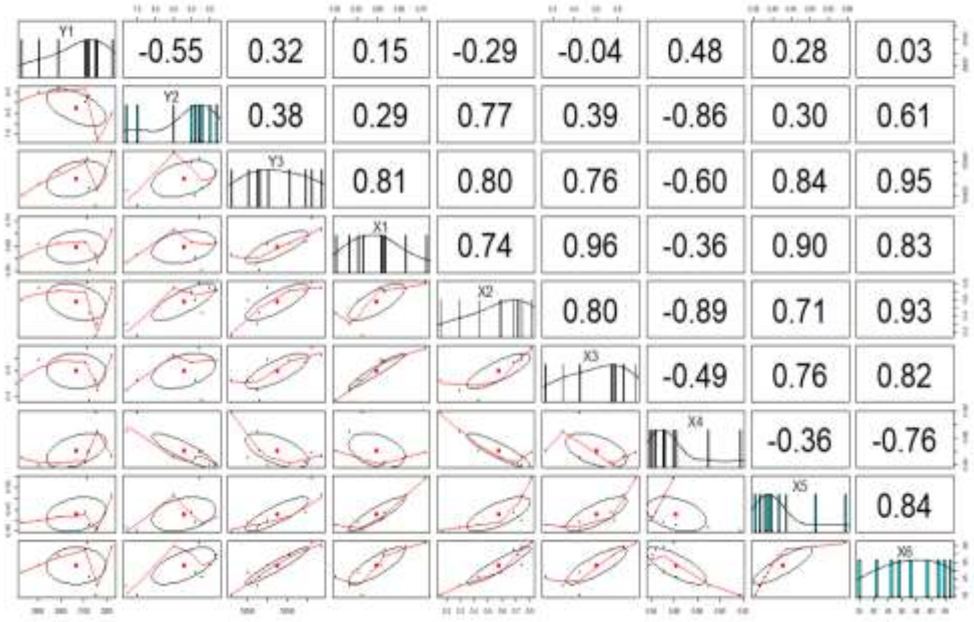
It can be observed that the cluster with countries with an average level of economic and digital technology development (pink) and the cluster with countries with a high level of economic and digital technology development (blue) are very close to each other.



Regression Analysis

We built a multiple regression model for Ukraine based on the studied indicators from 2012 to 2020. This model allows you to make a forecast of values for the resulting indicators.

Data distribution diagrams and values of Pearson's correlation coefficients.



With the help of constructed graphs and calculated values of Pearson's correlation coefficients and Spearman's rank correlation coefficients, it is possible to monitor the closeness of the relationships between factor and outcome variables. It is also possible to conclude about the presence of multicollinearity between the factor variables.

In order to eliminate the close linear relationship between regressors, the method of stepwise inclusion of factor variables was applied. Further calculations are performed in STATISTICA.

Regression Summary for Dependent Variable: Y1 (Spreadsheet
R= ,88771299 R?= ,78803436 Adjusted R?= ,66085497
F(3,5)=6,1962 p<,03881 Std.Error of estimate: 76,392

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			-5152,80	1921,508	-2,68164	0,043734
X4	1,86206	0,445919	9395,57	2250,014	4,17578	0,008690
X6	2,38884	0,739755	28,50	8,826	3,22923	0,023226
X1	-1,15174	0,520438	-2320,22	1048,438	-2,21302	0,077808

Fig. 1. The result of the stepwise inclusion method for Y1

$$Y1 = -5152.80 + 9395.57 * X4 + 28.50 * X6 - 2320.22 * X1.$$

Regression Summary for Dependent Variable: Y2 (Spreadsheet1_
R= ,85729264 R?= ,73495067 Adjusted R?= ,69708648
F(1,7)=19,410 p<,00314 Std.Error of estimate: ,48356

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(7)	p-value
Intercept			33,7377	5,667668	5,95266	0,000569
X4	-0,857293	0,194587	-28,9733	6,576329	-4,40570	0,003135

Fig. 2. The result of the stepwise inclusion method for Y2

Regression Summary for Dependent Variable: Y3 (Spreadsheet1_
R= ,97879210 R?= ,95803397 Adjusted R?= ,94404530
F(2,6)=68,486 p<,00007 Std.Error of estimate: 375,28

N=9	b*	Std.Err. of b*	b	Std.Err. of b	t(6)	p-value
Intercept			2198,83	972,263	2,26156	0,064410
X6	1,555159	0,229969	224,40	33,183	6,76247	0,000510
X2	-0,649817	0,229969	-4503,41	1593,752	-2,82567	0,030129

Fig. 3. The result of the stepwise inclusion method for Y3

Thank you for attention!