Digital Transformation in the Banking Sector: A Review of Key Concepts and Quantitative Assessment Methods

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Abstract-**The article provides a review of approaches to the quantitative assessment of digital transformation in commercial banks. Digital transformation is considered a complex, multi-level process affecting business models, operational processes, product offerings, and data management. The study analyzes the main composite indices used in international and national practice to measure this process, including their construction methods and data sources. Special attention is given to empirical studies on the impact of digital transformation on banks' performance indicators. The results of these studies are ambiguous, largely due to differences in methodologies and the limitations of technology-focused approaches. The methodological contribution of the paper lies in the systematization of existing approaches and the justification for developing an integrated index that accounts for the multi-faceted nature of digital changes and the specifics of banking operations. The findings provide a foundation for further empirical research on the economic effects of digital transformation in banks.**

Keywords: Digital transformation, banking activity, fintech, digital maturity, digitalization, composite index.

JEL Classification: G21, O33, C43.

1. INTRODUCTION

Digital transformation (DT) has become one of the key directions in banking sector development in recent years, exerting a significant influence on the structure of financial markets, competitive conditions, and the nature of bank-client interactions. The active adoption of digital technologies, including big data, artificial intelligence, cloud solutions, and platform models, is accompanied by changes in traditional forms of banking organization and creates new sources of competitive advantage.

At the same time, both academic literature and methodological and regulatory documents lack a unified understanding of the content and boundaries of bank DT, and no generally accepted definition has been established. The complex, multi-faceted nature of DT significantly complicates the formalization and quantitative assessment of this phenomenon.

In recent years, various approaches to measuring the level of bank DT have been developed, including the creation of composite indices. However, the sets of indicators, data sources, and aggregation methods used in different studies vary substantially, making it difficult to compare results and limiting the possibilities for generalizing empirical findings.

Studies analyzing the economic effects of DT demonstrate contradictory results: alongside conclusions about the positive impact of digitalization on banking efficiency, short-term negative effects are noted, driven by high investment and organizational costs, as well as cases where no statistically significant relationship is found. This may be related to the fact that existing methodologies often focus primarily on the technological component of DT and do not fully account for institutional, organizational, and strategic aspects of transformation processes.

The purpose of this paper is to systematize existing approaches to measuring bank DT and to justify the need for developing an integrated index that allows comprehensive assessment of the level of digital changes. The methodological focus of the study is aimed at forming a foundation for subsequent empirical work devoted to analyzing the impact of digital transformation on indicators of profitability, efficiency, and stability of banking operations.

2. LITERATURE REVIEW

Defining Key Concepts

In modern economic literature, the term "digitalization" is interpreted as a component of complex transformations

of organizational operating models, including the transfer of communications to the digital environment and automation of standard processes; the totality of these processes forms the basis of digital transformation (DT) [1]. The relatively recently adopted concept of DT characterizes new, rapidly developing phenomena from various fields of knowledge, and therefore a single, generally accepted definition has not yet been established.

In World Bank terminology, DT of the economy is defined as the manifestation of qualitative, revolutionary changes consisting not only of individual digital transformations but also of fundamental changes in the structure of the economy, shifting value creation centers to the sphere of building digital resources and end-to-end digital processes. The OECD defines DT as the impact of digital technologies and data, as well as their use in existing and new types of activities.

Researchers at the Higher School of Economics (Moscow) propose a definition of DT that appears to be the most universal: qualitative changes in business processes or business models resulting from the implementation of digital technologies, leading to significant socio-economic effects. This definition emphasizes the key distinguishing feature of DT from related concepts of digitalization or IT implementation: qualitative changes in business processes and activity models whose implementation leads to significant socio-economic effects [2].

The diversity of definitions of digital transformation is characteristic of both scientific studies and applied materials from IT and consulting companies, some of which are presented in Table 1.

Table 1. Definitions of DT in Applied Materials of IT and Consulting Companies

Company	Definition of DT
McKinsey	Restructuring an organization to create value through continuous large-scale technology deployment
CISCO	Application of technologies to rethink existing or create new business processes; DT drivers include technology trends changing user behavior (AI, cloud computing, IoT)
IBM	Business strategy embedding digital technologies across all areas of an organization, modernizing processes, products, operations, and technologies to ensure continuous, fast, and customer-oriented innovations
Oracle	A set of initiatives enabling enterprises to abandon manual and analog processes in favor of digital ones
Citrix	Strategic deployment of digital technologies to improve productivity, manage business change, and transform customer and employee experience

In addition, the following interpretations of DT are found in specialized scientific literature: technological change at different levels of the organization, using digital technologies to improve existing processes and adopting digital innovations that can change the business model [3]; the application of digital technologies to improve customer service quality, optimize operations, or form new business models [4]; comprehensive embedding of digital technologies across all areas of organizational activity aimed at radical renewal of its business model through both optimization of existing processes and formation of new ones [5]; transformation of an object based on changes to its basic structure and oriented toward the integration of information, systems, and technologies [6]; the use of modern digital technologies such as AI, IoT, and blockchain for substantial transformation of organizational activities [7]; a process of improving operations, activities, skills, and competencies to benefit from the transition to digital technologies [8]; and changes in processes, procedures, organizational culture, and business capabilities implemented through digital technologies [9].

Analysis of the presented definitions shows that despite differences in emphasis, authors converge in understanding DT as a complex, multi-level process that goes beyond simple automation or implementation of individual information technologies. In most interpretations, the key elements of DT are changes in business processes, organizational structures, and business models under the influence of digital technologies, as well as orientation toward creating new value for customers [10].

The term "fintech," as defined by the European Central Bank, refers to technological innovations in financial services that may lead to new business models, applications, processes, or products having a significant impact on the delivery of financial services [11, 12]. As a collection of technologies and innovations, fintech serves as a driver of

the DT process.

A key factor in the successful DT process is technological and managerial readiness, i.e., a certain level of organizational digital maturity. This has driven the active development of the Digital Maturity Index concept as a tool for the integrated assessment of an organization's digital capabilities.

The banking industry is currently one of the leaders in digital transformation, serving as a center for generating new ideas, technologies, and business models. The ability to quickly bring modern, high-quality digital products to market has become a decisive factor for banks in maintaining competitiveness and retaining customers. As a result, customers gain access to comprehensive and personalized offerings combining banking, telecommunications, educational, and commercial services, while the speed and convenience of financial operations increase significantly [1].

According to a survey by the European Central Bank [13], the key goals of DT include enhancing customer orientation, increasing operational efficiency through process automation and infrastructure modernization, and ensuring round-the-clock delivery of digital products and services. Among innovative technologies, cloud solutions, APIs, and AI technologies have gained the widest adoption.

Approaches to Measuring the Level of Digital Transformation in Banking

The problem of inadequate methods for assessing DT in commercial banks is widely discussed in contemporary academic literature. In particular, the imperfection of developed assessment criteria and difficulties in collecting relevant information [14, 15], as well as the absence of structured data on digital technologies in organizations [16, 17] are noted. The specifics of banking activities significantly limit the application of indices developed for measuring DT in real sector organizations.

Creating a universal DT index for banks would allow comprehensive assessment of the effectiveness of digital strategy implementation, benchmarking of organizations, and identification of best practices. For investors, detailed information about the level of bank digitalization opens opportunities to more accurately assess competitive positions. From a regulatory perspective, such an index could become an additional indicator in forming supervisory ratings [18].

The main methodologies for assessing digitalization in the banking sector use the following information sources: results of sample surveys of organizations; text analysis (frequency of mentions of DT-related terms); and hard data extracted from banking and statistical reporting. The greatest interest lies in methodologies that combine these parameters into composite indices, brief information on which is presented in Table 2.

At the origins of such research was the Center for Digital Business at MIT, which launched the Initiative on the Digital Economy. The jointly developed Industry 4.0 Maturity Model with Capgemini Consulting [19] assessed three areas of digital transformation. Alternative models were proposed by KPMG and Cisco. Cisco also calculated a country-level Digital Readiness Index for 146 countries based on standardized World Bank data using z-scores.

The HSE Digitalization Index of Economic Sectors and Social Sphere of Russia represents a weighted sum of five sub-index values, each consisting of parameters obtained primarily from statistical information.

The World Bank Digital Adoption Index covers 180 countries and is calculated as a simple arithmetic mean of three sub-indices incorporating technologies necessary for development in the digital era.

The Digital Acceleration Index, calculated by the Boston Consulting Group based on surveys of more than 11,000 companies, enables benchmarking according to digital technology achievements.

The Deloitte Digital Maturity Index is based on surveys of more than 800 executives in Germany, Japan, the UK, and the USA, placing enterprises in six digital archetypes, from 'digital laggards' to 'digital champions.'

Table 2. Digitalization Indices: Developers and Key Measurement Aspects

Index	Developer	Key Aspects
MIT Initiative / Industry 4.0 Maturity Model	MIT Center for Digital Business & Capgemini Consulting	Customer experience; Operational processes; Business models
DT Readiness Assessment	KPMG	Clear digitalization strategy; Digital talents; Key process digitalization; Agile infrastructure; Innovation-stimulating governance
Cisco APAC SMB Digital Maturity Index	CISCO & International Data Corporation	Strategy and organization; Processes and management; Technologies, personnel and skills

CISCO Digital Readiness Index	CISCO	Technology infrastructure; Technology adoption; Ease of doing business; Human capital development; Business and government investment; Basic population needs; Startup environment
Digitalization Index of Economic Sectors	Higher School of Economics (Russia)	Use of digital technologies; Business process digitalization; Digital skills of personnel; ICT expenditure; Cybersecurity
Digital Adoption Index (DAI)	World Bank	Population; Government; Business
Digital Acceleration Index	Boston Consulting Group	42 parameters: digital customer journeys; digital supply chains; marketing personalization, etc.
Digital Maturity Index	Deloitte	90 operational and strategic criteria: digital investments; smart asset investments; intelligent planning; connected customer apps; digital roadmap clarity, etc.

Significant experience has been accumulated by international organizations in developing digital government indices that assess online services, telecommunications infrastructure, human capital, and other aspects of GovTech. A brief overview of these indices is presented in Table 3.

Table 3. Digital Government Indices: Developers and Key Measurement Aspects

Index	Developer	Countries	Criteria
UN e-Government Development Index (EGDI)	United Nations	193	Telecommunications infrastructure; Human capital; Online services
EU eGovernment Benchmark	European Commission	37	User orientation; Transparency; Key technological enablers; Cross-border mobility
OECD Digital Government Index (DGI)	OECD	38	Digital government governance; Public sector capabilities; Data-driven public sector; Open government data; Service design and delivery in the digital age
GovTech Maturity Index (GTMI)	World Bank	198	Core government systems support (15 indicators); Service delivery enhancement (6 indicators); Citizen engagement (12 indicators); GovTech enablers (15 indicators)

Among the largest international studies in banking digitalization is the Deloitte Digital Banking Maturity (DBM) survey, conducted since 2016. In 2024, the sixth round included 349 banks from 44 countries [23]. The DBM methodology assesses both functional capabilities and customer needs. The survey includes 1,005 functions grouped across six stages of the bank customer journey (Table 4).

Table 4. Key Characteristics of the Deloitte Digital Banking Maturity Survey

No.	Customer Journey Stage	Number of Functions	Assessment Focus
1	Information Availability	18	Completeness and convenience of accessing information about banking products, services, terms, and tariffs
2	Account Opening	56	Degree of digitalization of account opening and card issuance procedures, including remote application and client identification
3	Client Onboarding	63	Initial bank-client interaction processes, service configuration, product activation, and initiation of digital service channels
4	Daily Banking Operations	494	Everyday operations including account management, payments and transfers, balance monitoring, and transaction history
5	Expanding Client Relationships	360	Long-term client relationships including bancassurance, ecosystem and investment services,

			account aggregation, cross-selling, and additional products
6	Account Closure	14	Degree of digitalization of account closure procedures

Each stage receives a quantitative score, and the aggregated result forms a global bank ranking distributed into four groups. The top 10% are classified as 'digital champions.' Analysis of DBM results for 2022 and 2024 revealed a shift in DT priorities: the focus is moving from developing new digital functions to improving customer interaction channels, including optimizing user interfaces and enhancing intuitiveness. Currently, the key value of digital banking is determined not by the number of implemented functions but by their alignment with actual customer needs.

The Digital Maturity Index for Russian retail banks is formed by SDI360 based on analysis of 35 banks (2024). The methodology assesses three blocks comprising 12 categories and 36 indicators: digital environment presence (website, mobile app, social networks, content marketing); promotion and communications (traffic volumes, marketing activity, reputation, client interaction); and online sales (financial marketplaces, product pages, payment services, identification and personal data management).

In Vietnam's banking sector, the ICT index developed by the Ministry of Information and Communications jointly with the Vietnam Informatics Association [24] is used to assess DT. It comprises four sub-indices: technological infrastructure, human resources potential, internal banking applications, and online banking.

In recent scientific research, models for integrated DT assessment have been developed. Most notably, the Peking University Commercial Bank Digital Transformation Index [14] evaluates three aspects of DT: strategic transformation, business transformation, and management transformation (Table 5). Input data are extracted from banking and statistical reporting as well as text analysis. The final index is constructed using weighted average fusion from bottom up, with weights determined by principal component analysis.

Table 5. Peking University Commercial Bank Digital Transformation Index

No.	DT Aspect Measured	Sub-dimension	Indicators
1	Strategic Transformation	-	Frequency of mentions of digital technology-related words in banks' annual reports
2	Business Transformation (Digital Technology Adoption)	Digital Channels	Launch of mobile application and WeChat banking during the study year
-	-	Digital Products	Availability of remote asset management and lending, e-commerce
-	-	Digital R&D	Frequency of digital technology-related words in banks' patent applications
3	Management Transformation	Digital Structure	Creation of fintech departments or subsidiary fintech companies
-	-	Digital Talent	Share of experienced IT executives in management
-	-	Digital Cooperation	Frequency of mentions of 'cooperation' and 'alliance' in banks' annual reports

An alternative approach using banking and statistical reporting was proposed in [25]. The DT index comprises six variables: ratio of intangible assets to total assets, ratio of total assets to number of employees, ratio of total assets to number of branches, ratio of annual web traffic to total assets, ratio of app downloads to total assets, and average annual app rating. Principal component analysis with three latent factors was applied for dimensionality reduction, interpreted as indicators of digital channel development, network efficiency, and IT investment.

3. RESULT AND DISCUSSION

International Experience in Analyzing the Relationship between DT and Bank Performance

The essence of DT lies in the systematic improvement of operations, competencies, and management aimed at obtaining economic benefits from digital technologies. Consequently, DT should have a significant impact on banks' financial results. Recent studies have empirically confirmed the relationship between DT levels and banking efficiency, revealing cost reductions, profitability growth, and enhanced sustainability and competitiveness [14, 26-32].

However, empirical results do not always indicate a stable positive correlation. Regression analysis of panel data covering 1,516 observations from 279 EU banks for 2017-2022 revealed increased costs and reduced operational efficiency at the initial stage of digital technology adoption; however, in the long term, DT contributed to profitability growth [25]. This finding is consistent with research on fintech innovations and financial risks of systemically

important Chinese banks, which showed that risk initially increases but then decreases as technologies develop [33]. Analysis of Russia's banking sector also showed that digitalization contributes to profit growth in the long term, although profitability temporarily declines during incomplete stages of implementation [34]. Results from Indonesian banks [7] demonstrated that long-term profits from business growth and improved process efficiency outweigh costs associated with new digital IT infrastructure; however, the positive impact manifests only upon reaching a certain level of DT intensity.

Some studies indicate that DT may not have a significant positive impact on company performance despite substantial investments in digitalization [35] or may even produce negative effects [36].

No consensus has been reached regarding the impact of DT on bank risk levels and stability. Analysis of bank performance in 29 Asian countries [37] showed that DT is beneficial only for banks with low diversification: investments in digital technologies with increased diversification increase banks' vulnerability. In [24], results indicate that DT significantly reduces credit risk but has virtually no effect on liquidity risk.

In Russian academic publications, the relationship between the SDI360 digital maturity index and banks' financial performance has been examined repeatedly. A high-ranking position positively affects market and investment attractiveness [38, 39]. At the same time, according to [40], there is no statistically significant relationship between ranking position and capitalization level (correlation coefficient of only 0.07), leading to the conclusion that an alternative indicator is needed.

In the vast majority of studies, panel data regression methods were used for quantitative assessment. The methodology of several key studies is summarized in Table 6.

Table 6. Methods for Assessing the Impact of Digital Transformation on Bank Efficiency

N	Independent Variable	Dependent Variable	Estimation Method	Sample	Period
1	DT Index [25]	ROA	Unbalanced panel FE regression (OLS)	279 banks, 27 EU countries	2017-2022
2	Peking Univ. DT Index [14]	ROA; Net interest margin; Cost-to-income ratio	Panel FE regression (OLS)	200 commercial banks, China	2010-2018
3	Peking Univ. DT Index [32]	ROA	Panel FE regression (OLS)	54 rural commercial banks, China	2010-2021
4	Log of DT expenditure [7]	Profit	ARDL panel model (short-term and long-term effects)	7 digital banks, Indonesia	2016-2023
5	ICT Index [24]	Credit risk; Insolvency risk; Liquidity risk	Panel regression (OLS, corrected standard errors)	26 commercial banks, Vietnam	2013-2022

4. CONCLUSIONS

Digital transformation in the banking sector remains a conceptually heterogeneous notion; however, in most scientific studies it is interpreted as a complex, multi-level process of modernizing business models, operational processes, product offerings, and data management approaches under the influence of digital technologies.

The conducted review shows that composite indices designed for comprehensive assessment of bank DT levels have been actively developed in recent years. At the same time, the indicators and data sources used vary significantly, reflecting the multidimensional nature of DT but simultaneously limiting the comparability of empirical results.

Analysis of works devoted to the impact of DT on banking efficiency does not allow for unambiguous conclusions. Along with results confirming positive effects through cost reduction, operational activity growth, and improved customer service, short-term negative effects are identified, associated with high investment and organizational costs at early transformation stages. Results of individual studies demonstrate the absence of statistically significant DT impact or even negative effects. Furthermore, assessment is complicated by DT's complex and difficult-to-formalize nature. Methodologies focusing primarily on technological aspects do not fully account for institutional, organizational, and strategic dimensions of transformation processes.

In this regard, the methodological contribution of this paper lies in the systematization of existing approaches to measuring bank DT and the justification for developing an integrated index that accounts for the multi-faceted nature of digital changes. The presented results form a methodological foundation for subsequent empirical studies aimed at constructing such an index and assessing its impact on indicators of profitability, efficiency, and stability of banking operations.

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