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INNOVATIVE TRENDS OF FINANCIAL ENGINEERING TO THE WAY OF DIGITAL ECONOMY

ABSTRACT

The modern world is undergoing rapid and profound changes driven by the rapid development of digital technologies that are affecting all aspects of economic life. The transition to a digital economy is becoming increasingly evident, creating new opportunities and challenges for various sectors, including the financial industry. Financial engineering, as a discipline that combines finance, mathematics, statistics, and information technology, is a key tool in shaping modern financial strategies and products. In this context, it is important to explore the innovative trends that determine the development of financial engineering in the digital economy. This article aims to explore the latest trends in financial engineering that contribute to the transition to the digital economy. Particular attention will be paid to analyzing the impact of digital financial instruments on global markets and the role of financial institutions in the new digital environment. The study of these aspects will not only help to understand the current transformation processes but also to predict further directions of financial engineering development and its impact on the digital economy. This, in turn, will help to develop more effective strategies for managing financial risks and opportunities in the new environment, ensuring the sustainable development of the financial system and the economy as a whole. The digital economy is fundamentally changing the way financial markets and businesses operate. This article explores the main innovative trends in financial engineering that contribute to the emergence and development of the digital economy. Also, the prospects and challenges associated with the implementation of these technologies are discussed.

Keywords: FinTech, financial innovation, financial sector, financial forecasting, financial markets, development; challenges

JEL Classification: G17, O47, E44

INTRODUCTION

The transition to a digital economy is accompanied by significant changes in the financial sector. Innovations in financial engineering play a key role in this process, ensuring the efficiency, transparency and accessibility of financial services. In today's world, the rapid evolution of digital technologies is significantly changing the economic landscape, creating new opportunities and challenges for financial markets. Financial engineering, as one of the key disciplines of finance, plays an important role in ensuring the adaptation and implementation of innovative solutions in this new digital context. Innovative trends in financial engineering pave the way for more efficient use of financial resources, risk optimisation, and the creation of new financial products that meet the needs of the digital economy.

The field of financial engineering is rapidly evolving, driven by the pervasive influence of digital technologies. This transformation is reshaping the traditional landscape of finance, giving rise to innovative trends that are integral to the digital economy. As such, it is imperative to understand the key objectives guiding research and practice in this domain.

LITERATURE REVIEW

The study of innovative trends in financial engineering on the way to the digital economy is relevant and requires a comprehensive analysis of modern approaches and technologies that affect the financial industry in the context of digitalisation. For this analysis, a number of sources were selected that cover various aspects of financial engineering and innovative technologies in the financial sector.

For example, Chen et al. (2022) highlight the importance of artificial intelligence and machine learning in modern financial engineering, which is a key element of the digital economy. Ferilli et al. (2024) demonstrate how fintech innovations contribute to improving financial literacy, which is an important aspect of the digital economy. Forrer&Forrer (2014) focus on the dynamics of financial innovation depending on economic conditions, which is important for understanding financial engineering trends. Friess et al. (2024) show how digital technologies are changing financial transactions in the B2B sector, which is part of the broader process of digitalisation of the economy. Khalatur et al. (2017, 2020, 2021, 2022, 2023) illustrate how innovation and digital technologies can be used to improve the stability and efficiency of the financial sector in different contexts, including crisis situations.

Miao & Run (2020) analyse the risks associated with innovation in the financial sector, which is critical for the stability of the digital economy. Murinde et al. (2022) highlight the opportunities and risks associated with fintech innovation, which is central to the digital transformation of the financial sector. Nkem & Akujinma (2017) examine the impact of e-banking on bank efficiency, which is an important aspect of the digital economy. Savchenko et al. (2024) analyse the regional aspects of innovation, which is important for understanding the local characteristics of the digital economy. Zheng (2022) proposes a model that allows assessing risks in the digital economy, which is important for financial stability.

Shucui Wang, Yutong Song, Anna Min Du, Jia Liang and co-authors (2024) explore the relationship between the digital economy and entrepreneurial dynamics in China. Their findings indicate that the development of digital infrastructure and a favourable regulatory environment stimulate entrepreneurial growth. Ukraine can borrow these approaches to develop small and medium-sized businesses, which are the backbone of the economy and create new jobs. Supporting entrepreneurship in the context of digitalisation can be a key driver of economic growth. On the other hand, studies by Zijun Wang, Jialong Zhang, Yuanhang He, and Hancheng Liu (2024) point to the potential of the digital economy to reduce carbon emissions in the agricultural sector. For Ukraine, which has a significant agricultural potential, this study is extremely relevant. The introduction of digital technologies in agriculture can help increase productivity, optimise resources, and reduce environmental impact.

Wei Li, and Muhammad Nadeem (2024) investigate the relationship between the digital economy, renewable energy development and economic development in South America. Their findings highlight the importance of renewable energy investments in the context of digital transformation. For Ukraine, with its large green energy potential, this experience can be useful in developing strategies aimed at increasing energy security and resilience. Mohd Javaid, Abid Haleem, Ravi Pratap Singh, and Anil Kumar Sinha (2024) analyse the role of the digital economy in enhancing the Industry 4.0 culture, in particular through the introduction of innovative technologies in production processes. This study is important for Ukraine, which seeks to integrate into global production chains and modernize its industry. The introduction of digital solutions can significantly increase the competitiveness of Ukrainian industry in the global market. Rizwana Yasmeen, Tian Tian, Hong Yan, and Wasi Ul Hassan Shah (2024) examine the simultaneous impact of the digital economy, environmental technologies, and business activity on economic growth and the environment in the G7 countries. Their findings emphasize the importance of effective institutions to achieve synergies from the introduction of digital technologies. This study is an important benchmark for Ukraine, which needs institutional reform to ensure successful digital transformation and sustainable economic growth.

The analysed scientific literature reveals various aspects of innovative trends in financial engineering, emphasising the role of digital technologies in the transformation of the financial sector. These studies show that the introduction of innovative technologies, such as artificial intelligence, machine learning, fintech, and digital platforms, is a key factor in the development of the digital economy. In addition, they emphasise the need to consider risks and stability in the process of digital transformation of the financial sector.

AIMS AND OBJECTIVES

This article aims to contribute to a deeper understanding of the transformative power of financial engineering innovations and their critical role in shaping the future of the digital economy.

The primary objectives of this article are as follows:

1. Identify key innovative trends: to delineate and analyze the most significant innovative trends in financial engineering that are currently shaping and are expected to shape the digital economy.
2. Enhance strategic decision-making: to offer strategic guidance on leveraging these innovative trends to enhance decision-making, improve efficiency, and foster sustainable growth in the digital economy.

This article discusses modern innovative approaches to financial engineering that contribute to the transformation of traditional financial structures and processes. Special attention is paid to how these innovations help to solve the main problems related to the security, transparency and efficiency of financial transactions. The main purpose of the article is to explore and evaluate current and future trends in financial engineering, determine their impact on the development of the digital economy, and outline possible areas for further research and practical application.

METHODS

The methodology section of this article outlines the systematic approach employed to investigate the innovative trends in financial engineering within the context of the digital economy. This research integrates qualitative and quantitative methods to understand the subject matter comprehensively.

A mixed-methods research design was adopted to capture the complexity and multifaceted nature of financial engineering trends in the digital economy. This approach allows for data triangulation, enhancing the findings' validity and reliability.

Literature Review: A comprehensive review of existing literature was performed, focusing on academic papers, industry reports, and relevant case studies. This helped to identify prevailing trends, theoretical frameworks, and practical applications of financial engineering in the digital economy.

Market Analysis: Data from financial markets and reports from leading financial institutions were analyzed to understand current market trends and the role of digital technologies in financial innovation.

Content Analysis: Literature and secondary data were examined through content analysis to identify key trends, emerging technologies, and their implications for the financial sector.

Statistical Analysis: data were subjected to statistical analysis to quantify the prevalence of specific trends and the impact of digital technologies on financial engineering practices.

Trend Analysis: Market data were analyzed using trend analysis techniques to identify significant patterns and changes in financial engineering practices over time.

Triangulation: Data from multiple sources were triangulated to ensure the validity and reliability of the findings. This involved cross-verifying the information obtained from literature, and market analysis.

RESULTS

Fintech as a driver of digital transformation

It is clear that digitalisation is changing the way businesses and organisations do business. Digitalisation is not only affecting customers; it is also changing the way businesses operate internally. Businesses in all sectors are increasingly using artificial intelligence to map models and processes. At this level, digitalisation helps make services more efficient and convenient for customers.

But digitalisation is not just changing the internal workings of businesses. The entire market is changing. The wave of digitalisation has brought new competitors to the market, especially young and technologically strong companies. These companies often specialise in and compete in one element of the value chain. So, the value chain is being disrupted. It is clear that digitalisation is changing all sectors of the economy. Businesses and organisations need to respond to this if they want to operate effectively in the future. Businesses need to realise that it is not possible to control the new digital world and its risks with the same tools and at the same levels.

Digital change brings fundamental changes to the economy and society. New transformational approaches to solutions are needed to address the opportunities and challenges that come with them. Digitalisation, innovation trends, globalisation and demographic changes have far-reaching implications for the economy. A functioning financial system is an important

catalyst - it finances innovation, supports competition, helps protect against risks and - crucially - enables payment transactions.

However, the financial system itself is often affected by structural change. Digitalisation and technological change are affecting the core functions of financial intermediaries - receiving and processing information, and promoting growth and stability. At the same time, the competitive environment within the financial system itself is changing, with new providers entering the market and existing business models being challenged or made obsolete. More competition can ultimately lead to greater efficiency. However, increased competition in the financial sector can also have side effects and destabilize markets. Through digital innovation, smart regulation and governance, the financial system will not only become more efficient and more functional, but also more stable overall.

Despite the significant benefits, the introduction of innovative technologies in financial engineering is accompanied by certain challenges. These include security issues, regulatory barriers, insufficient infrastructure and lack of standardisation. Addressing these issues is key to the further development of the digital economy.

In today's globalised environment and the rapid development of digital technologies, financial engineering is becoming increasingly important for the economic development of countries. The study of innovative trends in this area allows us to understand which technologies and approaches contribute to successful digital transformation. This is especially important for countries seeking to improve their competitiveness in the global economy. This article analyses and compares innovative trends in financial engineering around the world in order to identify the most effective approaches and their applicability in Ukraine. Taking into account the different aspects of the digital economy, the study focuses on countries such as Poland, Estonia, Israel, Singapore, India, China and Finland. These countries were chosen because of their unique achievements and approaches in the field of financial technology, which could be useful for adaptation and implementation in the Ukrainian context. Table 1 presents the main reasons for selecting each country for comparison with Ukraine and outlines the key innovation trends observed in these countries. Studying these aspects will not only allow us to understand the current state of financial engineering development in different regions but also to identify the most promising areas for further development and innovation in Ukraine.

Table 1. Analysis and comparison of countries in the study of innovative trends in financial engineering in the digital economy.

Country	Reason for comparison with Ukraine	Innovative trends
Poland	A similar historical path of economic transformation, geographical proximity and common challenges on the way to the digital economy.	Poland is actively developing the fintech sector, investing in blockchain technologies, and developing new payment systems.
Estonia	A well-known example of successful digital transformation, with a high level of e-government and digital services implementation.	Implementation of e-citizenship, digital identification systems, and innovative financial solutions.
Israel	High level of innovation, especially in start-ups and financial technologies, and active government support for innovative projects.	Development of cybersecurity in the financial sector, investments in artificial intelligence and machine learning for financial solutions.
Singapore	One of the global leaders in the adoption of financial technologies, and regulatory initiatives to support fintech innovation.	Development of regulatory "sandboxes" for testing financial innovations, and introduction of blockchain and cryptocurrency technologies.
India	Rapid development of the digital economy, significant potential for fintech innovation, and a large domestic market.	Massive implementation of mobile payment systems, development of infrastructure for digital financial services, and innovations in microfinance.
China	The rapid development of the digital economy, large investments in technological innovations, and leadership in financial technologies.	The implementation of mobile payment systems, the development of financial platforms based on artificial intelligence, and the widespread use of blockchain.
Finland	Finland is actively introducing digital technologies into the economy and has a strong focus on financial innovation.	Current trends include blockchain technologies, artificial intelligence-based financial analytics, and automation of financial processes.

For further analysis, the following types of World Bank data were used: economic indicators, financial data, data on the digital economy, innovation and technological development, and socio-economic indicators. This data will help analyse the state and prospects of financial engineering in the context of the digital economy, identify key trends and challenges, and develop recommendations.

When studying innovative trends in financial engineering on the way to the digital economy, it is important to pay attention to access to financial services and investment in different countries. Table 2 provides a detailed overview of the key financial indicators for the countries under study for the period from 2003 to 2023. It includes information on financial account ownership, the use of banks for investment and working capital, as well as net financial accounts and investments

in non-financial assets. These data provide valuable insights into how countries at different levels of development are innovating in the financial sector and adapting to the demands of the digital economy.

Table 2. Access to financial services and investment, average for 2003-2023. (Source: authors' calculations based on World Bank data)

Country Name	Account ownership at a financial institution or with a mobile-money-service provider, % of population ages 15+	Firms using banks to finance investment, % of firms	Firms using banks to finance working capital, % of firms	Net financial account, current USD	Net investment in nonfinancial assets, % of GDP
Ukraine	60.11	24.58	20.90	-2919500000	0.63
Singapore	97.51	22.50	22.70	54355256195	-2.00
Poland	82.63	38.25	34.80	-8456350000	2.24
Estonia	97.97	31.86	25.30	-78903731	3.40
India	61.45	44.33	35.57	-32674136114	0.23
Israel	91.54	46.40	34.30	10704390000	0.60
China	77.75	14.70	22.10	147423518273	0.05
Finland	99.74	25.00	42.00	-5437941713	1.68

An analysis of Table 2 data on access to financial services and investment on average for the period from 2003 to 2023 shows various trends that are important for understanding innovative trends in financial engineering and the transition to a digital economy.

1. **Access to financial services:** the highest rates of population coverage by financial institutions are observed in Finland (99.74%) and Estonia (97.97%), which indicates a high level of financial inclusion in these countries. In countries such as Ukraine (60.11%) and India (61.45%), access to financial services is much lower, which may indicate a need to improve financial systems to facilitate access to services.
2. **Investment and working capital financing:** the level of bank usage for investment and working capital financing varies across countries. For example, Poland (38.25% for investment) and India (44.33% for working capital) show relatively high levels of bank use for financing, which may reflect the mature financial services infrastructure in these countries. In contrast, countries such as China (14.70% for investment) have a lower level of dependence on bank finance, which may be a sign of the greater influence of alternative sources of finance.
3. **Net financial account and investments in non-financial assets:** countries such as Singapore (USD 54.35 billion) and China (USD 147.42 billion) have positive net financial accounts, which indicates their positive financial balance and significant influence on global financial markets. At the same time, countries with a negative net financial account, such as Ukraine (USD 2.92 billion) and India (USD 32.67 billion), may face challenges in managing financial flows and maintaining economic stability.
4. **Investment in non-financial assets:** countries with high rates of investment in non-financial assets, such as Estonia (3.40% of GDP) and Poland (2.24% of GDP), demonstrate a high level of investment activity in fixed assets, which is a positive signal for economic development. At the same time, the low level of investment in non-financial assets in China (0.05% of GDP) may indicate a predominance of investment in financial assets or the need to further stimulate investment in the real economy.

These trends underscore the importance of integrating innovative financial solutions and approaches into the transition to a digital economy. Countries that are highly financially inclusive and use the latest technologies can more effectively adapt to rapidly changing economic conditions and maintain sustainable economic growth.

In the process of transition to the digital economy and the introduction of innovative technologies, an important aspect is to assess the development of high technologies and research in different countries. Table 3 provides a comprehensive overview of indicators characterising high- and medium-high technology exports, medium-high technology value-added, research and development expenditure, and the number of researchers per million people in the countries studied. These data are the key to understanding innovative trends in financial engineering and their impact on the digital economy. The analysis of the presented indicators allows us to assess how different countries promote technological innovation and what factors affect their ability to adapt to rapid changes in the global economic environment.

Table 3. High technology and research. (Source: authors' calculations based on World Bank data)

Country Name	High-technology exports, % of manufactured exports	High-technology exports, current USD	Medium and high-tech exports, % manufactured exports	Medium and high-tech manufacturing value added, % manufacturing value added	Research and development expenditure, % of GDP	Researchers in R&D, per million people
Ukraine	5.99	1530213360	39.30	31.43	0.66249	1104.912
Singapore	49.85	137065016313	69.35	77.35	2.077188	6389.472
Poland	8.72	15351809694	55.45	32.81	0.891909	2157.924
Estonia	18.40	1910146331	48.45	25.56	1.459924	3247.049
India	9.07	18454667412	30.03	40.21	0.739587	203.6456
Israel	21.00	11794028063	53.41	48.31	4.381794	-
China	30.31	614242574016	59.13	41.45	1.85001	1136.495
Finland	11.97	6643266898	51.03	42.63	3.194258	7359.296

The analysis of Table 3 reveals key trends in high technology and research in the studied countries, which may be useful for understanding innovative trends in financial engineering and the digital economy.

- Leaders of innovation:** Singapore and Finland are high performers in all key categories: high shares of high technology exports, a significant share of medium and high technology in manufacturing, significant R&D expenditure, and a high density of researchers. This indicates their leading role in the development and implementation of new technologies, which is critical for the development of the digital economy and financial engineering.
- The impact of R&D spending:** Countries with high R&D spending, such as Israel and Finland, have a high level of high technology in their production and a significant share of medium and high technology in their total exports. This underscores the importance of investment in R&D to stimulate innovation.
- The gap between developed and emerging economies:** Developed economies such as Singapore and Finland have significantly higher R&D performance than emerging economies such as Ukraine and India. This indicates that developed economies have better infrastructure to support innovation and technological progress.
- Potential for growth:** Both Ukraine and India have the potential to significantly improve their positions in the high-tech sector. In particular, Ukraine, although it has a low share of high technology in exports and R&D expenditures, shows a fairly significant amount of research per capita. This indicates the possibility of further development through increased investment in technology and science.
- Global trends:** Overall, the global trend shows that investment in high technology and research is critical for economic growth and the development of the digital economy. Countries that invest heavily in these areas demonstrate high rates of innovation and effective implementation of new technologies.

Therefore, for countries that want to become leaders in financial engineering and the digital economy, it is important to focus on increasing R&D spending, expanding investments in high technology, and stimulating the development of the relevant infrastructure.

In the context of the rapid development of the digital economy, innovative trends in financial engineering are gaining particular importance. Patent applications are an important indicator of innovation processes in different countries, reflecting the level of technical and technological achievements, as well as investments in research and development. To analyse these trends, see Figure 1, which compares the number of patent applications filed by residents and non-residents in the period from 2004 to 2023 for the selected countries. Figure 1 includes data for Estonia, Finland, Poland, Ukraine, Israel, Singapore, India and China, which allows us to assess global trends in patenting innovations. In particular, there is a significant difference in the volume of patent applications between residents and non-residents, which reflects different levels of technological development and investment attractiveness of countries. Such data is critical for understanding the dynamics of innovation and adapting financial engineering to the digital economy.

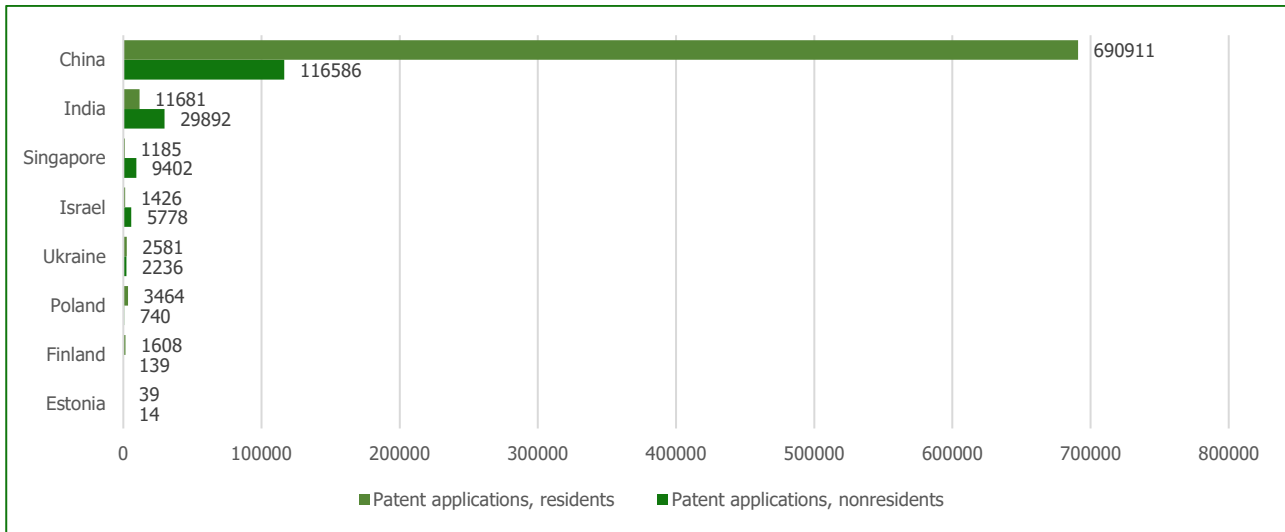


Figure 1. Patent applications, residents and non-residents, on average, 2003-2023. (Source: authors' calculations based on World Bank data)

The analysis of patent applications from 2004 to 2023 shows significant differences in innovation activity between residents and non-residents in different countries. This reflects the trends in the development of financial engineering in the context of the digital economy.

1. **Countries with a high level of innovation activity:** China and India are the leaders in terms of the number of patent applications, which indicates their dominant role in the global innovation market. China, in particular, significantly exceeds other countries in terms of the number of applications filed by both residents and non-residents. This underscores the importance of China as a major player in the development of new technologies and financial instruments, which is critical to understanding global trends in financial engineering.
2. **The role of countries with a moderate level of innovation:** India, Singapore and Israel have high volumes of patent applications from non-residents, which indicates their international recognition as centres for financial innovation. In particular, India has a significant volume of applications from residents, which may be due to the active development of financial technologies and digital payment systems at the local level.
3. **European countries and their contribution:** Poland, Finland and Estonia have a moderate level of innovation activity, with a higher volume of patent applications from residents. This indicates a developed national innovation potential, albeit on a smaller scale compared to the leaders. Such data may indicate a stable but less aggressive approach to the introduction of new technologies in the financial sector.

Implications for the digital economy: Overall, the data show a significant difference in innovation activity between the countries studied. Countries with high levels of patent filings, such as China and India, can be considered major centres for the development of new technologies that impact the global digital economy. Meanwhile, countries with lower patent volumes but a high proportion of resident applications demonstrate the importance of local innovation development in the context of specific national needs and market conditions. This analysis highlights the need for companies and investors to closely monitor global and local trends in patent activity in order to effectively adapt their financial engineering and digital economy strategies.

In today's globalised world, information and communication technologies (ICT) play a key role in the development of the digital economy and financial engineering. Table 4 provides a comprehensive overview of ICT indicators in the countries studied, including the share of ICT goods exports and imports, ICT services exports, the level of Internet usage by the population, and the number of secure Internet servers. The data presented in Table 4 illustrate significant differences between countries in terms of the level of ICT integration in their economies. Thus, Ukraine has low exports of ICT goods (0.92%) compared to Singapore (30.77%) and China (27.83%). At the same time, Ukraine demonstrates a significant level of ICT services exports (15.53%), which highlights its potential in the service sector. Other countries, such as India and Israel, have a significant percentage of ICT services exports - 46.31% and 40.84% respectively, which indicates their high specialisation in this area.

The level of Internet use also varies between countries. For example, in Estonia and Singapore, more than 75% of the population uses the Internet, while in India the figure is only 14.67%. These figures reflect both infrastructure development

and the availability of ICTs to the population. Table 4 also provides information on secure Internet servers, which are a critical element for ensuring data security in the digital economy. Singapore (218870.1 servers) and China (309128.4 servers) have the highest figures, reflecting their efforts to ensure cybersecurity. This data serves as a basis for further analysis of innovative trends in financial engineering on the way to the digital economy, helping to understand how different countries are integrating ICT into their economic systems and what factors influence their success in this area.

Table 4. Information and communication technologies (ICT), on average, 2003-2023. (Source: authors' calculations based on World Bank data)

Country Name	ICT goods exports, % of total goods exports	ICT goods imports, % total goods imports	ICT service exports, % of service exports	ICT service exports, current USD	Individuals using the Internet, % of the population	Secure Internet servers	Secure Internet servers, per 1 million people
Ukraine	0.92	3.97	15.53	2525650000	37.19	117422.6	2636.353
Singapore	30.77	25.96	5.38	9979995739	77.95	218870.1	38669.2
Poland	6.81	8.69	8.53	5222000000	64.39	255212.5	6725.303
Estonia	10.42	9.47	12.16	989639626	78.69	32033.27	24175.46
India	1.56	7.72	46.31	73728164437	14.67	155308.4	112.58
Israel	11.04	9.45	40.84	18536465000	66.03	38290.27	4312.343
China	27.83	22.48	9.50	22633383052	42.22	309128.4	219.8432
Finland	7.44	8.76	30.82	8338078871	86.06	108582.9	19684.63

The analysed Table 4 provides a deep insight into the development and spread of information and communication technologies (ICT) in different countries, which allows us to draw several important conclusions about innovative trends in financial engineering towards the digital economy.

- High level of exports of ICT goods and services:** Singapore and China are the leaders in the export of ICT goods, accounting for 30.77% and 27.83% of total merchandise exports, respectively. This reflects their important role in the global supply of ICT products and their influence on the global digital economy. India and Israel stand out with a significant share of ICT services exports, accounting for 46.31% and 40.84% of total services exports, respectively. These countries have significant potential in software development and IT consulting, which underlines their key role in the global ICT industry.
- Imports of ICT goods:** China, Singapore and Poland have a high percentage of ICT goods imports (22.48%, 25.96% and 8.69% respectively), indicating their dependence on high-tech imports to support and develop their own digital economies.
- Internet use and network security:** Finland and Estonia have the highest percentage of Internet users among the population (86.06% and 78.69% respectively), reflecting high levels of digital literacy and access to the Internet. Internet security is an important indicator of the digital economy. Singapore has the highest number of secure Internet servers per million people (38669.2), demonstrating a high level of cybersecurity infrastructure.
- Financial impact of ICT services:** Significant exports of ICT services in monetary terms are observed in India (USD 73 728 164 437) and Israel (USD 18 536 465 000), which underlines the importance of these services for the economic development of countries.

Overall, the data in Table 4 underline the importance of ICT as a key factor in the development of the digital economy. Innovative trends in financial engineering are increasingly focused on supporting and developing ICT industries, which contributes to the strengthening of digital economies at the global level. Countries that invest in the development of ICT infrastructure and cybersecurity have significant advantages in building a sustainable and competitive digital economy.

Table 5 analyses key indicators of insurance and financial services in a number of countries, including Ukraine, Singapore, Poland, Estonia, India, Israel, China and Finland. These data include the share of insurance and financial services in commercial exports and imports, the percentage of interest payments to income, and the number of mobile subscriptions and their share per 100 people. They allow us to assess the level of development of the financial sector and the impact of digital technologies on the economy in these countries. In particular, it is worth paying attention to the high percentage of insurance and financial services in Singapore's commercial exports (15.75%), which indicates its developed financial infrastructure. At the same time, India shows the highest percentage of interest payments from revenues (25.64592%),

which may indicate a high debt burden. In terms of mobile subscriptions, China leads the way with over 1.1 billion subscriptions, but in terms of the percentage of subscriptions per 100 people (80.89176), it is behind countries such as Singapore, Poland and Finland.

Table 5. Insurance and financial services, on average, 2003-2023. (Source: authors' calculations based on World Bank data)

Country Name	Insurance and financial services, % of commercial service exports	Insurance and financial services, % of commercial service imports	Interest payments, % of revenue	Mobile cellular subscriptions	Mobile cellular subscriptions, per 100 people
Ukraine	1.53	7.06	6.460401	52226555.58	118.8912
Singapore	15.75	5.32	0.190011	7442726.316	138.1904
Poland	2.22	5.90	5.714346	46916390.79	121.5012
Estonia	1.96	2.79	0.269403	1792820.421	134.932
India	4.64	7.17	25.64592	780581696.8	58.8911
Israel	0.09	2.48	10.21902	9970159.842	127.6258
China	2.41	6.19	3.311507	1123791600	80.89176
Finland	2.14	4.38	2.941838	7140952.632	131.754

These indicators are important for analysing innovative trends in financial engineering, as the introduction of digital technologies plays a key role in the modernisation of financial services and the development of the digital economy in general. This data helps to understand the current state and potential of countries in the context of global changes in financial markets and their ability to adapt to new technological challenges.

Digitalisation is undoubtedly a "megatrend", a development that is changing society as a whole, whether it is the banking sector, industry, trade, insurance, etc. The social security and insurance systems operate in an unfavourable economic environment in the country, which has a destructive impact on the level and quality of life of the insured. This, in turn, affects the financial security of the latter, which depends on a stable process of financial resource formation, their distribution and efficient use.

Table 5 shows the key indicators of insurance and financial services in the countries studied, which provides important information for analysing innovative trends in financial engineering on the way to the digital economy. Key findings:

1. **Exports and imports of insurance and financial services:** Among the countries presented, Singapore has the largest share of insurance and financial services in total exports of commercial services (15.75%), which indicates the high development of the financial sector and its significant role in international trade. By comparison, Ukraine's share is only 1.53%, indicating potential for growth in this area. In terms of imports, India shows the highest percentage (7.17%), which may indicate a significant demand for insurance and financial services from abroad, while Israel has the lowest (2.48%).
2. **Interest Payments:** High-interest payments as a percentage of revenues in India (25.65%) and Israel (10.22%) may indicate a high cost of funds or significant debt obligations. By comparison, in Singapore, this figure is only 0.19%, which indicates a stable financial situation and low cost of borrowing.
3. **Mobile telephony:** The high level of mobile subscriptions per 100 people in all countries (over 100%) reflects the high level of mobile penetration. Singapore stands out (138.19 subscriptions per 100 people), indicating the potential for the development of digital financial services through mobile platforms. The lowest level of mobile subscriptions per 100 people is observed in India (58.89), indicating significant potential for the development of mobile and digital financial services in this country.

Key conclusions and recommendations:

- Ukraine and Poland should consider opportunities to strengthen their insurance and financial sectors through the introduction of innovative digital solutions, given their relatively low exports of insurance and financial services.
- India should focus on lowering the cost of funds and developing mobile financial services, given its high interest rates and low mobile penetration.
- Singapore and Finland can serve as examples of successful digital financial innovation due to their developed financial sectors and high mobile penetration.

Table 6 shows the general economic indicators and stability of the countries studied, which are key players in the global economy. This data demonstrates the diversity in political stability, the importance of the service sector in GDP, the growth rate of this sector and the number of procedures required for registering a business. When analysing political stability and the absence of violence (terrorism), we can see significant differences that affect the economic development of countries. For example, Singapore demonstrates a high level of stability (1.32), while in Ukraine this indicator is negative (-0.90). At the same time, the service sector accounts for a significant share of GDP in all the countries under consideration, this underscores its importance in the modern economy. It is also worth noting the different growth rates of this sector, in particular in China (8.81%) and India (7.15%), which indicates dynamic development. The data in Table 6 serve as an important basis for discussing innovative trends in financial engineering on the way to the digital economy. They reveal the relationship between stability, service sector development, and the business environment, which are important factors for the introduction of innovative financial technologies and the transition to a digital economy.

Table 6. General economic indicators and stability, on average, 2003-2023. (Source: authors' calculations based on World Bank data)

Country Name	Political Stability and Absence of Violence/Terrorism: Estimate	Services, value-added, % of GDP	Services, value-added, annual % growth	Start-up procedures to register a business, number
Ukraine	-0.90	53.69	0.99	9.25
Singapore	1.32	68.97	4.97	3.69
Poland	0.67	56.14	3.76	7.38
Estonia	0.66	60.17	2.86	4.50
India	-1.04	46.83	7.15	12.71
Israel	-1.14	68.50	4.34	4.69
China	-0.47	48.14	8.81	9.00
Finland	1.24	58.94	1.32	3.00

Analyzing the overall economic performance and stability of the countries under study, we can identify several important trends that affect the development of the digital economy and innovative areas of financial engineering.

1. **Political stability:** a high level of political stability is observed in Singapore (1.32) and Finland (1.24), which creates favourable conditions for the development of innovative projects and digital solutions. Low political stability scores in countries such as India (-1.04) and Israel (-1.14) may be a barrier to investment in digital technologies, although these countries are also experiencing high growth in the services sector.
2. **Share of services in GDP:** Singapore (68.97%) and Israel (68.50%) have a high percentage of value added in services. This indicates the significant role of the service sector in the economies of these countries, which is a favourable factor for the development of financial innovations and digital platforms.
3. **Growth of the service sector:** The highest growth in the service sector is observed in China (8.81%) and India (7.15%), which indicates the dynamic development of these economies. This creates significant opportunities for the introduction of new digital solutions and financial instruments.
4. **Business registration procedures:** The lowest number of procedures for business registration in Finland (3.00) and Singapore (3.69) facilitates the quick start of new businesses, including technology start-ups. In countries with more complicated procedures, such as India (12.71) and Ukraine (9.25), starting new businesses can be more labour-intensive, slowing down innovation.

Thus, high political stability and simplified business registration procedures facilitate investment in digital technologies and financial engineering. Countries with a high share of services in GDP and rapid growth in this sector have significant potential for the development of the digital economy. However, political instability and complicated regulatory procedures may hinder these processes, despite the high growth potential. The introduction of innovations in financial engineering in the digital economy depends on a comprehensive approach that takes into account both macroeconomic indicators and the political and regulatory environment.

Table 7 shows the innovative trends in financial engineering in the countries under study.

Table 7. Innovative trends in financial engineering.

Country	Trend	Description	Trend details
Ukraine	Fintech	Development of digital banks and mobile payment systems	Example: Monobank, Privat24 Focus on the development of mobile applications for banking operations, payment services and integration with international payment systems.
Singapore	Blockchain	Using blockchain for financial transactions and smart contracts	Examples: Project Ubin, VeChain Using blockchain to ensure the transparency and security of financial transactions, implementing smart contracts to automate financial processes.
Poland	Robotisation of financial processes	Automation of accounting and reporting	Examples: Robo-advisors, reporting automation Use of software to automate financial analysis, data processing and reporting.
Estonia	e-Residency	e-Residency programmes for investors and entrepreneurs	Examples: e-Residency programmes Providing foreigners with access to Estonian financial services through e-Residency programmes, promoting start-ups and investments.
India	UPI-based payment systems	Interoperable payment systems based on a single interface	Examples: Google Pay, PhonePe, Paytm Development of a unified payment infrastructure for fast and secure transactions between different banking systems.
Israel	Cybersecurity	Protecting financial data and transactions from cyber threats	Examples: Check Point Software, CyberArk High level of protection of financial data and transactions from cyberattacks, development of innovations in the field of cybersecurity.
China	Digital Yuan	Development and introduction of a national digital currency	Examples: E-CNY (Digital Currency Electronic Payment) Introducing and testing a digital national currency to reduce dependence on traditional cash and improve control over the money supply.
Finland	Green finance	Investments in environmentally friendly and sustainable projects	Examples: Green bonds, financing of environmental projects Investing in projects that promote sustainable development, reduce the carbon footprint, and introduce environmentally friendly technologies.

Comparison with these countries will help identify best practices and possible ways to develop innovative financial engineering trends in Ukraine on the way to the digital economy. Based on the analysis of innovative trends in financial engineering in the countries studied in Table 7, the following conclusions can be drawn. Countries are actively implementing the latest technologies to improve financial services and processes, which facilitates the transition to a digital economy. Ukraine places a significant emphasis on the development of fintech, including digital banks and mobile payment systems. Singapore is a leader in the use of blockchain technologies for financial transactions and smart contracts, which increases the transparency and security of financial transactions. Poland is introducing robotisation of financial processes, automating accounting and reporting, while Estonia offers innovative e-residency programmes to support entrepreneurship and investment. India is developing interoperable payment systems based on a single interface that ensures fast and secure transactions. Israel focuses on cybersecurity, protecting financial data from cyberattacks. China is actively working to introduce a national digital currency, reducing its dependence on traditional cash. Finland is contributing to the development of green finance by investing in environmentally friendly and sustainable projects. These trends demonstrate a global trend towards integrating innovation into the financial sector, which contributes to efficiency, security and sustainable development.

DISCUSSION

Based on the study of innovative trends in financial engineering in the digital economy, a number of important conclusions can be drawn regarding opportunities and challenges for Ukraine. The analysed countries, such as Poland, Estonia, Israel, Singapore, India, China, and Finland, have demonstrated different approaches to the introduction of digital technologies in the financial sector, which indicates different levels of development of the digital economy and specific financial engineering tools.

According to research conducted by other authors, macro-financial mechanisms, corporate social responsibility regulation, green innovation, and energy transition, as well as the impact of digital technologies on entrepreneurship and regional development are important aspects of a successful transition to the digital economy.

The research by Eddie Gerba, Danilo Leiva-León, and Margarita Rubio (2024) emphasises the importance of macro-financial mechanisms for the development of financial engineering in the digital economy. Particular attention is paid to cross-border financial flows, which can stimulate economic growth and facilitate the effective implementation of innovative

financial technologies. For Ukraine, this may mean the need to strengthen macro-financial regulation and adapt global practices to strengthen the national economy. Muzammal Ilyas Sindhu, Windijarto, Wing-Keung Wong, and Laila Maswadi (2024) focus on the impact of corporate social responsibility on the financial and non-financial activities of the banking sector. Successful implementation of corporate social responsibility as part of financial engineering can improve the reputation and competitiveness of financial institutions. For Ukraine, this aspect is important in terms of integration into international financial markets.

Ganna Lytvynchenko's (2016) study points to the importance of financial mechanisms in programme management, which can be useful for Ukrainian enterprises and government agencies when planning and implementing digital initiatives. This highlights the need for effective financial management at the stage of digitalisation.

Xu Dong, Kejia Guo, and Xiaomeng Zhao (2024) investigate the impact of the digital economy on green innovation, which is relevant in the context of global environmental challenges. For Ukraine, this indicates the need to develop innovative financial instruments that will facilitate a green transition and reduce carbon emissions.

To further deepen the analysis, it is important to pay attention to additional aspects considered in modern scientific works related to the digital economy and financial engineering. Sylvester Senyo Horvey, Jones Odei-Mensah, Tankiso Moloi, and Godfred A. Bokpin (2024) explore the synergies between the digital economy, financial development, and the energy transition in Africa. They point out the importance of integrated approaches to ensure sustainable development. This study is particularly relevant for Ukraine, which is seeking to modernise its energy infrastructure and reduce its dependence on traditional energy sources. The introduction of digital technologies in the energy sector can be a key factor in the successful transformation of the economy. Asif Raihan (2024) highlights the potential opportunities and challenges of the digital economy for sustainable development in his review. He emphasises the importance of combining innovative technologies with financial inclusion, which can contribute to a more equitable distribution of benefits. Faced with the problems of inequality and social injustice, Ukraine can use these insights to create an inclusive digital economy that takes into account the interests of all social groups.

Based on a comparison with other studies, it can be concluded that successful digital transformation of financial engineering in Ukraine requires a comprehensive approach that includes the development of macro-financial mechanisms, support for green innovations, strengthening of the regulatory framework, and the introduction of digital technologies in key sectors of the economy. Ukraine has significant potential to implement best practices, but this requires coordination of efforts at the state level, the use of international experience, and adaptation to local conditions. Successful digital transformation can become a key driver of economic growth and increase the country's competitiveness in the global market. It is important for Ukraine to take these international practices and trends into account when developing its own digital transformation strategies. Especially important is the experience of countries with dynamic markets, such as Singapore and Israel, which demonstrate how flexible regulation and innovative approaches to financial engineering can contribute to the rapid development of the digital economy. This underscores the need for active government support for innovation and the creation of favourable conditions for the development of financial technologies in Ukraine.

CONCLUSIONS

Innovative trends in financial engineering play a key role in the development of the digital economy. Fintech, blockchain technologies, artificial intelligence and big data are opening up new opportunities for the development of financial markets and improving the efficiency of financial services. However, in order to maximise the impact of these technologies, a number of securities, regulatory and infrastructure challenges need to be overcome.

In today's globalised environment and rapid development of digital technologies, financial engineering is becoming increasingly important for the economic development of countries. The study of innovative trends in this area allows us to understand which technologies and approaches contribute to successful digital transformation. This is especially important for countries seeking to improve their competitiveness in the global economy. This article analyses and compares innovative trends in financial engineering around the world in order to identify the most effective approaches and their applicability in Ukraine. Taking into account various aspects of the digital economy, the study focuses on such countries as Poland, Estonia, Israel, Singapore, India, China, and Finland. These countries were selected because of their unique achievements and approaches in the field of financial technology, which could be useful for adaptation and implementation in the Ukrainian context.

Despite the significant benefits, the introduction of innovative technologies in financial engineering is accompanied by certain challenges. These include security issues, regulatory barriers, insufficient infrastructure and lack of standardisation. Addressing these issues is key to the further development of the digital economy.

Prospects for further research

The study of the innovative trends of financial engineering in the context of the digital economy is important, but there are numerous avenues for further exploration. Here are some key prospects for future research:

1. Investigation of artificial intelligence, and machine learning and how they can further optimize financial models, risk assessment, and investment strategies in a digital economy.
2. Analyzing ethical considerations and societal impacts of financial engineering innovations, particularly concerning data privacy, algorithmic biases, and financial inclusivity.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ІННОВАЦІЙНІ ТРЕНДИ ФІНАНСОВОГО ІНЖИНІРИНГУ НА ШЛЯХУ СТАНОВЛЕННЯ ЦИФРОВОЇ ЕКОНОМІКИ

Сучасний світ зазнає швидких і глибоких змін, обумовлених стрімким розвитком цифрових технологій, що впливають на всі аспекти економічного життя. Перехід до цифрової економіки стає все більш очевидним, що створює нові можливості та виклики для різних секторів, включаючи фінансову індустрію. Фінансовий інжиніринг як дисципліна, що об'єднує фінанси, математику, статистику та інформаційні технології, є ключовим інструментом у формуванні сучасних фінансових стратегій і продуктів. У цьому контексті важливо дослідити інноваційні тенденції, які визначають розвиток фінансового інжинірингу в умовах цифрової економіки. Це дослідження спрямоване на вивчення новітніх тенденцій фінансового інжинірингу, що сприяють переходові до цифрової економіки. Особлива увага приділена аналізу впливу цифрових фінансових інструментів на глобальні ринки та роль фінансових інститутів у новому цифровому середовищі.

Вивчення цих аспектів дозволить не лише зрозуміти поточні трансформаційні процеси, але й передбачити подальші напрями розвитку фінансового інжинірингу та його вплив на цифрову економіку. Це, у свою чергу, допоможе розробити більш ефективні стратегії управління фінансовими ризиками та можливостями в нових умовах, забезпечуючи сталий розвиток фінансової системи та економіки в цілому. Цифрова економіка кардинально змінює спосіб функціонування фінансових ринків і підприємств. Це дослідження вивчає основні інноваційні тренди у фінансовому

інжинірингу, які сприяють становленню та розвитку цифрової економіки. У статті також розглянуті перспективи та виклики, пов'язані з упровадженням цих технологій.

Ключові слова: фінтех, фінансові інновації, фінансовий сектор, фінансове прогнозування, фінансові ринки, розвиток; проблеми

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