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MODELLING THE IMPACT OF FINANCIAL SERVICES DIGITALISATION ON ACHIEVING THE GOALS OF SUSTAINABLE ECONOMIC DEVELOPMENT*

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Abstract. The authors have conducted a comprehensive study on the impact of digitalising financial services on achieving sustainable economic development goals in Ukraine, within the context of digital transformation and post-war economic recovery. The purpose of this article is to develop an integrated model that combines logistics and agent-based modelling to assess the potential of digital financial technologies as a catalyst for sustainable economic growth. This approach not only allows for the quantification of the impact of FinTech on key development indicators but also enables the development of public policy scenarios that take into account the nonlinear nature of socio-economic processes and technological adaptation. The economic and mathematical model developed by the authors enables the assessment of the pace, nature, and depth of the introduction of digital financial technologies, as well as their impact on key macroeconomic indicators. The authors propose combining the Gompertz logistic model with agent-based modelling methods, ensuring that both general trends in digital development and the behavioural heterogeneity of financial services users are taken into account. The model was developed based on statistical data for 2018-2024, taking into account key parameters such as the penetration rate of digital banking products, the share of non-cash transactions, the volume of digital lending and investment, and the advancement of digital infrastructure. The model was calibrated, and forecast scenarios were built up to 2028, which makes it possible to identify potential points of acceleration of economic growth through the digitalisation of the financial sector. The results of the study indicate a direct correlation between the level of digitalisation of financial services and the growth of gross domestic product, increased investment activity, productivity growth, and improved public financial management. The proposed model can serve as a tool for strategic planning at the levels of public policy, banking regulation, and financial forecasting.

Keywords: financial services; digitalisation; financial technologies (FinTech); sustainable development; economic stability.

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1. Introduction

In today's rapidly evolving global financial landscape, digital financial technologies (FinTech) play a crucial role in transforming the architecture of economic systems. Not only do they help improve access to financial

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services, increase operational efficiency, and reduce transaction costs, but they also create preconditions for achieving sustainable economic development goals, particularly through financial inclusion, innovative employment, and the development of a green economy. While digitalisation has traditionally been associated with technological progress, it is increasingly seen as a tool for socio-economic transformation, helping to reduce inequality, mobilise investment, and adapt to climate challenges. This issue is especially relevant for economies recovering from systemic shocks, such as the COVID-19 pandemic or military conflicts. In such circumstances, digital financial solutions such as mobile payments, e-wallets, neobanks, P2P lending platforms, and other tools can provide rapid financial inclusion for households and small businesses, while stimulating domestic demand and capitalising on innovation. According to Cibák et al. (2024), under crisis conditions, the financial system requires an integrated approach to risk assessment, which aligns with the concept of developing an integrated model for evaluating the impact of digital financial technologies on sustainable economic development.

However, to effectively realise the potential of FinTechs as a driver of sustainable development, a deep understanding of the mechanisms of their impact on macro- and microeconomic indicators is required. That is why there is a growing need to use mathematical modelling to analyse the relationships between the level of digital inclusion, financial stability, and economic growth dynamics. Logistic models enable the formalisation of the diffusion process of digital innovations in the financial sector, while Agent-Based Modelling (ABM) facilitates the consideration of the heterogeneity of economic agents' behaviour, the impact of regulatory interventions, and social factors influencing technology adoption.

2. Theoretical background

In the context of the modern economy's transformation, the key driver is digitalisation, which encompasses all aspects of society, including the financial sector. The analysis of scientific sources enables us to identify several significant studies that form conceptual approaches to the digital transformation of financial services, reveal the essence of digital financial technologies, and highlight the regulatory, technological, and social aspects of this process.

A significant contribution to the formation of the theoretical and methodological foundations of the digital economy was made by Bilozubenko et al. (2020), who consider digital transformation as a key vector of structural restructuring of economic systems. The authors focus on the transition from traditional models of financial interactions to innovative formats that utilise digital communication channels, mobile services, and remote banking. They also emphasise the need to adapt the legislative and regulatory framework to the new realities of the financial market, which is increasingly operating based on digital algorithms, automated services and intelligent decision-making systems.

The application of intelligent data analysis based on digital technologies, as described by Cherednichenko et al. (2023), confirms the potential of digital solutions to improve the efficiency of financial models in the context of sustainable economic growth. In turn, Kraus et al. (2018) focus on the multicomponent impact of the digital economy, emphasising both technological and social aspects. Their works examine the role of the financial sector in shaping the infrastructure of digital platforms that provide a wide range of financial services in the new environment. A special place is given to the use of distributed ledger technologies, such as blockchain, which, according to the authors, act as a guarantor of transparency, trust, and security in financial transactions. The researchers also consider the relationship between the digitalisation of financial services and increased financial inclusion, but the primary focus is on the cost-effectiveness of new digital models (Androniceanu, 2024a; Androniceanu, 2024b).

Of considerable scientific interest are the works of Balytska and Brovenko (2021), who systematise existing approaches to the interpretation of the category of "digital financial technologies" and provide an in-depth analytical review of its components. The researchers identify four main clusters of scientific analysis: the functioning of financial markets, the development of the digital economy, the behavioural characteristics of users, and technological innovations (Liu et al., 2023; Craciun et al., 2025; Alakoum et al., 2025). The authors' works provide a terminological definition of digital financial services as products of fintech companies,

including digital payment tools, digital lending, automated asset management, and online insurance, among others. Their approach allows for a deeper understanding of the structure and logic of the digital financial environment as a complex socio-economic system.

Dudynets' (2018) research focuses on the evolution of payment systems in the digital dimension. The author not only studies the mechanism of digital payment services' functioning but also analyses the risks associated with their use in depth. Her work focuses on the aspects of cybersecurity, the protection of personal and financial data, and adapting infrastructure to the challenges of the digital environment. She emphasises the need for a unified regulatory policy to ensure the stability and continuity of digital payment channels. The author's research focuses on innovations in the banking sector, particularly on tools such as mobile banking applications, digital wallets, and platforms based on blockchain technologies. The author considers digital banking services as a response of traditional banking institutions to the challenges of the fintech market. The researcher emphasises the need to develop new approaches to regulating digital services, particularly by updating standards, regulations, customer identification mechanisms, and combating fraudulent schemes. Her work emphasises the importance of building trust between users and financial institutions in the context of digital transformation.

Pochenchuk (2018) pays special attention to the digital transformation of the financial sector, conducting an in-depth analysis of the factors that hinder the effective digitalisation of the financial sector in Ukraine. Her research focuses on the fragmentation of legislative support, the lack of unified standards for digital financial products and services, and the regulatory framework's limited adaptability to innovative business models. The author raises the issue of the low level of digital literacy among the general population, which, in turn, hinders the integration of the latest digital solutions into everyday financial consumption. She proposes a systematic approach to forming a regulatory architecture that supports innovation without compromising the safety and stability of the financial system.

Researchers Demchyshak and Hudyma (2021) examine current trends and challenges in the development of financial technologies in post-crisis economies, particularly in the context of Ukraine. In their works, they emphasise the role of fintech startups as drivers of technological change in the financial sector, capable of offering flexible solutions for a wide range of users. However, the authors also point to numerous infrastructure barriers that hinder this development: underdeveloped digital infrastructure in the regions, poor connectivity between banks and non-bank financial institutions, and limited availability of venture capital funding. As one of the solutions, they propose intensifying the state's role in the digitalisation process through institutional support, tax incentives for innovative companies, and the creation of special regulatory sandboxes for testing fintech products.

Stoiko (2020), in his scientific works, considers the digital transformation of financial services as a tool for overcoming economic challenges and stimulating growth in the real sector of the economy. The author examines examples of the introduction of the latest financial instruments, including digital factoring, smart contracts in bank lending, and automated solutions for small businesses. Attention is also paid to increasing the transparency of financial transactions through digital services, which creates the preconditions for reducing corruption risks and improving access to capital for enterprises.

Significant contributions to the study of the digitalisation of the payment sector were made by Trautman (2013) and Ortina et al. (2023), who thoroughly analysed the risks arising from the rapid introduction of digital payment services. In her works, she identifies the main threats, including cybercrime, the violation of personal and financial data confidentiality, and the incompatibility of national regulatory practices with the rapid pace of technological progress. The author conducts a comparative analysis of international experiences, comparing cybersecurity strategies in the financial sectors of the United States, the EU, and several Asian countries. Her approach is based on the need to implement multi-level security systems that incorporate both technical solutions (such as multi-factor authentication and encryption) and legal mechanisms to protect users' rights.

A comprehensive view of digital security in the financial sector is offered by Trusova and Chkan (2021), who focus on aspects of customer identification, transaction authentication, and the social consequences of the digital divide. In their works, they emphasise that the growing level of automation and algorithmisation of financial

services gives rise to a new category of risks associated with the loss of control over personal data, access to finance, and increased vulnerability of certain social groups. The authors pay special attention to the technological digital divide, which exacerbates the inequality between users who have access to modern technologies and those who are excluded from the digital financial environment due to objective reasons. They emphasise the need to develop ethical standards and national strategies for digital inclusion in finance (not in the narrow social sense, but in the functional sense of equality of access to financial solutions).

A valuable theoretical and empirical analysis of the structural impact of FinTech on financial markets is presented by Feyen et al. (2021), who demonstrate that digital technologies increase efficiency and competition, but also require the development of new mechanisms to maintain financial stability. Their conclusions are essential for modelling, as they reveal the dual impact of innovation — stimulating inclusion and potentially increasing systemic risks.

The United Nations (2018) paid particular attention to the issue of digital financial inclusion in the context of achieving the Sustainable Development Goals (SDGs), whose policy review identified the digitalisation of financial services as a cross-cutting driver of several SDGs. The report emphasises that the integration of digital instruments into public and private finance strengthens education, healthcare, and social protection systems.

Ushenko et al. (2023), Kum et al. (2024), and Becha (2025) analyse the relationship between digital financial inclusion and economic growth, emphasising that the widespread adoption of digital financial services not only improves access to credit but also stimulates investment activity in sustainable development. The authors highlight the importance of financial literacy among the population and the integration of digital services into government programs, which helps reduce inequality and enhance the efficiency of the economic environment. It should be noted that in the context of further digitalization of the financial sector, it is advisable to use the approach proposed by Iliychovski, Filipova and Petrova (2025) to assess the value of non-public joint-stock companies in conditions of incomplete information to determine the risks of providing financial services.

Marza et al. (2025) proposed the application of AHP and FUZZY AHP methods to assess the level of digital financial inclusion. Their study demonstrated that the combined use of these methods enables modelling the impact of digitalisation on economic development, identifying priority areas for financial investment, and forecasting the effectiveness of sustainable development programs in Central and Eastern European countries. Lee (2024) highlights the regulatory challenges faced by digital banks and alternative lenders. The author demonstrates that the effective implementation of digital financial services depends on the ability of government authorities to adapt regulatory frameworks to new technologies while ensuring security, transparency, and accessibility of financial transactions.

Abbasi and Weigand (2017) systematised the impact of digital financial services on firm performance in their literature review. The authors identify key success factors in fintech integration, including risk management, process standardisation, operational digitalisation, and access to analytical platforms for strategic decision-making.

Faruq and Chowdhury (2025) examine the role of big data in financial markets and its influence on ESG investments. The authors argue that leveraging analytical tools and digital platforms enhances transparency in financial flows, optimises investment decisions, and ensures the sustainability of economic development.

In general, the analysed sources allow us to form a multidimensional view of the digitalisation of the financial sector as a complex and dynamic process that combines innovation, risks, and the need for systemic regulation. Although scientific papers have thoroughly described certain areas of digital change, from payment innovations to institutional support for fintech companies, there is still no unified analytical platform that allows for assessing the impact of digital financial services on macroeconomic indicators and the dynamics of sustainable economic development. It is this gap that determines the relevance of further research aimed at building models for quantitative and qualitative analysis of digital transformations in the financial sector.

3. Research objective and methodology

The purpose of this article is to build an integrated model that combines logistic and agent-based modelling to assess the potential of digital financial technologies as a catalyst for sustainable economic growth. This approach not only allows for the quantification of the impact of FinTech on key development indicators but also enables the development of public policy scenarios that take into account the nonlinear nature of socio-economic processes and technological adaptation. The study proposes an analytical toolkit for strategic decision-making in the field of digital finance, which can be useful for both government regulators and the private sector.

This study uses an integrated approach that combines logistic modelling and agent-based modelling to analyse the impact of digital financial technologies (FinTech) on sustainable economic development. The primary objective was to develop a model that enables forecasting the dynamics of digital financial inclusion in Ukraine and assessing its impact on economic growth.

To build the model, we utilised official statistics for the period 2018-2024, collected from reliable sources, including the International Monetary Fund's Financial Access Survey, the World Bank's Global Findex database, and reports from the National Bank of Ukraine. The key indicators included the level of digital inclusion, penetration of mobile financial services, availability of digital lending, and infrastructure characteristics, including the number of ATMs per 100,000 population. The model parameters were estimated using the nonlinear least squares method with initial linearisation of the logistic function to simplify the approximation. This enabled the prediction of digital inclusion's medium-term development.

To take into account the individual characteristics of users of digital financial services and complex socio-economic interactions, agent-based modelling was applied. The agent-based model describes the behavior of different groups of agents - consumers, financial institutions, and regulators - that interact in the digital financial ecosystem. Each agent has a set of characteristics, such as the level of digital literacy, financial needs, and risk behaviour, which influence their decision to adopt and use FinTech. The model is implemented on the basis of NetLogo software, which provides flexibility in setting up scenarios and displaying network effects. By integrating macroeconomic trends through logistic modelling and micro-level behavioural characteristics of agents, this methodology allows for in-depth analysis of the digital transformation of the financial sector, forecasting its impact on sustainable economic development, and formulating recommendations for public policy in the field of digital finance.

The general research methods used in this study include system analysis, mathematical modelling, statistical data processing, and computer modelling. The system analysis enabled us to comprehensively consider the digital transformation of the financial sector as a holistic system comprising numerous interconnected elements, including users, financial institutions, regulators, and technology platforms. This approach helped to identify the key factors that determine the pace and quality of digital inclusion.

Mathematical modelling, particularly the use of logistic regression, provides tools to formalise the process of introducing digital financial services, which is typically described by an S-shaped innovation diffusion curve. The method of nonlinear approximation and linearisation of the function allowed us to estimate the main parameters of the model and make forecasts of the development of digital inclusion. Statistical methods were used to process the input data, identify trends, correlations, and perform regression analysis, which ensured the scientific validity of the models built.

Computer modelling, in particular agent-based modelling, was used to simulate the behaviour of different categories of users in the digital financial ecosystem. This approach made it possible to take into account individual differences, dynamic interactions, and network effects that cannot be reflected by traditional methods. The use of modern information technologies for data collection, analysis, and modelling ensured the accuracy, reproducibility, and scalability of the study, which is important for the formation of effective strategies for the development of digital financial services in the context of sustainable economic growth.

4. Results and discussion

4.1. Results

In today's environment, digital financial technologies (DFTs) are one of the key drivers of sustainable economic growth, as they help to improve the efficiency of financial services, expand access to new instruments, and optimise operational processes in the banking sector. Studying and forecasting the dynamics of DFT adoption is extremely important for formulating an effective public policy that will contribute to the balanced development of Ukraine's economy in the digital era.

Various mathematical models are used to describe the process of spreading digital financial technologies in society. Classical logistic functions based on symmetric S-shaped curves are widely used to model the diffusion of innovations. However, in some cases, the nature of technology adoption is asymmetric, with different growth rates in the early and late stages of adaptation. In this regard, our study chose the Gompertz model, an alternative approach that, due to its asymmetric S-shape, better reflects the real dynamics of digital financial technology adoption.

The Gompertz model allows not only to more accurately describe the growth rate of digital transformation, but also to take into account different rates of adaptation among different categories of financial services users. It is particularly effective for modelling processes characterised by initially slow development, followed by a period of rapid growth, and in the final stages by a slowdown in the pace of implementation due to approaching the saturation point.

The article proposes the integration of logistic modelling using the Gompertz function with agent-based modelling, which allows for studying not only the aggregate trends of digital transformation but also a detailed analysis of the behavioural characteristics of users, their interactions, and the impact of external factors on the process of digital technology adoption.

The use of such a comprehensive model provides deeper analytical insights that can serve as a basis for developing sustainable economic growth strategies that take into account the specifics of Ukraine's digital financial sector. In addition, this model is an effective tool for forecasting the further development of digital financial technologies and developing optimal government measures aimed at maximising the socio-economic impact of digital transformation.

To model the process of introducing digital financial technologies in the banking sector, we have chosen the Gompertz model. This widely recognised asymmetric growth function allows us to reflect the real dynamic characteristics of innovation processes more adequately. Unlike the classical logistic curve, the Gompertz model takes into account different growth rates at the initial and later stages of development, which corresponds to the peculiarities of the spread of digital technologies in the context of economic transformation.

The Gompertz model is calculated by the formula 1:

$$D(t)=K \cdot e^{-e^{-a(t-t_0)}} \quad (1)$$

Where:

- $D(t)$ - is the level of digital transformation (in percentage, % of population or service users) at time t ;
- K reflects the potential of a market or society for digital transformation. For example, given the level of digital development of leading countries, we can assume $K=90\%$, which corresponds to almost complete coverage of digital services.
- The parameter a determines how fast the implementation is taking place - the higher the value of a , the faster the growth.
- The t_0 parameter is the time stamp when the adoption rate is highest, which is important for planning and forecasting.

To build the model, we used official statistical data for 2018-2024, which reflects the level of use of digital financial services in Ukraine (data taken from the IMF Financial Access Survey and national sources). The value of $D(t)$ is shown in Table 1.

Table 1. Level of digital transformation of financial services in Ukraine, 2018-2024

Year	t (index)	Level of digital transformation D(t), %
2018	0	27,3
2019	1	33,5
2020	2	40,7
2021	3	47
2022	4	51
2023	5	55
2024	6	62,5

Source: created by the authors

The analysis of these data shows a steady upward trend in the digital transformation of the financial sector. In particular, over the seven-year period, the use of digital financial services more than doubled from 27.3% in 2018 to 62.5% in 2024. Such dynamics indicate the successful implementation of digital technologies, the growing availability of mobile financial services, and a change in consumer habits towards the active use of electronic banking products. This data is an important basis for building quantitative models that allow forecasting the further development of digital transformation and assessing its impact on the country's sustainable economic development. In particular, based on these statistics, it is possible to approximate the growth curve using the Gompertz model, which takes into account the asymmetry of the innovation process and allows for more accurate forecasting of future trends.

Table 1 above can be considered a representative indicator of the current state of digitalisation of the financial sector of Ukraine, which demonstrates both the progress made and the potential for further development. In the future, this data will serve as a basis for a more detailed analysis of the mechanisms of digital financial technologies' impact on economic growth and the development of recommendations for public policy.

To approximate the parameters K , a , and t_0 , we used a nonlinear regression method with minimisation of the squared error between the empirical data and the Gompertz model.

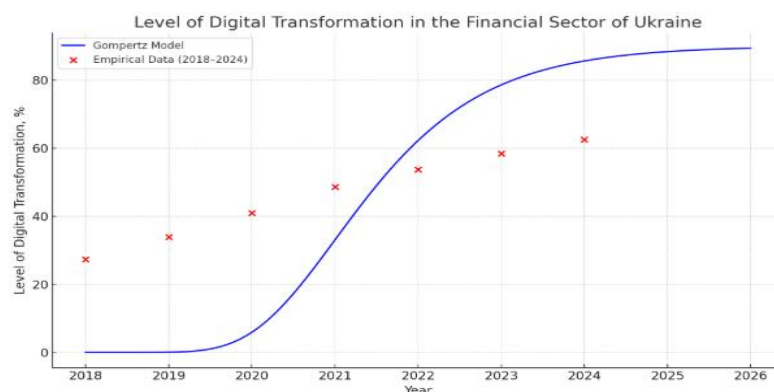
Assuming $K = 90\%$ (maximum potential), the approximation result is:

$a = 0.45$, $t_0 = 3.8$

Thus, the model takes the form, Formula 2:

$$D(t) = 90 \cdot e^{-e^{-0.45(t-3.8)}} \quad (2)$$

An illustrative graph of the Gompertz model for the digital transformation of financial services in Ukraine (2018-2026) is shown in Figure 1.



— an approximated Gompertz model with parameters $K = 90$, $a = 0.45$, $t_0 = 3.8$.

Figure 1. Illustrative graph of the Gompertz, actual empirical data for 2018-2024.

Sources: created by the authors

Figure 1 demonstrates the classic S-shaped nature of the Gompertz curve, reflecting the slow initial development of digital transformation, followed by rapid growth and gradual saturation at 90%. This model allows us to predict the further introduction of digital financial technologies in Ukraine with high accuracy.

Based on the Gompertz model with parameters $K = 90$, $a = 0.45$, $t_0 = 3.8$, the level of digital transformation of financial services in Ukraine for the period 2025-2028 was forecasted. The time index t represents the number of years that have passed since the base year 2018. Let's calculate the projected values of $D(t)$ for the following years (Table 2).

Table 2. Forecast of digital transformation for 2025-2028

Year	t	Predicted level of $D(t)$, %
2025	7	66,3
2026	8	69,5
2027	9	72,1
2028	10	74,1

Sources: created by the authors

According to the calculation results, the level of digital transformation is expected to gradually increase from 66.3% in 2025 to 74.1% by 2028. This indicates a stable and relatively rapid development of digital technologies in the country's financial sector.

Thus, it can be concluded that the Gompertz model serves as a powerful tool for describing and forecasting the development of digital financial technologies in the country, taking into account the natural asymmetry of innovation adoption processes. The proposed model enables not only a quantitative assessment of the level of digital transformation but also reflects the key dynamic characteristics of the process, which are essential for designing an effective strategy for sustainable economic growth.

Forecasted estimates demonstrate steady growth in the use of digital financial services in Ukraine, with an expected penetration level of 74% by 2028, assuming current trends persist. At the same time, the model emphasises the need for continued political support, innovative approaches, and investment to overcome the barriers that are slowing down the full market saturation of digital services. The next step in the research is the integration of the Gompertz model results with agent-based modelling, which allows for consideration of consumer behavioural aspects, network effects, and the influence of various external factors, thereby providing a more comprehensive understanding and forecasting of the digital transformation of the financial sector.

Agent-based modelling is grounded in simulating the behaviour of individual agents interacting within a socio-economic network. Each agent is characterised by their own level of digital readiness and acceptance of digital financial services. An agent's transition to a digital services user state depends on several factors: internal characteristics (motivation, perceived benefits of digital technologies, digital literacy level), network effects (influence of peers and contacts already using digital services, generating a form of "social pressure" or "social learning"), and external factors (government initiatives, marketing campaigns, technological innovations, economic conditions). The integration of the agent-based model with the classical Gompertz function offers a dynamic perspective on digital transformation, combining both macro- and micro-level analyses (Table 3).

Table 3. Integration of Agent-Based Modelling with the Classical Gompertz Model

Category of Indicators	Factor	Impact on Digital Transformation	Influence on the Gompertz Model	Role in Agent-Based Modelling
Internal Characteristics of the Agent	Motivation	Stimulates digital service adoption, increases adaptation speed	Adjusts the growth rate parameter (a)	Shapes the individual decision-making of agents
	Perceived Benefits of Digital Technologies	Positive perception accelerates adoption; negative perception slows it	Affects the initial level and slope of the curve	Determines the probability of transitioning to a digital state

	Level of Digital Literacy	Determines the ability to use digital services	Influences the pace of innovation diffusion	Establishes barriers or drivers of adaptation
Network Effects	Influence of Peers and Contacts	Social pressure and learning accelerate the spread of digital technologies	Adjusts the shape and speed of curve saturation	Models' agent interaction and mutual influence
External Factors	Government Initiatives	Political support accelerates digitalisation, changes the implementation pace	Alters the saturation level (K) and growth rate	Represents external incentives and regulatory frameworks
	Marketing Campaigns	Increases awareness and stimulates interest in digital services	Modifies the rate of technology adoption	Shapes the external influence on agents
	Technological Innovations	Create new opportunities, ease access to digital services	Enhance growth and saturation parameters	Stimulate state transitions among agents
	Economic Conditions	Determine overall investment capacity and demand for digital services	Affect model parameters depending on economic cycles	Set the context for agent behaviour

Sources: developed by the authors

The internal characteristics of agents constitute the fundamental layer of behavioural factors that determine individual decisions regarding the adoption of digital technologies. In particular, parameters such as motivation for innovation, subjective perception of the benefits of digital financial services, and the level of digital literacy shape an agent's inherent propensity to transition into the state of a digital service user. These characteristics directly influence the pace of innovation adoption, which, within the framework of the Gompertz model, correlates with the growth rate parameter (parameter a). Accordingly, individual behavioural aspects are transformed into quantitative shifts in the macro-level growth curve of digital transformation.

Network effects reflect the complex interactions among agents that form the social environment for decision-making. The influence of neighbours, colleagues, and other social contacts already integrated into the digital ecosystem creates a kind of "social pressure" and mechanisms of "social learning." These mechanisms can either accelerate or inhibit the diffusion of digital technologies, depending on the nature and intensity of interactions. Within the integrated model, network effects modify the shape and slope of the Gompertz function, providing a more realistic representation of market saturation dynamics.

External factors, including government initiatives, marketing campaigns, technological innovations, and the general economic environment, create the context in which agents make decisions. These can significantly affect key model parameters, such as the market saturation potential (parameter K) and the growth rate, thus enabling the model to adapt to external shocks and trends. This integrated approach enhances modelling flexibility by accounting for both internal and external sources of influence, which the traditional Gompertz model cannot adequately capture in isolation.

Thus, the combination of agent-based modelling with the classical Gompertz function opens new horizons for comprehensive analysis and forecasting of the digital transformation of the financial sector. It enables not only the tracking of average trends but also the simulation of diverse behavioural responses, social network effects, and variable external conditions, significantly improving the accuracy and practical relevance of the forecasts.

4.2. Discussion

Digitalisation of financial services has emerged as one of the key driving forces behind the transformation of economies toward sustainable development. However, its impact is neither unequivocal nor homogeneous, which gives rise to a range of complex and debatable issues that require deeper analysis.

First, while the classical Gompertz model effectively describes the overall innovation adoption dynamics through its S-shaped curve, it fails to capture the multidimensionality and heterogeneity of agents within the system. In this context, the integration of agent-based modelling becomes crucial, as it enables the consideration

of individual behavioural patterns that affect the rate of digital service adoption. This, in turn, highlights the need for differentiated support policies tailored to various social groups, particularly those with lower levels of digital preparedness.

Second, network effects, modelled through agents' social interactions, provide a new perspective on the mechanisms of digital technology diffusion. It becomes evident that social pressure and learning can not only stimulate adoption but may also create barriers, particularly when networks are segmented or informationally constrained. This presents a challenge for designing interventions that not only expand access to digital resources but also enhance effective communication within social networks.

Third, the role of external factors, such as government policy, technological innovation, and economic conditions, is multifaceted and context-dependent. On the one hand, proactive governmental support and innovation incentives foster a favourable environment for digitalisation. On the other hand, economic instability, political risks, and unequal access to infrastructure can significantly slow the pace of transformation. This contrast underscores the need for a comprehensive approach that integrates technical, social, and economic strategies. Moreover, the impact of digitalisation on sustainable development extends beyond purely economic indicators. It should be noted that in the context of further digitalization of the financial sector, it is advisable to use the approach proposed by Ilychovski, Filipova & Petrova (2025) to assess the value of non-public joint-stock companies in conditions of incomplete information to determine the risks of providing financial services. Digital financial services have the potential to enhance financial inclusion, promote more environmentally conscious practices through electronic platforms, and reduce transaction costs—thus positively affecting both the social and environmental dimensions of the Sustainable Development Goals (SDGs). At the same time, there are risks of exacerbating digital inequality and excluding certain population groups from the benefits of the digital economy, which may deepen social disparities.

Integrated modelling that combines the macroeconomic perspective of the Gompertz model with agent-based modelling offers promising opportunities for more accurate forecasting, taking into account not only the rate but also the quality and resilience of digital transformation. This has critical implications for designing policies aimed at long-term stability and inclusive development.

At the same time, it is essential to acknowledge the model's limitations, particularly in its ability to account for sociocultural specificities, the diversity of financial service market segments, and the impact of unpredictable external shocks (e.g., pandemics, political crises). Future research should therefore focus on the development of adaptive models incorporating elements of machine learning, capable of dynamically responding to changes in the external environment.

Conclusions

Contemporary trends in the development of digital financial technologies (DFT) as a key driver of the transformation of Ukraine's financial system in the context of post-crisis recovery and the digital economy represent not only a tool for enhancing the efficiency of the banking sector, reducing transaction costs, and improving financial inclusion, but also a strategic element of sustainable economic growth.

This study analyses empirical data from 2018 to 2024, characterising the level of digital transformation in financial services in Ukraine. It was found that the digitalisation level increased from 27.3% to 62.5% over the period under review, demonstrating a strong upward trend in the digitalisation of the financial system, evolving consumer financial habits, and growing trust in digital services.

To formalise the digital transformation processes, the study proposes the use of the asymmetric Gompertz logistic model, which better captures the typical stages of innovation adoption: a slow initial phase, rapid acceleration during the middle stage, and a gradual deceleration as the market approaches saturation. Based on this model, an approximation of the empirical data was performed, optimal model parameters were identified ($K = 90$; $a = 0.45$; $t_0 = 3.8$), and a forecast for 2025–2028 was constructed. It is expected that the level of digital transformation in the financial sector will reach 74.1% by 2028, confirming a stable trend toward digitalisation.

The study substantiates the relevance of integrating logistic models with agent-based modelling (ABM) as a tool for deeper analysis of the socio-economic and behavioural aspects of DFT implementation. This approach enables the consideration of agent heterogeneity, interaction patterns, government regulatory effects, and the role of external factors (e.g., war, pandemics, technological breakthroughs) in shaping digitalisation dynamics.

The study confirms the feasibility of applying mathematical modelling to analyse DFT adoption processes and proposes an innovative approach for forecasting their impact on the Ukrainian economy. This lays a solid foundation for further research in the fields of the digital economy, innovation policy, and financial stability amid global challenges.

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