








# “Clustering of banks by the level of digitalization in the context of the COVID-19 pandemic”

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# CLUSTERING OF BANKS BY THE LEVEL OF DIGITALIZATION IN THE CONTEXT OF THE COVID-19 PANDEMIC

## Abstract

The COVID-19 pandemic has complicated the operating environment for banks around the world. Determining the drivers of digitalization of banking services based on the principles of corporate social responsibility of banks makes it possible to find a way out of the crisis. The objective of the study is to develop a model for clustering banks in terms of the level of digitalization on the principles of corporate social responsibility.

In this study, a twofold model has been proposed: the first part includes the calculation of the level of digitalization of banking, and the second part includes mathematical simulation of the clustering of bank digitalization level. This study reveals new possible solutions to the digitalization of banking in the face of new threats. In particular, factor analysis identifies the main factors, cluster analysis ranks banks into three categories (A, B, C) of service digitalization, and a dendrogram identifies digitalization drivers. The model was tested on 22 banks. Eight per cent of the banks are rated A "Very good" and B "Good". 92% have Level C "Satisfactory". The results of the study prove that the model should be validated. It should be confirmed that the application of the developed methodology for increasing the digitalization of banking services will increase customer loyalty by 15%, improve sustainability by reducing risk by 10%, and make banks attractive for investment by 15-20%.

**Keywords** digitalization, corporate social responsibility, digital banking, coronavirus

**JEL Classification** D21, G21, M15

## INTRODUCTION

The emergence and rapid spread of the coronavirus pandemic has forced the whole world to reconsider its attitude to its activities, improve old and develop new approaches taking into account the current situation, and respond in a new way to the rapid changes taking place in all economic spheres, both on the national and global arena. The banking system, as the most dynamically changing and vulnerable area, faced various problems that required an immediate response. The only way for it to survive was to transform its business processes and adapt to the introduction of various approaches that would guarantee its efficient performance.

Digital economy has an inevitable impact on all areas of life in the social and economic system, changing the traditional rules and mechanisms of its operation taking into consideration the global trends in digitalization. The banking system is one of the most easily affected areas of the national economy to the introduction of innovations and the application of new digital solutions. The range broadening of banking services digitalization is caused by the trend towards personalized banking development. On the one hand, personalization is nowadays

a key competitive advantage of a modern bank, which is focused on meeting the unique customer needs. On the other hand, the personalized approach in the banking segment is an adequate response to the personal economic and psychological expectations of consumers of banking products. These expectations are related, firstly, to the growth of the population's standard of living (according to the IMF and UN, income is expected to grow by 3.0-10.0% by 2025, depending on the region), secondly, to the growth of middle class – the main driver of innovation for individuals (according to World Data Lab, the global middle class will reach 5.3 billion people by 2030), and thirdly, to the changes in personal motivations to organize financial services for their life style and needs (life-style banking). All these factors create a fertile field for the development of digital services to personalize banking products, taking into account national peculiarities of Industry 4.0. All these factors, taken together, specify new requirements for corporate social responsibility of banks at a new level.

The relevance of this study is confirmed by a combination of factors. From a theoretical point of view, there is an opportunity to develop and apply new digital technologies for online banking in a pandemic. From the practical point of view, the use of an algorithm for clustering of banks according to the level of digitalization achieved offers a new tool for the application of sustainable banking drivers based on corporate-social principles in the context of pandemic environment. Thus, the study of banking digitalization, new drivers of sustainable development of banks based on corporate-social principles in the context of the COVID-19 pandemic is an important research issue.

## 1. THEORETICAL BASIS

### 1.1. Digital transformation of banking in the context of the COVID-19 pandemic

In recent years, there has been a rapid increase in interest among the academic community in the range of problems of digital transformation of the banking sector, especially in the corporate social responsibility of customer service digitalization (Amit & Zott, 2012; Björkdahl & Holmen, 2013; Burmeister et al., 2016; Gangi et al., 2018).

The digital transformation of banking in the context of the COVID-19 pandemic manifests itself in the need for another approach to the use of corporate social responsibility (CSR): using the ethical aspects of business implementation, charitable, social programs that give 'publicity effect' amid remote service environment. According to Hąbek and Wolniak (2016), Mohd and Kaushal (2019), Muzurura and Chigora (2019), and Lin (2011), CSR can be demonstrated in three aspects in online service in the context of the COVID-19 pandemic.

The first aspect is based on Milton Friedman's idea of 'the social responsibility of business is to make money'. From the perspective of Iwu-Egwuonwu (2020), this theory of corporate selfishness has been

used by the US business system in its attempt to regulate social remote banking operation in the context of the COVID-19 pandemic.

The second aspect is the theory of corporate altruism (developed in Europe in the 1970s). Kabir and Thai (2017) believe that putting this theory into practice maximizes the development of society and solves the problems it faces.

The third aspect is the theory of rational egoism. Nobanee and Ellili (2016) explain this theory as using the ability to take into account the cost-effectiveness of implementing measurements to solve the problems of digitization of banking on the basis of their future payback.

Scientific image on the social responsibility of banking digitalization has evolved successively, from the concept of 'business social responsibility' (Bakar et al., 2013; Baptista, & Oliveira, 2015) to 'corporate citizenship' theory (Dhote et al., 2020; Gandolfo, 2020) and the 'triple line of social responsibility' (Chaouali et al., 2017; Goularte & Zilber, 2020).

The variety of the concepts under study demonstrates the ambiguity and contradictory nature of the phenomenon of digital transformation of banking in the context of the COVID-19 pandemic based on CSR principles. Having differences in de-

tail, these definitions reflect the essential features of the digital transformation of banking in the context of the COVID-19 pandemic on CSR principles: the “three-fold” approach of online banking; taking into consideration the interests of all parties concerned in online banking; direct link to sustainable development, including information technology; civic (responsible) position of online banking; compliance with legislative and ethical norms. Thus, online banking implements the universal requirements of ISO standards, GRI 4 reporting guidelines.

The main driving reasons for allocating funds to implement and develop the concept of digital transformation of banking in the context of the COVID-19 pandemic on the principles of CSR are as follows:

- perception of necessity for social responsibility of digital transformation of banking;
- increase in a bank’s competitiveness through the implementation of CSR;
- a bank’s desire to enter the international market;
- the need to reduce negative public opinion.

Digital transformation of banking in the context of the COVID-19 pandemic based on CSR principles can be beneficial due to the following effects:

- improved reputation and image among stakeholders and in the competitive environment;
- an increase in customer loyalty, mainly in terms of long-term partnerships;
- increased labor productivity, increased motivation to digitalize staff work through the introduction of staff training and development programs.

## 1.2. The history of digital banking in the world

The COVID-19 outbreak in 2019–2020 has become one of the most active catalysts during the entire history of the emergence of remote banking. Buriak et al. (2019) suggest that the pandemic is like a spring, rapidly pushing forward the development of bank-

ing services, forcing to reconsider traditional customer communication strategies and models. Bolla-Araya and Seguí-Mas (2014) believe that even now, the effect of the jump start still remains. Ramdani et al. (2020) believe that this will be one of the key drivers of smart digital banking worldwide in the nearest 2-3 years. Shcherbak et al. (2019), Selcuk (2019) and Szegedi et al. (2020) present “digital business model of banking services” as a way of digital interaction between a bank and customers focused on creating new value by applying the latest digital technology in a virtual mechanism to create and promote personalized banking products and services with new socially responsible content.

Murthy and Mani (2013) and Leon (2019) distinguish the main stages of incorporation of the banking system into the digital economy based on digital technologies in banking business processes. The first successful example of digitalization of banking services was the creation of the Barclays Bank’s sustainable ATM in London in 1969, which laid the foundation for the development of a new segment of the banking market – banking card products. In 1970, Bank Americard was issued in the US, which later became Visa International (Al-Husein & Sadi, 2015).

The second stage is considered to be the period from 1980 to 2000. Alkhalidi and Kharma (2019) have a theory that the client-bank remote banking methodology was developed at this stage, which, in fact, is the basis for modern digital solutions and services.

The third stage can be described as the time period from 2001 to 2010, when various services and products were actively filling the previously created “client-bank” platform (Alraja & Aref, 2015). From 2011 onwards, the era of open banking is on. The COVID-19 pandemic gradually develops large-scale digital spaces involving a growing number of representatives from the non-financial sector within the frame of industry-specific partnerships: FMCG businesses, HoReCa, airlines, taxi companies, which fall within the sphere of interest of leading banks (Baabdullah et al., 2019). Generally, the evolution of digitalization stages of business models in the banking industry is shown in Appendix A.

As shown in Table A1 of Appendix A, the transition from the physical to digital business model has taken place over a quite short period of time. During

the COVID-19 pandemic, the banking business has evolved rapidly towards digitalization and personalization of virtual bank-customer interaction. The use of open API standards, developed by the Open Banking Working Group, the EU payment directive PSD2 allows banks to use customer data of other organizations, taking into account privacy policies in order to improve banking services, and allows customers to transfer their financial transaction management rights to third parties. These two events turned out to be a bifurcation point in the digitalization of banking services: everything that operated before the adoption of the open API standard have become known as traditional remote banking and everything that came later as digital banking (Bollas-Araya & Seguí-Mas, 2014; Baabdullah et al., 2019). Table 1 shows the substantive and methodological differences between traditional remote banking and digital banking.

The information generalized in Table 1 allows for the conclusion that digital banking is a qualitatively new technical and functional superstructure, which in the context of the COVID-19 pandemic is a free constructor for the formation of unique financial mar-

ketplaces, taking into account the needs of a particular retail customer, corporate business requirements, and comply with corporate social responsibility principles and rules.

Summing up, it should be recognized that there are now many ideas about the opportunity of using CSR-based e-banking digitalization technologies in the context of the COVID-19 pandemic, and a lot of research has been done in this area. Nevertheless, there is still a need to analyze the efficiency of new drivers of CSR-based banking digitalization in the context of the COVID-19 pandemic and their contribution to the competitiveness of banks.

Thus, the objective of this paper is to find a new tool for clustering of banks according to the level of digitalization, i.e. to develop a model for clustering of banks according to the level of digitalization in the context of the COVID-19 pandemic. The practical application of this model will allow determining the effective complementarity of banking digitalization drivers in the context of the COVID-19 pandemic, which can help to achieve the necessary level of CSR; justify the system of indicators for assessing the level

**Table 1.** Description of the substantive and methodological differences between traditional remote banking and digital banking

Criterion for comparison	Traditional remote banking	Digital banking
1. Chronological phase	1969–2015	2015 – present time
2. Business model	Violet (a rigid vertical structure created by the bank based on the portfolio of services and services it offers)	Customer-centric (banking is a constructor that responds flexibly to customer needs and can adapt to customer behavior)
3. Main source of information	Personal customer data that constitutes banking secrecy	Open customer data, BigData on customer transactions, data from social media, thematic discount cards available to a particular customer
4. Tools for service delivery	End-to-end solutions or tariff plans having rigid framework defined by the bank and offered to the customer (it is usually difficult to change their functional composition)	Marketing, behavioral (software products are intelligent and capable of self-adapting taking into account behavioral response or customer's lifestyle, his/her professional preferences)
5. Source of income for a bank	Commission fees for certain transactions by the customer based on the banking infrastructure	Commission fees for managing the customer's personal data, ensuring cybersecurity of their interactions on the internet
6. Format of the banking service operation	Physically oriented on a bank's own infrastructure and specialists of a particular bank (one and the same service may be qualitatively different depending on the competence of the bank's specialists)	Online oriented on special open infrastructure solutions (whatever bank is, the customer gets almost identical services in terms of quality and safety)
7. Tools to compete and attract clients	Pricing. Banks offer flexible tariffs and discount schemes as well as loyalty programs in exchange for attracting customers	Technical. Banks attract customers with the convenience of solutions, accessibility and a wide range of means of individualization of financial instruments



of CSR of banking digitalization in the context of the COVID-19 pandemic and suggest an approach for identifying activator/deactivator indicators.

## 2. RESULTS

### 2.1. Building a banking digitalization model in the context of the COVID-19 pandemic based on CSR principles

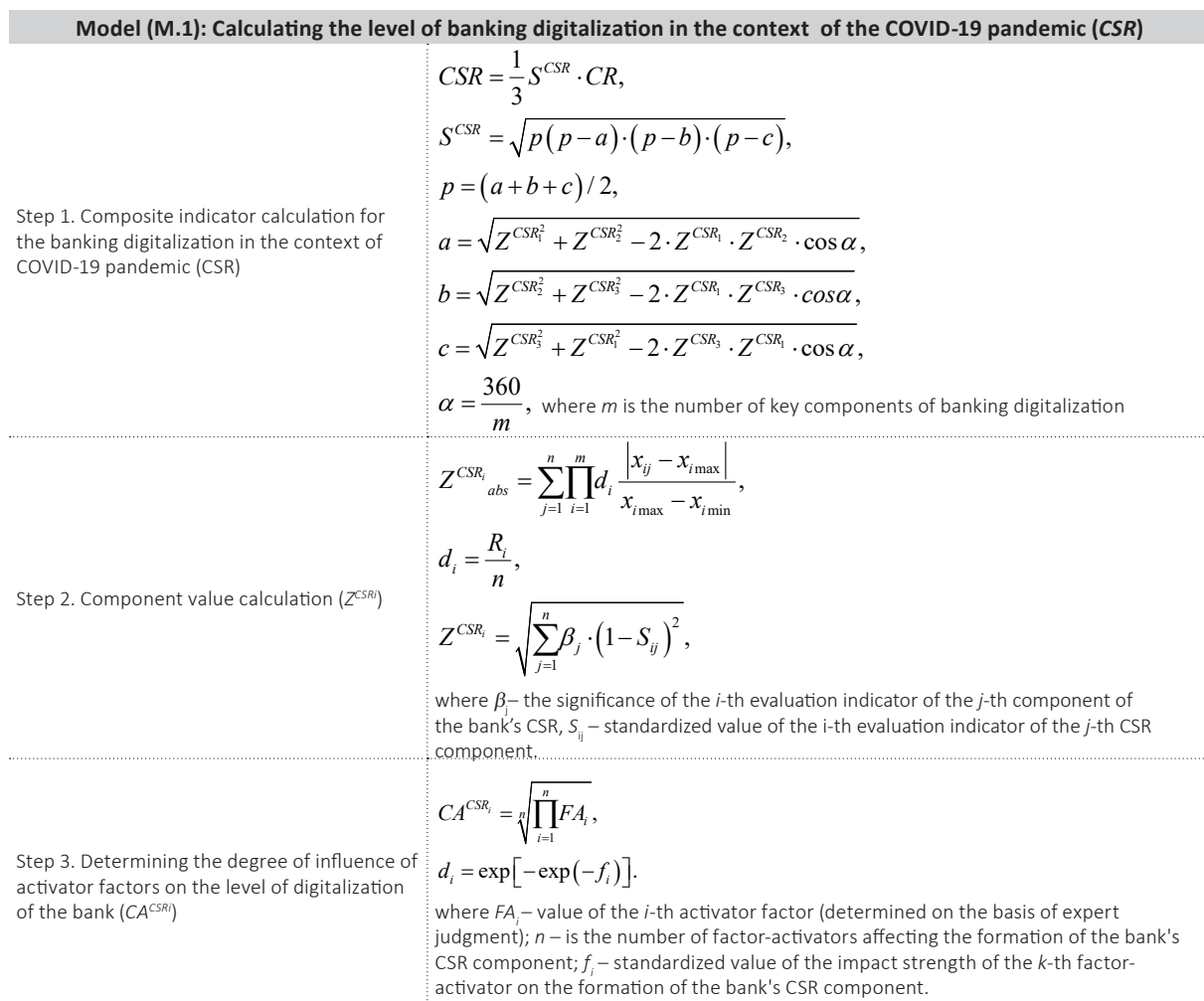
Building a model for the digitalization of the banking system in the context of the COVID-19 pandemic based on CSR principles helps specify its main components. This tool can help calibrate the value of each of the components, which allows reaching at least a minimum level of corporate so-

cial responsibility of online banking in the context of the COVID-19 pandemic.

The methodology has a number of steps and can be divided into two parts (Figure 1). The first model (M.1) is the calculation of the development level of banking digitalization in the context of the COVID-19 pandemic (CSR); the second model (M.2) is the mathematical modelling for clustering of banking digitalization level.

### 2.2. Banking digitalization model (M.1) in the context of the COVID-19 pandemic based on CSR principles

In a graphical representation, banking digitalization model (M.1) in the context of the COVID-19



**Figure 1.** Development level calculation of banking digitalization in the context of the COVID-19 pandemic

Model (M.2): Mathematical modeling for clustering of the level of banking digitalization	
Step 1. Factor analysis of bank digitalization indicators	$CSR_{F_i} = \sum_{i=1}^m F_i$ <p><math>m</math> – the number of key components of bank digitalization equal to the number of factors</p> $F_i = \frac{1}{Expl.F_i} \cdot \sum (a_{ij} \cdot X_{ij}),$ <p><math>Expl.F_i</math> – factor load of the <math>i</math>-th component; <math>a_{ij}</math> – indicator value <math>X_{ij}</math>; <math>X_{ij}</math> – <math>ij</math>-th indicator.</p>
Step 2. Cluster analysis of bank digitalization indicators	<p>Making indicators dimensionless:</p> $z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j},$ <p>Minimising the standard deviation from the cluster centre:</p> $\min \left[ \sum_{i=1}^k \sum x(j) \in S_i \ x^{(j)} - \mu\ ^2 \right],$ <p>where <math>x^{(j)} \in R^n</math>; <math>\mu_i \in R^n</math>; <math>\mu_i</math> – cluster centroid <math>R_i</math>.</p>
Step 3. Identification of activating factors for the level of bank digitalization using a dendrogram	$\mu_i = \frac{1}{S_i} \sum_{x^{(j)} \in S_i} x^j,$ <p>Recalculating cluster centres:</p> $\mu_i^{step t} = \mu_i^{step t+1};$ <p>where <math>step t</math> – previous iteration, <math>step t+1</math> – current iteration</p>

**Figure 1 (cont.).** Development level calculation of banking digitalization in the context of the COVID-19 pandemic

pandemic based on CSR principles can be represented as in Figure 2.

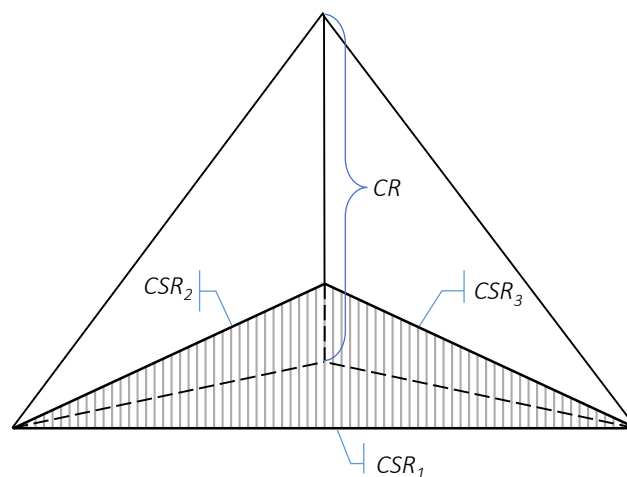
To build a model for banking digitalization (M.1) in the context of the COVID-19 pandemic based on CSR principles, the following indicators are proposed for use (Table 2).

In order to make them comparable, indicators need to be standardized. The significance coefficients of the activator factors are determined according to the Harrington scale (Table 3).

### 2.3. Cluster modeling of banking digitalization level

The proposed model was pretested on the basis of financial and non-financial reporting data of 24 Ukrainian banks for 2020–2021 using the STATISTICA 13 software. The results of the factor analysis are shown in Figure 3.

The data in Figure 3 shows that the first factor includes the indicators reflecting the level of social responsibility to employees, stakeholders, and the



*Note:*  $CSR_1$  is a comprehensive assessment of social responsibility level before employees, stakeholders and the government;  $CSR_2$  – comprehensive assessment of banking digitalization level in the context of the COVID-19 pandemic;  $CSR_3$  – comprehensive assessment of ecosystem performance level.

**Figure 2.** Model for banking digitalization in the context of the COVID-19 pandemic

**Table 2.** Initial data to build a model for banking digitalization in the context of the COVID-19 pandemic based on CSR principles

Indicators	Designation
Security and privacy of banking digitalization in the context of COVID-19 pandemic	X <sub>11</sub>
Online system accessibility	X <sub>12</sub>
Wage adequacy of bank employees to the minimum cost of living	X <sub>21</sub>
Level of differentiation or pay inequality ratio of bank employees	X <sub>22</sub>
Attracting qualified staff: supporting employees through training programs, supplementary pension schemes	X <sub>23</sub>
Improving trust among the local community, employees, shareholders by publishing an annual social report	X <sub>24</sub>
E-Customer Satisfaction Outlet level	X <sub>25</sub>
Loyalty, trust of the e-customer	X <sub>26</sub>
Fulfilment of tax and other obligations by the banks before the state	X <sub>27</sub>
Share of health and safety costs related to remote working conditions, COVID-19 pandemic in total costs	X <sub>31</sub>
Share of environmental protection costs related to remote working conditions, COVID-19 pandemic in total costs	X <sub>32</sub>

**Table 3.** Harrington's desirability scale

Linguistic rating	Range of values of desirability function $d(i)$
Very good	1.00-0.80
Good	0.79-0.63
Satisfactory	0.62-0.38
Badly	0.37-0.20
Very badly	0.19-0.00

Variable	Factor Loadings (Unrotated) (Data) Extraction Principal components (Marked loadings are >.700000)		
	Factor 1	Factor 2	Factor 3
X <sub>11</sub>	0.071997	0.974608	-0.065606
X <sub>12</sub>	0.280630	0.923083	0.071997
X <sub>21</sub>	0.816155	0.350419	0.280630
X <sub>22</sub>	0.962092	-0.111387	-0.110219
X <sub>23</sub>	0.915258	0.116480	0.278199
X <sub>24</sub>	0.804644	0.529786	0.577700
X <sub>25</sub>	0.908031	-0.256237	-0.217769
X <sub>26</sub>	0.956077	0.043291	0.156965
X <sub>27</sub>	0.791679	-0.368352	-0.328265
X <sub>31</sub>	-0.011020	0.156965	0.764889
X <sub>32</sub>	0.149018	0.469455	0.745070
Expl. Var	6.6225161	1.522013	1.410862
Prp. Totl	0.602047	0.138365	0.128260

**Figure 3.** Listing of the factor analysis results of digitalization level indicators of Ukrainian banks for 2020–2021



state. They reflect the major part of the value of the digitalization potential, the dispersion value is 60.2%. The dependence function of the first component of banks' digitalization is as follows:

$$CSR_1 = \frac{1}{6.622} \cdot (0.816155 \cdot x_{21} + 0.992092 \cdot x_{22} + 0.915258 \cdot x_{23} + 0.804644 \cdot x_{24} + 0.908031 \cdot x_{25} + 0.956077 \cdot x_{26} + 0.791679 \cdot x_{27}). \quad (1)$$

The second factor includes the indicators reflecting the level of banking digitalization in the context of the COVID-19 pandemic. The variance value of the second factor is 13.836%. The dependence function of the second component of banks' CSR is as follows:

$$CSR_2 = \frac{1}{1.522} \cdot (0.974608 \cdot x_{11} + 0.923083 \cdot x_{12}). \quad (2)$$

The third factor includes indicators that reflect the level of ecosystem performance. The variance of the third factor is 12.826%. The dependency function of the second component of banks' CSR is as follows:

$$CSR_3 = \frac{1}{1.411} \cdot (0.764889 \cdot x_{31} + 0.745070 \cdot x_{32}). \quad (3)$$

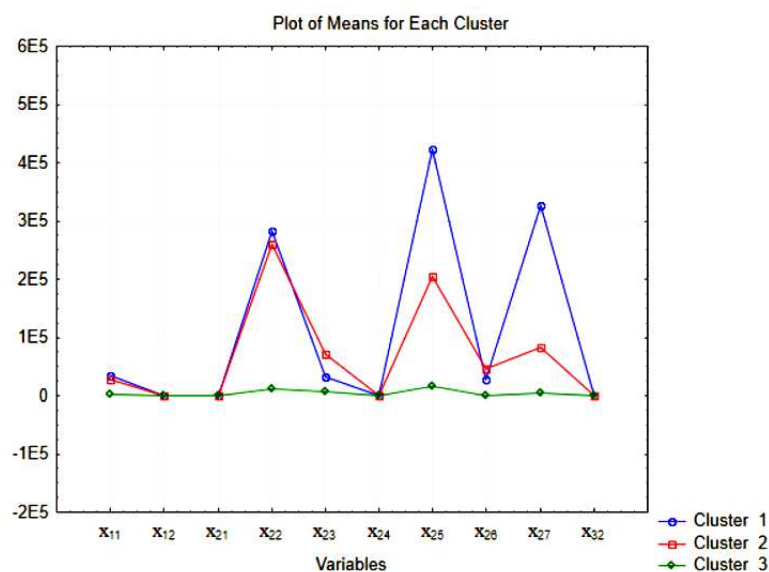
The data in Table B1 of Appendix B allow us to assess the impact of the individual components on the integral indicator of banking digitalization level. In the following step, the use of cluster analysis makes it possible to rank the analyzed banks according to the level of digitalization achieved (Figure 4).

The first cluster included one bank – Monobank, and the second cluster also included one bank – Neobank. The remaining 22 banks in the study sample fell into the third cluster: A-Bank, Alfa-Bank, Kredobank, Procredit Bank, Pumb, Ukrsibbank, Forward Bank, PrivatBank, Raiffeisen Bank Aval, Oschadbank, Credit Agricole Bank, Ukreximbank, Ukrsibbank, Prominvestbank, OTP Bank, Universal Bank, MTB Bank, Megabank, Crystalbank, Tascombank, Bank Vostok, Ukgasbank (Figure 5).

The calculation data of CSR development level of banking digitalization in the context of the COVID-19 pandemic of 24 Ukrainian banks under study are shown in Appendix B.

Test determination of the activator factors for the level of bank digitalization using the dendrogram is shown in Figure 6.

These dendograms allow us to visualize and identify the activators of digitalization process for the Ukrainian banks in the context of the COVID-19 pandemic based on CSR principles.



**Figure 4.** Listing of the cluster analysis results of digitalization level for Ukrainian banks in the context of the COVID-19 pandemic using CSR principles for 2020–2021

Case No	Members of Cluster Number 3 (Data) and Distances from Respective Cluster Center Cluster contains 22 cases
	Distance
C_1	4367.10
C_2	5301.45
C_3	8518.77
C_4	6724.95
C_5	5156.44
C_6	1462.36
C_7	8864.12
C_9	3504.73
C_10	4702.52
C_11	6631.40
C_13	4764.23
C_14	38121.41
C_15	5186.39
C_16	2691.19
C_17	4359.90
C_18	5655.47
C_19	13541.65
C_20	2896.24
C_21	4377.67
C_22	4052.07
C_23	4642.69
C_24	6184.26

Figure 5. Banks in the third cluster

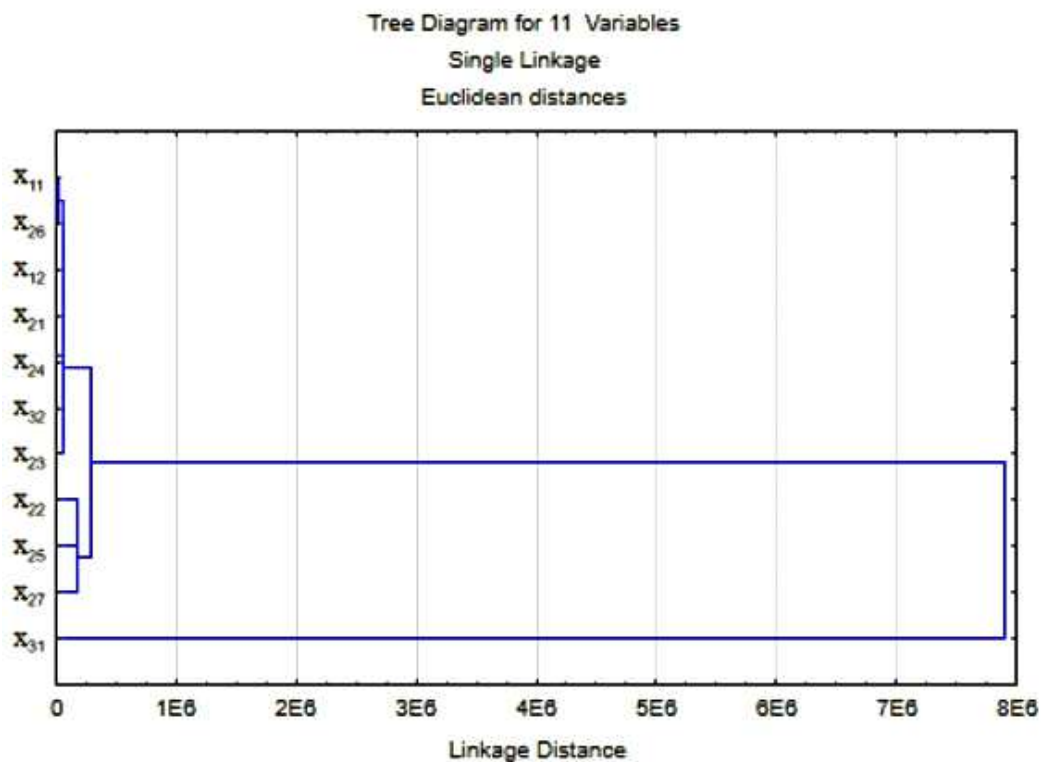


Figure 6. Dendrogram to identify the activators of the banking digitalization level in Ukraine in the context of the COVID-19 pandemic based on CSR principles for 2020–2021

### 3. DISCUSSION

Thus, the proposed model can be used as a tool to cluster the digitalization level for the Ukrainian banks in the context of the COVID-19 pandemic, based on CSR principles. First, it is necessary to determine the achieved level of development of the individual components using the model (M.1). The proposed model continues the theoretical developments of Baptista and Oliveira (2015), Björkdahl and Holmen (2013) in key aspects.

The proposed approach to identifying the driver indicators of the banking digitalization process allows us to identify the most significant factors among all those affecting this process amid the pandemic. In this way, the point of view of Hong (2019) and Mohammadi (2015) can be approved that indicator  $x_{11}$  “Security and privacy of banking digitalization in the context of the COVID-19 pandemic” is 5% more significant than indicator  $x_{12}$  “Online system accessibility”. That is, for the problem of digitalization of online customer service, this indicator is a driver of this process.

The degree of impact of the activators on the level of social responsibility towards employees, stakeholders and the state refutes the point of view of Raza et al. (2018), Singh and Srivastava (2018), and Szegedi et al. (2020) that indicator  $x_{27}$  “Fulfilment of tax and other obligations of the bank to the state” can be an activating factor for social responsibility to the state in the context of the COVID-19 pandemic. Besides, the point of view of Ventre and Kolbe (2020) and Walker (2019) cannot be affirmed that indicator  $x_{24}$  “Building a trust among the local community, employees and shareholders through the publication of the annual social report” may be a driver of this process. Furthermore, the views of Venkatesh et al. (2003) and Venkatesh et al. (2012) are justified. Indeed, indicators  $x_{22}$  “Level of differentiation or pay inequality ratio of bank employees” and  $x_{26}$  “Loyalty, e-customer trust”, firstly, are 10-15% higher than average in the component of bank social responsibility towards employees, stakeholders, and the state; secondly, they reflect the essence of digitalization process of trust in a bank in the context of the COVID-19 pandemic.

The power of influence of the activator factors in the component “Comprehensive assessment of ecosystem performance level” is approximately equal. Thus, the role of indicator  $x_{31}$ , “Proportion of labor protection costs related to remote working conditions, pandemic COVID-19 in total costs” as a driver of increased environmental accountability to bank employees confirms the point of view of Khan et al. (2009). And the role of  $x_{32}$  “The share of environmental protection costs related to remote working conditions, Covid-19 pandemic in total costs” as a driver of increased environmental responsibility to the environment confirms the view of Shcherbak et al. (2021).

Testing of the proposed bank clustering model on the level of digitalization in the context of the COVID-19 pandemic suggests that the basic assumptions of the model are correct. To compare the results obtained by Yehorycheva et al. (2017), it is important to test the model for the stability of all three components: economic, social and environmental.

This means that further research in this area is urgently needed. This is particularly relevant as scientists and practitioners anticipate that the stressful effects of the pandemic will be felt until 2024. Therefore, the proposed model should be tested again, taking into account the changes taking place in banking services and society as a whole.

At the same time, a number of limitations have to be taken into consideration. For example, to find the most effective solutions for the digitalization of not only banking services, but all areas of life, especially when it comes to hybrid banking information technology. This will make it possible to test Kolodiziev and Gontar’s (2014) point of view on the possibility of scenario-based behavior of banks in the given situation. For example, combining transport logistics with remote banking.

Consequently, in order to obtain more comprehensive results of the impact of the digitalization process on all spheres of society, increasing its social responsibility, on the one hand, the scope and tools of the study should be extended, and on the other hand, the set of model indicators can be expanded.

## CONCLUSION

The paper proposes a new scientific and practical approach to clustering of banks according to the level of digitalization in the context of the COVID-19 pandemic, based on the principles of social and corporate responsibility.

The methodology consists of the sequential use of two models. The first model allows determining the level of digitalization achieved by a bank, which consists of three components: the level of social responsibility to employees, stakeholders and the state; the level of banking digitalization in the context of the COVID-19 pandemic; the level of ecosystem performance. Each of the components is the integral of individual indicators. The second model is used to cluster banks according to the level of digitalization. One of the iteration of the clustering process is to construct a dendrogram, the visualization of which enables the identification of complementary sets of driver indicators.

The proposed model was pre-tested using the financial and non-financial reports of 24 Ukrainian banks for 2020–2021. This allowed us to rank the banks under study into three levels of banking digitalization in the context of the COVID-19 pandemic on the principles of corporate social responsibility: “Very good”, “Good”, and “Satisfactory”. This corresponded to the three clusters obtained. No banks with “Badly” and “Very badly” levels of digitization were identified.

The use of a dendrogram made it possible to identify the activators of the banking digitalization process in the context of the COVID-19 pandemic. The drivers are expected to outperform the deactivators by 10-15% on average. A clear differentiation of all indicators into activators/deactivators will enable banks to develop a long-term strategy and short-term measures to increase the level of responsibility of the bank in terms of digitalization to all stakeholder categories. Therefore, an important question is whether banks will be able to continue to use these models to increase the level of digitalization, maintain a stable, sustainable course towards high levels of social and technical responsibility towards online customers, increase market share and improve competitiveness. This will allow banks to develop their key competitive advantages while operating in the context of the COVID-19 pandemic and receive a proper rating at the global level.

## AUTHOR CONTRIBUTIONS

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## APPENDIX A

**Table A1.** Key stages in the digitalization evolution of banking business models

Business model development stage	Stage description
1. Stage of a physical business model	<i>Chronological boundaries: 1950–1970, 20th century.</i> Stage content: banking business focuses on active development of a physical presence in the maximum geographical area. Time of rapid growth of bank branches and representative offices in foreign countries. The use of remote services (radio, telephone, television) is of a point-to-point operational nature and is usually concentrated in the marketing block of the banking business
2. Stage of a technocratic business model	<i>Chronological boundaries: 1980–1990, 20th century.</i> Features of methodological paradigms: The banking business is actively developing the technical side of its activities by means of using telephone tools, the emerging Internet connection to manage remote branches and develop a new line of business such as remote banking services as an independent business unit
3. Stage of a cross-border communication model	<i>Chronological boundaries: 1990–2000, 20th century.</i> Stage content: as banking business scales up and goes beyond national financial markets, there is a demand to include the factor of foreign influence of stakeholders into the business model and the need to manage their economic interests in a predicative manner. Active development of the concept of personal information accumulation, the first attempts to create a digital customer profile
4. Stage of a banking and non-financial business synergy model	<i>Chronological boundaries: 2001–2011, 21st century.</i> Stage content: banking business to improve its own competitive position in the market, as well as to develop a portfolio of cross-functional products and services is increasingly actively involving non-financial enterprises in its sphere of activity on the principles of partnership and technical cooperation (e.g. cooperation of the bank with fintech companies, creation of bank-based venture capital funds to support innovation)
5. Digital business model stage of financial ecosystems and marketplaces	<i>Chronological boundaries: 2011 – present day.</i> Stage content: the rapid growth of digital technologies and their rapid scaling has led bank management to focus on the formation of digital marketplaces combining a multitude of independent physical and virtual businesses binded by partnership contracts and operating in an autonomous zone of mutual non-competition. The market (beginning of the COVID-19 pandemic) has generated a new message of business models in the form of ecosystems – autonomous socio-economic systems that implement product and service packages through the Internet of Things (IoT) within the integrated space

## APPENDIX B

**Table B1.** Calculation data for digitalization components of corporate social responsibility of Ukrainian banks for 2019–2021

Bank	CSR <sub>1</sub>	CSR <sub>2</sub>	CSR <sub>3</sub>	CSR	Rating
Monobank	0.941	0.906	0.922	0.928	A
Neobank	0.866	0.820	0.901	0.857	B
A-Bank	0.783	0.813	0.808	0.785	C
Alfa-Bank	0.779	0.751	0.801	0.727	C
Kredobank	0.777	0.708	0.774	0.703	C
Procredit Bank	0.756	0.704	0.774	0.694	C
Pumb	0.744	0.688	0.768	0.687	C
Ukrsibbank	0.743	0.679	0.754	0.682	C
Forward Bank	0.737	0.653	0.695	0.680	C
PrivatBank	0.721	0.637	0.681	0.663	C
Raiffeisen Bank Aval	0.702	0.627	0.647	0.655	C
Oschadbank	0.684	0.626	0.614	0.649	C
Credit Agricole Bank	0.672	0.620	0.611	0.621	C
Ukreximbank	0.654	0.599	0.608	0.596	C
Ukrsibbank	0.614	0.589	0.601	0.592	C
Prominvestbank	0.590	0.570	0.580	0.590	C
OTP Bank	0.578	0.564	0.574	0.573	C
Universal Bank	0.578	0.555	0.564	0.573	C
MTB Bank	0.572	0.554	0.561	0.564	C
Megabank	0.560	0.539	0.536	0.546	C
Crystalbank	0.554	0.536	0.520	0.536	C
Tascombank	0.542	0.512	0.507	0.530	C
Bank Vostok	0.496	0.493	0.488	0.513	C
Ukrasbank	0.484	0.480	0.445	0.510	C