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ASSESSING THE IMPACT OF DIGITAL PAYMENT INSTRUMENTS DEVELOPMENT ON THE SCALE OF ECONOMIC INFORMALISATION: INTERNATIONAL AND NATIONAL CONTEXTS

ABSTRACT

The rapid development of digitalization of the payment sphere and its growing role in achieving transparency of financial flows both in the world and in Ukraine, actualizes research in this area to develop recommendations for the formation of effective state financial and fiscal policy. The purpose of our study is to assess the effectiveness of the implementation of digital financial instruments in reducing shadow economic processes to determine the priority areas of state policy in the field of digitalization of the payment sphere.

The article examines the relationship between the spread of digital payment instruments and the dynamics of the shadow economy using the example of Ukraine and Poland. To assess the density and direction of the relationship between these indicators, the Fechner correlation method was used, which made it possible to determine the consistency of the trends in changes in the relevant indicators in the countries studied. The results of the study indicate the presence of an inverse statistical relationship between the growth of the share of non-cash transactions and the reduction of the level of the shadow economy, which confirms the de-mining potential of the digitalization of the payment infrastructure. The value of the correlation coefficients (0.5) proves that to combat the shadow economy, it is necessary to take measures also in the tax sphere, the sphere of institutional support, the legal framework, and finance in general. At the same time, a significant use of electronic payment instruments and deposit ATMs in the informal economy in Ukraine was revealed, which requires increasing the effectiveness of control over the use of these instruments.

The study also took into account the level of income across countries and showed that countries with higher income levels have a higher share of cashless payments and a lower level of the shadow economy.

Keywords: shadow economy, digital payment instruments, cashless economy, payment terminals, bank self-service devices, de-shadowing, financial inclusion

JEL Classification: G20, G35, O17, O57

INTRODUCTION

In the sphere of the digital transformation of economic processes, the advancement of cashless payments is becoming increasingly significant as an important instrument for enhancing the transparency of financial flows and, consequently, reducing the size of the shadow economy. This is largely due to the fact that cashless transactions make it considerably more difficult to conceal income or artificially inflate expenditures. Moreover, such transactions are more easily monitored through tax administration mechanisms, which in turn contribute to ensuring the necessary revenues for public budgets.

The shadowing of economic processes represents a global challenge. Data on the level of the shadow economy across fourteen distinct geographical regions of the world in 2023 indicate that the lowest levels were observed in North America, Western, Northern, and Southern Europe, as well as in the Middle East, where the estimates ranged from

5.0% to 8.2% of GDP. By contrast, the highest levels of the shadow economy were recorded in various parts of Africa and in South Asia, where they ranged from 24.1% to 41.6% of GDP (Figure 1).

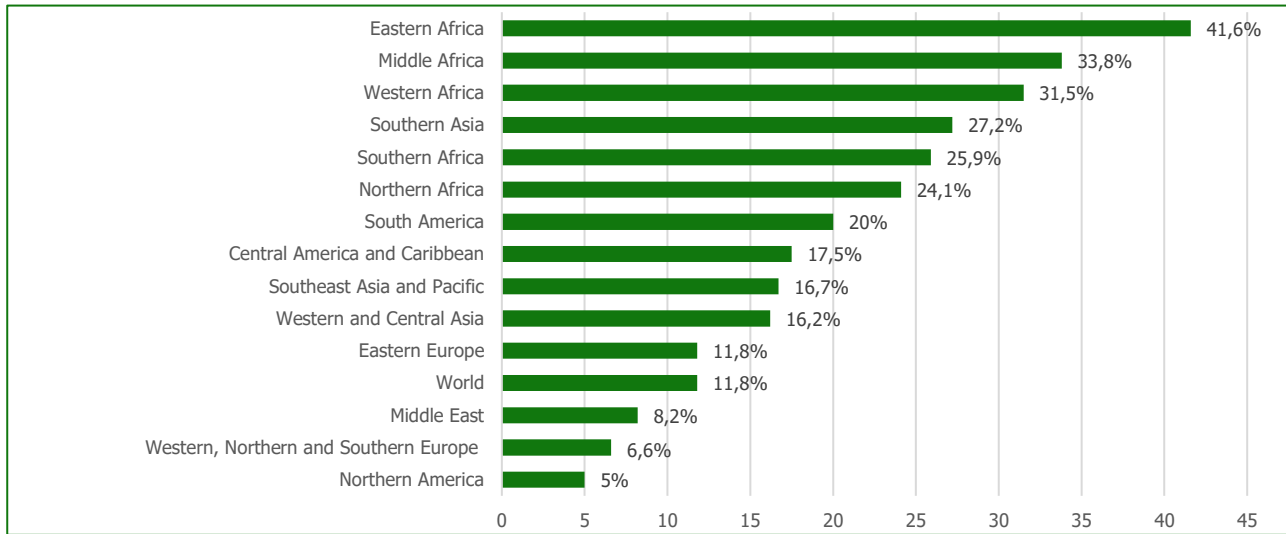


Figure 1. The level of the shadow economy by region in 2023. (Source: EY Report (2025))

As can be observed, economic shadowing impacts all regions of the world to varying extents. In contemporary conditions, efforts to counteract shadow economic activity increasingly involve the digitalisation of payment systems and settlement mechanisms.

In countries with underdeveloped payment infrastructure and relatively low levels of financial literacy among the population, the shadow economy poses a serious threat to fiscal stability, fair competition, and economic security in general. In this regard, identifying the underlying relationships between the scale of the shadow economy and the development of cashless payment instruments makes it possible to formulate more substantiated and effective policies aimed at the de-shadowing of economic activity. Such research is also valuable in terms of building an analytical foundation for managerial and policy decisions designed to enhance the transparency of financial flows.

LITERATURE REVIEW

Considerable scholarly attention has been devoted to the issue of limiting the informal sector of the economy and estimating its size across individual countries and groups of states. Particular emphasis has been placed on the development of the cashless economy, fintech, and financial inclusion, highlighting their importance in mitigating the scale of the informal economy.

Medina and Schneider (2018) conducted a global analysis of the informal economy across 158 countries from 1991 to 2015, identifying an average level of 31.9% of GDP. The highest shares were observed in Zimbabwe and Bolivia, whereas the lowest levels were recorded in Austria and Switzerland. Schneider, Buehn, and Montenegro (2010) performed research aimed at estimating the level of the shadow economy across 162 countries between 1999 and 2007, revealing an average size of 38.4% of GDP in Sub-Saharan Africa, 36.5% of the economy's size in Central Asia and Europe, with a mere 13.5% economy shadowed in highly developed OECD countries. Their findings also revealed that the global average level of the shadow economy declined from 34% in 1999 to 31% in 2007.

Lobont̃ et al. (2025) studied the influence of the shadow economy on the economic development of EU countries. The authors argue that the expansion of informal economic activity constrains economic growth and emphasise the need to strengthen tax administration in order to combat the shadow economy more effectively.

By contrast, Reimers, Schneider, and Seitz (2020) identified a direct relationship between cash transactions and the shadow economy in the countries of the euro area during the period 2002–2019, irrespective of the size of the country. According to their findings, the wider use of cashless payment instruments contributes to a reduction in the demand for cash and, consequently, to a contraction of the informal sector.

A systematic review of studies on access to finance and financial inclusion is presented in the work of Al-Khazaleh et al. (2026), which is based on the analysis of more than 2,600 academic publications. The authors demonstrate the important role played by fintech innovations, financial intermediaries, and regulatory mechanisms in reducing poverty. Rahman et al. (2023) analysed how the development of fintech and the expansion of digital banking services affected the size of the shadow economy in the BRICS countries from 2004 to 2018. Additionally, Syed et al. (2021) examined the impact of digital finance on the informal economy in South Asian countries. Both studies confirm the importance of expanding the use of digital financial instruments as a means of reducing the informal sector of the economy.

Hassan (2024) conducted a study on the impact of mobile banking development on the informal economy within South African countries, using data spanning from 1993 to 2022. The findings demonstrate that greater accessibility of mobile banking services contributes to a reduction in the size of the shadow economy by increasing the transparency of financial transactions.

Kowal-Pawul and Lichota (2024) demonstrate that the scale of the shadow economy is fueled by cash usage, which complicates tax enforcement. To counter this, the authors advocate for a broader usage of cashless payments as a means of reducing informal economic activity. A 2025 study conducted by Przekota, Kowal-Pawul, and Szczepańska-Przekota explored the various factors that drive the informal economy across the EU. Buszko (2022) found that the development of the shadow economy in Poland and Lithuania during 2000–2019 was influenced by the overall macroeconomic situation, living standards, income levels, crime rates, and the structure of the tax system.

In an earlier study, Buszko (2017) examined the threats posed by the shadow economy to public finances in Poland and emphasised the need for comprehensive measures aimed at reducing the informal sector and strengthening tax control. Gołdyn (2021) identifies the multifaceted impact of economic shadowing on the national economy. In particular, the expansion of the informal sector is associated with ineffective state economic policy, while its reduction is linked to efforts to combat tax fraud and increase the share of cashless transactions.

Ukrainian scholars have also analysed the relationship between the cashless economy and economic shadowing. Ptashchenko (2021) argues that by integrating new financial technologies and incentivizing card usage, the state can achieve higher visibility in capital movements, which effectively shrinks the informal sector of the economy. Meanwhile, the theoretical dimensions of shadow banking systems across Europe and Ukraine are investigated by Zelinska and Oleshko (2023). Their research shows that the shadow banking sector within the EU is heterogeneous and varies significantly between countries, whereas in Ukraine, it is strongly shaped by a prevailing cash culture and insufficiently effective monitoring mechanisms.

Bukhtiarova and Tietierieva (2019) analyse financial monitoring in banks as an instrument for de-shadowing the Ukrainian banking system. The role of banks in processes of economic shadowing in Ukraine is also examined by Zolkover and Tarasenko (2024), who identify the use of fictitious companies and offshore accounts as key mechanisms through which the banking sector may become involved in shadow economic activity. To minimise such practices, the authors emphasise the importance of introducing modern digital technologies in banking operations.

The consequences of Ukraine's shadow economy on private citizens and businesses were explored by Kovalenko et al. (2022), who utilized a combination of energy-based and monetary assessment approaches. Their study suggests that the legalisation of the Ukrainian economy should be pursued through moderate liberalisation of the foreign exchange market and improvements in banking regulation.

Zeng, He, and Ma (2025) demonstrate that the expansion of cashless payments significantly restricts operations within the shadow banking sector. Examining the Chinese market, Shi et al. (2026) provide evidence from the Shanghai and Shenzhen stock exchanges' non-financial firms that fintech growth inversely affects the prevalence of informal economy activities.

Bhatter and Chhatoi (2023) establish a link between the financial success of banks in India and their commitment to social responsibility and financial inclusion. Giammatteo, Iezzi, and Zizza (2022) reaffirm that heavy cash reliance remains a driver of economic shadowing in Italy.

Goudarzi and Mittone (2023) experimentally show that digital financial expansion can incentivize formal participation in the economy despite increasing tax pressure.

Focusing on the economic data of 285 Chinese cities between 2011 and 2020, Du et al. (2023) evaluated how economic resilience is influenced by financial inclusion and digital finance. Their findings indicate that the integration of digital finance tools serves as a mechanism for bolstering the stability of city economies. This aligns with the observations of Younas et

al. (2022), who utilised data from 2008 to 2017 to demonstrate that while financial inclusion acts like a catalyst for GDP growth in developing countries, the presence of a substantial shadow economy size significantly hinders such growth.

AIMS AND OBJECTIVES

The article is about assessing the directions of influence of indicators reflecting the development of digital payment instruments on the scale of the informal economy in Ukraine and in an international context, with a view to identifying priority directions for state policy in the field of payment system digitalisation.

METHODS

The methodological basis of the study is the calculation of the correlation coefficients of parallel series using the Fechner method and using the CORREL function in Microsoft Excel, which allows you to calculate the Pearson correlation coefficient. The use of Fechner correlation coefficients - correlation of the signs of the series - is due to the specifics of the analysed data, the values of which do not correspond to the law of normal distribution. This method involves assessing the deviations of individual indicator values from their average value for the period. Next, the number of coincidences (A) (mismatches (B)) of the directions of movement of the deviations of the indicator values from their average for the period is counted. The correlation coefficient is calculated by the formula (Yarovyi A. T., & Strakhov Ye. M., 2015):

$$K_F = \frac{n_a - n_b}{n_a + n_b}$$

where n_a – the number of coincidences of the signs of deviations of individual values from the mean value; n_b – the number of discrepancies.

The CORREL function in Excel calculates the Pearson correlation coefficient (r) between two datasets, thereby determining the strength and direction of their linear relationship.

Both the Fechner and Pearson coefficients range from –1 to +1. If r (or the Fechner coefficient) is negative, the relationship is inverse; if it is positive, the relationship is direct.

The obtained correlation coefficients were interpreted in accordance with conventional statistical approaches:

- $|r| < 0.3$ — weak relationship;
- $0.3 \leq |r| < 0.7$ — moderate (noticeable) relationship;
- $|r| \geq 0.7$ — strong relationship;
- +1 — perfect positive correlation (functional relationship);
- –1 — perfect negative correlation (functional relationship);
- 0 — no relationship.

RESULTS

The distribution of indicators reflecting the level of the shadow economy and the degree of digitalisation of the payments sector across groups of countries classified by income level reveals clear patterns. As shown in Figure 2, which evaluates data on the informal sector's GDP share, digital payment adoption, and the share of the population holding electronic wallets (or bank accounts) in 2023. The analysis demonstrates a negative correlation between income levels and the scale of the shadow economy. In high-income countries, the informal economy amounted to mere 5.9% of GDP, whereas in low-income countries it reached 42.4% of GDP. A clear divide can be seen between wealthy and developing economies regarding their financial infrastructure, with digital payment penetration dropping from approximately 90% in the developed countries to just 35% in the latter. A strong inverse relationship is also observed between the level of the informal economy and indicators of payment digitalisation (namely the level of digital payment usage and the share of the population possessing electronic wallets), with correlation coefficients of –0.8883 and –0.9513, respectively.

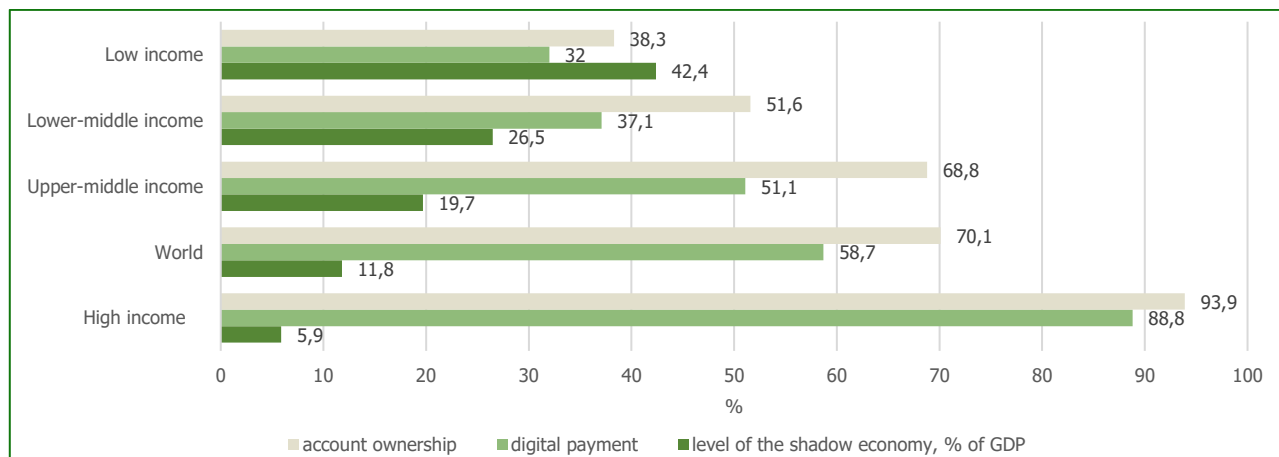


Figure 2. Level of the shadow economy and indicators of the cashless economy by country income groups. (Source: EY Report (2025)).

To gain a deeper understanding of how economic shadowing correlates with the growth of cashless systems globally, Pearson coefficients were calculated between the size of the informal economy and two indicators reflecting the development of the cashless economy and financial inclusion: the level of digital payment usage and the share of the population holding electronic wallets. The results reveal a noticeable negative relationship between these indicators and the level of the shadow economy: $r = -0.55388$ for the relationship between the shadow economy and digital payments, and $r = -0.64054$ for the relationship between the shadow economy and financial inclusion. Thus, regions characterised by higher levels of digital payment usage and financial inclusion tend to exhibit lower shares of shadow economic activity, and vice versa. Consequently, in their efforts to combat economic shadowing, countries should focus on expanding financial inclusion and encouraging cashless payments, in particular by developing reliable infrastructure for electronic transactions. Despite significant progress in financial inclusion in recent years, considerable disparities across different regions of the world remain evident (Figures 3 and 4).

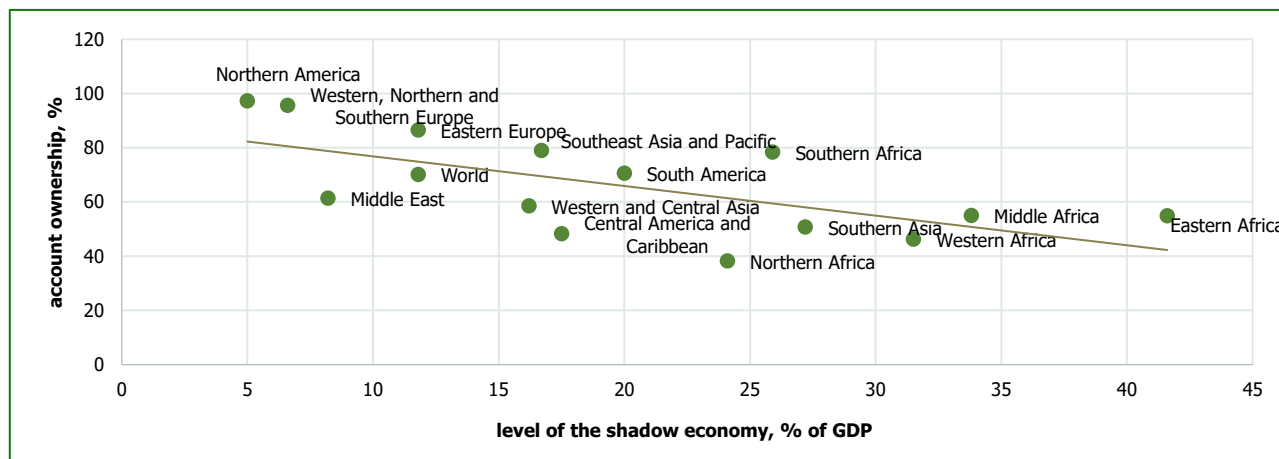


Figure 3. Distribution of geographical regions according to the criteria "shadow economy – financial inclusion." (Source: calculated and created by the authors based on data from the EY Report (2025))

Information on balances held in bank accounts and records of electronic payments constitutes an important source of data for tax authorities in detecting violations and instances of tax evasion. Provided that the tax administration has efficient access to such electronic records and possesses appropriate mechanisms for identifying and tracking unregistered transactions, cashless payments may serve as a significant factor in shrinking the informal sector of the economy. Despite the global increase in the popularity of digital payments, only a limited number of countries aim to move entirely towards cashless transactions due to several advantages associated with the use of cash. For instance, cash ensures the confidentiality of transactions, enables sellers to receive funds immediately, and does not require electricity or specialised devices to complete a payment. At the same time, for an increasing number of individuals, digital payments are becoming a more convenient and secure option, as they eliminate the need to carry large amounts of cash that may expose individuals to pickpocketing, while also providing confirmation of each transaction that can be used in the event of potential disputes between counterparties.

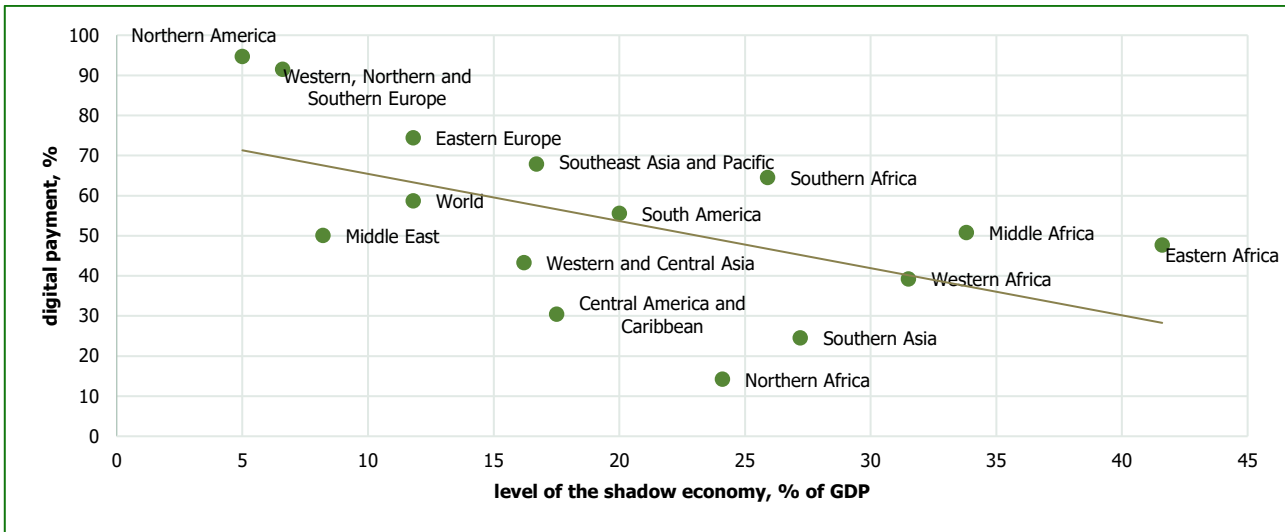


Figure 4. Distribution of geographical regions according to the criteria "shadow economy – digital payments". (Source: calculated and created by the authors based on data from the EY Report (2025))

This issue is also highly relevant for Ukraine, where, according to estimates of international organisations, the shadow sector remains considerable, while the transition towards cashless forms of settlement has not yet reached a critical level capable of significantly reducing shadow economic schemes (Figure 5).

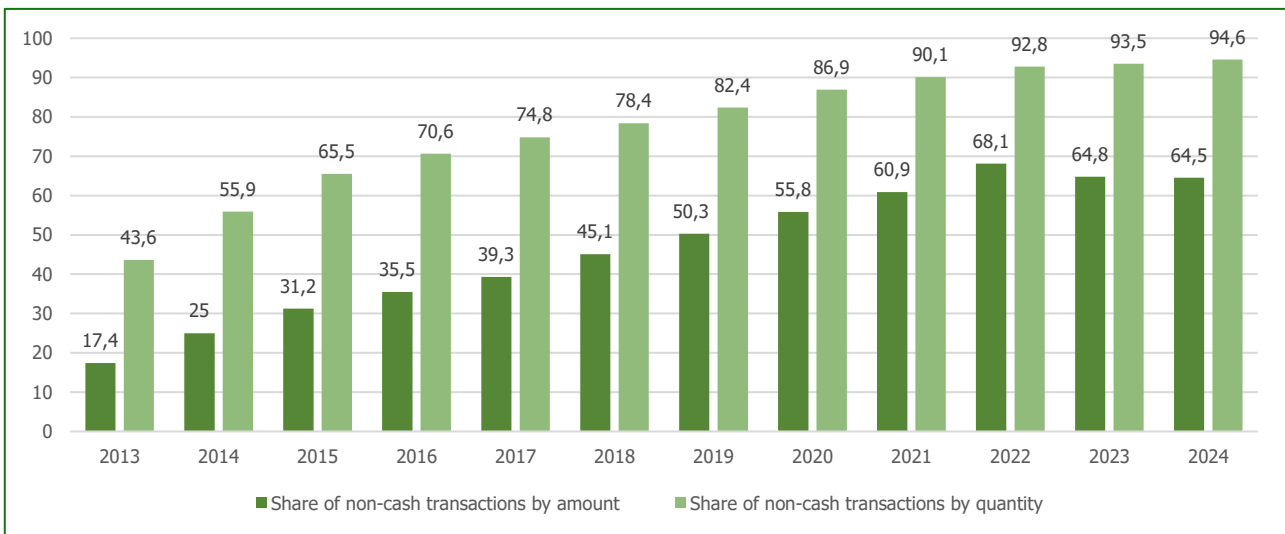


Figure 5. Dynamics of the share of non-cash transactions in Ukraine. (Source: compiled by the authors based on data from the National Bank of Ukraine (2025)).

In this article, we examined the factors driving the development of the cashless economy that exert the most substantial influence on the size of the informal economy in Ukraine. Under the current conditions of digitalisation, one of the priority directions of the transformation of Ukraine's financial system is the expansion of cashless payments, which contribute to greater transparency of economic transactions, reduce transaction costs, and stimulate the introduction of innovations in the banking sector. Among the key factors determining the level of development of the cashless economy, the following may be highlighted: the deployment of bank self-service devices, the spread of contactless payment terminals, and the growth in the number of electronic payment instruments in circulation.

Bank self-service devices. This category includes automated teller machines (ATMs), information and payment terminals, internet and mobile banking systems, as well as software and hardware self-service complexes and similar technologies. Their installation in a wide range of institutions and public spaces expands public access to financial services, increases the speed of payment processing, and reduces the need for cash usage. Self-service devices, therefore, represent an important component of the financial infrastructure that forms the basis for digital interaction between banks and their customers.

Contactless payment terminals (POS terminals). The introduction of contactless payment technologies, particularly those based on NFC (Near Field Communication), has substantially altered consumer behaviour in the field of payments. The expansion of POS terminal networks in retail trade and service sectors accelerates customer service, lowers barriers to the use of card-based and mobile payment instruments, and contributes to the gradual displacement of cash from circulation.

Number of electronic payment instruments in circulation. The increasing use of payment cards, electronic wallets, and mobile payment systems (such as Apple Pay, Google Pay, and others) serves as an indicator of growing public trust in digital financial technologies.

Taken together, these factors form the technological foundation for the development of an effective cashless economy. Their advancement represents an important condition for strengthening financial inclusion, increasing the effectiveness of monetary policy, and ensuring fiscal security within the state.

The study of correlation relationships between key factors in the development of the cashless economy and the level of the shadow economy is particularly relevant in the context of building a digital, transparent, and resilient financial system. Indeed, the cashless economy – through the widespread introduction of electronic payment instruments, the development of financial infrastructure, and the expansion of access to banking services – has the potential to significantly reduce the scale of the shadow sector.

Correlation analysis makes it possible to identify and quantitatively assess relationships between such indicators as the number of bank payment cards in circulation, the level of penetration of contactless technologies, the network of POS terminals, the spread of bank self-service devices, and the level of the shadow economy. Establishing statistically significant relationships between these variables enables researchers and policymakers to:

- assess the effectiveness of the introduction of digital financial instruments in reducing shadow economic activities;
- identify priority directions for state policy in the sphere of payment system digitalisation and fiscal administration;
- model the influence of individual factors on changes in the scale of shadow transactions;
- develop mechanisms for preventing tax evasion and informal settlements through strengthened electronic monitoring.

In accordance with the Fechner methodology, we selected a set of indicators reflecting the development of cashless payments over the period 2017–2024 (explanatory variables) and presented them alongside indicators of the level of the shadow economy (the dependent variable) in a consolidated table (Table 1).

Table 1. Indicators of the development of the cashless payments sector and the level of the shadow economy. (Source: compiled by the authors based on data from the National Bank of Ukraine (2025), Ministry of Economy of Ukraine (2022), and EY Report (2025))

Indicators	2017	2018	2019	2020	2021	2022	2023	2024
Number of electronic means of payment in circulation, million pcs.	55.46	61.79	68.30	73.43	89.11	109.80	115.14	132.04
Number of self-service banking devices	36 231	35 974	35 777	34 756	33 618	28 279	29 140	29 024
Number of deposit ATMs	1 654	1 743	1 778	2 425	2 914	2 596	2 624	2 754
Number of payment terminals (PTKS)	17 367	16 874	16 402	15 967	15 159	12 688	13 339	13 310
Number of contactless trading payment terminals	211 342	120 231	293 322	325 813	393 556	348 141	445 885	484 012
Number of bank payment terminals	9 340	12 584	14 988	13 963	12 623	9 251	19 840	26 334
Level of the shadow economy, % of GDP	32	29	28	30	32	45	40	43

In the following table, the analysed indicators are presented in the form of their year-to-year changes, as well as the average values of these changes (Table 2).

Table 2. Changes in indicators of the development of the cashless payments sector and the level of the shadow economy. (Source: calculated and compiled by the authors based on data from the National Bank of Ukraine (2025), Ministry of Economy of Ukraine (2022), and EY Report (2025))

Indicators	2017	2018	2019	2020	2021	2022	2023	2024	Average
Change in the number of electronic means of payment in circulation, million pcs.	10.57	6.32	6.51	5.13	15.67	20.69	5.34	16.91	10.893
Change in the number of self-service banking devices	-1086	-257	-197	-1 021	-1 138	-5 339	861	-116	-1 036.625
Change in the number of deposit ATMs	101	89	35	647	489	-318	28	130	150.125
Change in the number of payment terminals (PTKS)	-520	-493	-472	-435	-808	-2 471	651	-29	-572.125
Change in the number of contactless merchant payment terminals	39012	-91 111	173 091	32 491	67 743	-45 415	97 744	38 127	38 960.25
Changing the number of bank payment terminals	2578	3 244	2 404	-1 025	-1 340	-3 372	10 589	6 494	2 446.5
Change in the level of the shadow economy, % of GDP	32	29	28	30	32	45	40	43	1.5

Table 3 presents the intermediate data regarding deviations of changes in the analysed indicators from their average values.

Table 3. Signs of deviations of factor and resultant indicators.

Indicators	2017	2018	2019	2020	2021	2022	2023	2024
Change in the number of electronic means of payment in circulation, million pcs.	-1	-1	-1	-1	1	1	-1	1
Change in the number of self-service banking devices	1	1	1	1	-1	-1	1	1
Change in the number of deposit ATMs	-1	-1	-1	1	1	-1	-1	-1
Change in the number of payment terminals (PTKS)	1	1	1	1	-1	-1	1	1
Change in the number of contactless merchant payment terminals	1	-1	1	-1	1	-1	1	-1
Changing the number of bank payment terminals	1	1	-1	-1	-1	-1	1	1
Change in the level of the shadow economy, % of GDP	-1	-1	-1	1	1	1	-1	1

In order to calculate the Fechner correlation coefficient, it is necessary to identify the number of coincidences in the direction of deviations between the changes in the factor indicators and the resulting indicator. The factor indicators in the study are the following: the number of electronic means of payment in circulation, the number of self-service banking means, in particular, deposit ATMs and self-service software and hardware complexes, and the number of payment terminals, namely contactless trade and banking terminals. The resulting indicator is the level of the shadow economy. The identified coincidences are presented in Table 4.

Table 4. Calculation of the Fechner correlation coefficient.

Indicators	2017	2018	2019	2020	2021	2022	2023	2024	Fechner correlation coefficient
Change in the number of electronic means of payment in circulation	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	TRUE	0,75
Change in the number of self-service banking devices	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	-0,5
Change in the number of deposit ATMs	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	0,5
Change in the number of payment terminals (PTKS)	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	-0,5
Change in the number of contactless merchant payment terminals	FALSE	TRUE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	-0,5
Changing the number of bank payment terminals	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	-0,5

The results of the conducted study reveal a logical and consistent inverse relationship between changes in the number of banking self-service devices – particularly software and hardware self-service complexes (PTKS) – as well as the number of contactless retail and banking payment terminals, and changes in the level of the shadow economy. The value of the Fechner correlation coefficient between these indicators is relatively high (–0.5), indicating the existence of a noticeable relationship.

This dependency aligns with the expected theoretical framework: the development of cashless payment infrastructure contributes to reducing the scale of the shadow economy. The increase in the number of PTKS devices, POS terminals, NFC devices, and other contactless payment tools leads to a decline in cash transactions, which traditionally serve as a key channel for conducting shadow operations. Furthermore, the spread of self-service technologies through PTKS facilitates the inclusion of a broader range of participants in the digital financial sector, simplifying the payment of various bills without the involvement of shadow intermediaries.

Unlike cash transactions, contactless payment operations conducted through retail terminals or banking applications are recorded within the banking system. This significantly complicates the concealment of the real volume of transactions, as payment information becomes accessible to banks and, when required, to tax authorities through requests or automated data exchange mechanisms. The presence of POS terminals and PTKS devices at points of sale implies the introduction of electronic fiscalisation, which directly contributes to business formalisation and the reduction of shadow revenues.

It is also important to highlight the change in consumer behavioural patterns. The increasing convenience of contactless payment forms a habit among consumers to pay with cards or smartphones even for small purchases, thereby reducing the need for cash. This strengthens demand for transparent financial services while simultaneously decreasing tolerance toward shadow practices such as “payment without a receipt”, “cash discounts”, or undeclared employment.

A particularly interesting result is the Fechner correlation coefficient calculated between changes in the number of deposit ATMs and the level of the shadow economy, which equals +0.5. This suggests that the growth in the number of deposit ATMs has a negative impact on the reduction of the shadow economy in Ukraine. At first glance, the expansion of banking infrastructure should enhance economic transparency; however, deposit ATMs (cash-in ATMs) possess a specific functional feature that, under Ukrainian economic conditions, may produce the opposite effect. Deposit ATMs allow individuals to deposit cash into bank accounts without direct contact with bank cashiers. As a result, participants in the shadow economy may use ATM networks to deposit small sums into multiple bank cards (so-called “drop accounts”). This practice makes it possible to bypass financial monitoring procedures, which typically impose stricter controls on large cash transactions conducted at bank branches. In addition, the ability to deposit cash at any time of the day and at numerous locations makes transactions within the “grey” sector faster and more convenient for participants.

Considering this result, it appears necessary to strengthen financial monitoring of transactions conducted through deposit ATMs, including improvements to the regulatory requirements of the National Bank of Ukraine governing such operations, as well as further development of digital identification systems and transaction analytics. With Ukraine’s accession to the international system of tax information exchange, certain steps have already been taken, as banks synchronise account holder information across the entire system to facilitate data sharing with tax authorities. Such measures restrict the scope for speculative shadow operations.

A paradoxically strong positive relationship (Fechner correlation coefficient +0.75) was also identified between changes in the number of electronic payment instruments in circulation and changes in the level of the shadow economy. This result contradicts the widely accepted theoretical paradigm according to which the expansion of cashless financial operations contributes to the reduction of shadow economic activities. The explanation for this outcome lies in the specific characteristics of the national financial and institutional system. Due to insufficient institutional support for the digitalisation of payment infrastructure, the control of financial flows remains inadequate. As a result, electronic payment instruments are used not only in the formal sector but also within the informal economy. In particular, the widespread use of electronic wallets, mobile banking, and online transfers in transactions between individuals that are not accompanied by proper fiscalisation contributes to the emergence of new forms of shadow transactions. Consequently, in sectors such as self-employment, freelancing, courier services, or the activities of sole proprietors, a significant share of transactions remains outside official statistics despite the use of digital payment instruments.

It should also be noted that under conditions of economic instability and increased tax pressure, business entities in Ukraine may deliberately shift to shadow schemes while simultaneously making active use of legal electronic payment instruments. Therefore, the digitalisation of payments alone cannot serve as a determining factor of economic de-shadowing in conditions of low tax discipline.

Another important aspect explaining this paradoxical result is that the growth of financial digitalisation in Ukraine creates opportunities for the use of such instruments in the shadow sector due to the absence of sufficiently developed legislative regulation.

Thus, the identified positive correlation does not necessarily indicate a negative influence of digital payment instruments on the process of economic de-shadowing. Rather, it reflects the ineffectiveness of accompanying institutional reforms and the insufficient integration of electronic control instruments into fiscal policy. Successful reduction of the shadow economy through digitalisation is possible only under a comprehensive approach that includes the modernisation of the tax system, improvement of the legal framework, and enhanced risk management within the financial sector.

Using the Fechner correlation coefficient, we also examined the relationship between the level of the shadow economy and indicators of the cashless economy in Poland. The choice of Poland is determined by several factors. First, Poland is a neighbouring country that has successfully implemented a number of economic reforms in recent years and has achieved a significant reduction in the level of the shadow economy. Second, it is a member of the European Union, to which Ukraine also aspires to accede. Third, Poland is among the leaders in Central and Eastern Europe in terms of the development of cashless payments. The country demonstrates a high penetration of POS terminals, widespread use of contactless payments, and effective state programmes supporting cashless transactions (for example, the *Polska Bezgotówkowa* programme).

The initial data used in the study are presented in Table 5.

Table 5. Indicators of the development of the cashless payments sector and the level of the shadow economy in Poland. (Source: compiled by the authors based on data from the *Instytut Prognoz i Analiz Gospodarczych* (2019; 2025) and *Narodowy Bank Polski* (2019; 2025))

Indicators	2017	2018	2019	2020	2021	2022	2023	2024
Electronic means of payment (cards), million pcs.	39.1	41.2	42.8	43.1	43.3	44.5	45.4	46.4
Banking devices (ATMs), thousand pcs.	23.2	22.9	22.7	21.9	21.3	21.3	22.1	22.2
Bank payment terminals (POS), thousand pcs.	624	786	906	1020	1123	1221	1328	1375
Level of the shadow economy, % of GDP	18.7	18	17.2	18	18.3	18.5	18.9	18.5

The factor indicators in the analysis include the change in the number of electronic payment instruments, banking devices (ATMs), and banking payment terminals (POS). Meanwhile, the resulting indicator, which is affected by these factors, is the changing scale of Poland's informal economy. The specific values for these changes relative to the prior year, alongside their mean figures, are shown in Table 6.

Table 6. Changes in indicators of the development of the cashless payments sector and the level of the shadow economy in Poland.
 (Source: calculated and compiled by the authors based on data from Instytut Prognoz i Analiz Gospodarczych (2019; 2025) and Narodowy Bank Polski (2019; 2025))

Indicators	2017	2018	2019	2020	2021	2022	2023	2024	Average
Change in the number of electronic means of payment (cards), million pcs.	1.2	2.1	1.6	0.3	0.2	1.2	0.9	1	1.0625
Change of banking devices (ATMs), thousand pcs.	-0.2	-0.3	-0.2	-0.8	-0.6	0	0.8	0.1	-0.15
Change of bank payment terminals (POS), thousand pcs.	110	162	120	114	103	98	107	47	107.625
Change in the level of the shadow economy, % of GDP	-0.1	-0.7	-0.8	0.8	0.3	0.2	0.4	-0.4	-0.0375

Intermediate data on the deviations of changes in the analysed indicators from their average values are presented in Table 7.

Table 7. Signs of deviations of the factor and resulting indicators.

Indicators	2017	2018	2019	2020	2021	2022	2023	2024
Electronic means of payment (cards)	1	1	1	-1	-1	1	-1	-1
Banking devices (ATMs)	-1	-1	-1	-1	-1	1	1	1
Bank Payment Terminals (POS)	1	1	1	1	-1	-1	-1	-1
Level of the shadow economy, % of GDP	-1	-1	-1	1	1	1	1	-1

The identified sign matches between the factor indicators and the resulting indicator, as well as the calculation of the Fechner correlation coefficient, are presented in Table 8.

Table 8. Calculation of the Fechner correlation coefficient.

Indicators	2017	2018	2019	2020	2021	2022	2023	2024	Fechner correlation coefficient
Electronic means of payment (cards)	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	-0,5
Banking devices (ATMs)	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	0,25
Bank Payment Terminals (POS)	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	-0,5

Thus, the analysis of the relationship between changes in the indicators of the cashless economy and changes in the volume of the shadow economy in Poland revealed the existence of a noticeable inverse relationship between the level of economic shadowing and changes in the number of electronic payment instruments in circulation and banking payment terminals (Fechner coefficients -0.5). This indicates that these factors are important, though not the only determinants influencing the shadowing of economic processes in the country. At the same time, a direct and weak relationship was identified between changes in the number of banking devices and changes in the level of the shadow economy. The weak relationship between these indicators suggests that, compared to Ukraine, the shadow sector in Poland is less dependent on banking infrastructure and is subject to more effective financial monitoring mechanisms. The positive correlation coefficient in this case is likely related to the fact that an extensive ATM network simplifies the process of withdrawing funds, while cash remains the primary instrument used in shadow transactions. Accordingly, the greater the number of access points to physical cash, the easier it is for economic agents to avoid cashless payments, thereby supporting the persistence of the shadow sector.

In Poland, however, the widespread use of digital payments reduces the importance of the ATM network as a factor contributing to economic shadowing when compared to Ukraine. This difference can be explained by variations in the structure of the payment market, the level of trust in the financial system, the degree of digital inclusion, and the quality of tax administration.

Having examined the influence of specific indicators of the development of the cashless economy in Ukraine and Poland, it can be concluded that the development of digital payments represents an effective instrument for reducing the shadow economy. However, the moderate strength of the relationship indicates that eliminating the shadow economy entirely

requires additional measures, including tax system reforms, anti-corruption efforts, and improvements in the regulatory environment. Investments in the digital payment ecosystem create institutional and behavioural barriers to shadow transactions. In this context, an important role is played by state policy aimed at stimulating cashless payments, including tax incentives, regulatory requirements for the mandatory use of fiscal cash registers or software-based registers (RRO/PRRO), and support for micro and small businesses in transitioning to electronic payments. When adjusting policies aimed at expanding cashless payments, it is also necessary to consider the paradoxical correlation results obtained in the study, regarding the relationship between changes in the level of the shadow economy and changes in the number of deposit ATMs and payment instruments in circulation in Ukraine, as well as the relationship between changes in the number of ATMs and the shadow economy in Poland.

The state and development of the cashless economy, as demonstrated by the calculations above, are largely determined by the overall economic development of a country, particularly by population income levels, and significantly influence the level of the shadow economy. Countries with higher income levels tend to develop the cashless segment of banking services more intensively. However, it is also important to emphasise another crucial factor – financial inclusion. Broad inclusion of the population in fintech and digital banking services makes the expansion of banking infrastructure economically justified in terms of both profitability and customer convenience. Therefore, digital and financial literacy of the population serves as one of the key drivers of the spread of the cashless economy (Figure 6).

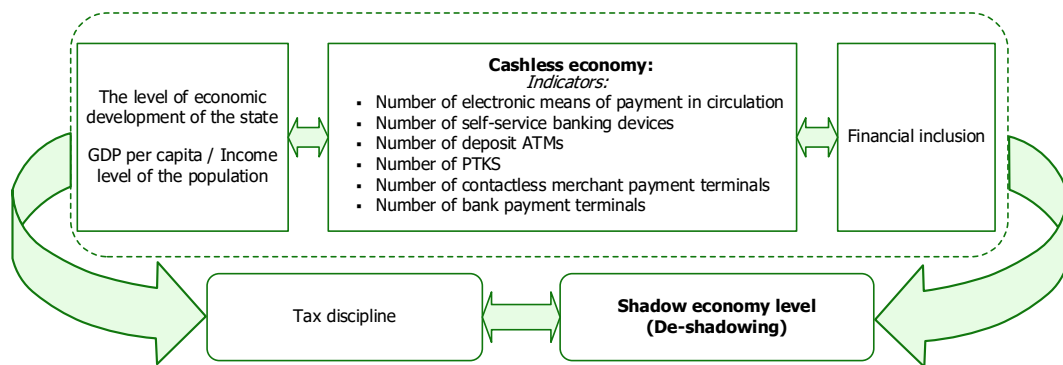


Figure 6. Conceptual model of the impact of the cashless economy on the level of economic shadowing, considering the country's level of development.

At the same time, the development of cashless payments for both individuals and businesses simplifies the work of tax authorities, automatically improving tax discipline. Tax discipline, combined with greater transparency in taxpayer transactions, ultimately leads to a reduction in the level of economic shadowing. Taking this into account, cashless payments and financial inclusion can become key drivers in reducing the shadow economy, strengthening tax discipline, and increasing tax revenues to the state budget.

Taking into account the results of the study, the priority vectors of state policy in the field of digitalisation of payment systems in order to minimise the shadowing of economic processes should, in our opinion, be the following:

1. Stimulating non-cash payments to increase the level of fiscal discipline and transparency. It is necessary to expand further the network of POS terminals and the use of PRRO (program registrars of settlement operations). This should be an imperative requirement of the state for all business structures.
2. Stimulating the development of financial inclusion of the population through the expansion of digitalisation processes. State policy should focus on stimulating the development of mobile banking, its simplicity, and convenience for users. In particular, the development of mobile banking is important for state banks, through which the population receives the bulk of social payments, particularly in rural areas.
3. Automation of tax monitoring. Tax monitoring should focus on using data on digital non-cash payments of the population and businesses to strengthen tax discipline without increasing administrative pressure on businesses from the state.

DISCUSSION

The spread of cashless payments and the digitalisation of banking activities is theoretically expected to influence the scale of the shadow economy. Indeed, even one of the most widely recognised and objective approaches to estimating the size

of the shadow economy – the monetary method – relies on the dynamics of non-cash monetary circulation as a key analytical benchmark. At the same time, empirical evidence concerning the relationship between the cashless economy and the shadow sector remains ambiguous, both in our study and in a number of thematically related investigations. A generalisation of the analysed scholarly findings suggests that the digitalisation of payments may strengthen tax discipline; however, its effectiveness largely depends on a broader set of factors, including the quality of institutions, macroeconomic conditions, and behavioural patterns of economic agents. This conclusion is supported, for instance, by the study conducted by Das et al. (2023), published in the *Journal of Public Economics*. The authors demonstrate that restrictions on access to cash may contribute to higher tax revenues by increasing the ability of tax authorities to detect and tax financial transactions conducted within the digital environment.

Similarly, a cross-country analysis of 57 states carried out by Teshaboev et al. (2021) reveals a stable negative relationship between the volume of card transactions and the size of the informal sector. The authors examined the determinants of the shadow economy using a wide range of indicators, including GDP per capita, unemployment, tax discipline, economic structure, and the use of digital payment instruments. The latter demonstrated a statistically significant mitigating effect on informal activity, thereby supporting the transparency hypothesis: the easier it is to track financial transactions, the lower the level of economic shadowing.

Mastac (2025) investigated the impact of cashless payments on the VAT gap. The findings indicate that within the EU, an increase in the volume of digital payments is closely associated with a reduction in the VAT gap – that is, the difference between expected and actual VAT revenues collected by the state. However, this trend is not accompanied by a proportional decline in the overall size of the shadow economy. Similar results were obtained by Przekota et al. (2025), who prove that the key factor limiting the shadow economy in EU countries is economic growth (growth in GDP per capita), while the share of card non-cash payments reflects more an increase in the general level of welfare of the population rather than acting as an independent determinant of de-shadowing. The findings of our study are broadly consistent with this conclusion. When assessed through specific indicators of digital customer service infrastructure, the development of the cashless economy demonstrates only a moderate influence on de-shadowing processes. In other words, the cashless economy itself cannot be regarded as an autonomous driver of de-shadowing in either Ukraine or Poland.

The experience of Greece further highlights the importance of institutional determinants in reducing the informal sector. Koufopoulou et al. (2021) estimate the average size of Greece's shadow economy at approximately 37.63%, a figure that exceeds the estimates reported in several other studies and indicates that other factors, such as income inequality, poverty, and labour force participation, exert a stronger influence on de-shadowing processes than the spread of cashless payments. Likewise, Kounadeas (2023), analysing the relationship between the shadow economy and tax revenues, finds no statistically significant correlation between these indicators. Thus, in the case of Greece, the digitalisation of payments does not automatically translate into improved fiscal performance.

Research by Marmora and Mason (2021) identifies an inverse relationship between the shadow economy, the use of cashless payments, and the velocity of cash circulation. According to their estimates, a 1% increase in underground economic activity reduces the impact of payment technology development on the velocity of cash circulation by 0.3%. This suggests that the transformative potential of payment innovations may be neutralised when the shadow sector expands.

Awasthi and Engelschalk (2018) emphasize that encouraging cashless payments will have a limited effect without a systemic approach to tax compliance management, including expanding tax authorities' access to data and the ability to compare it.

Ukrainian scholars have also addressed these issues. Studies by Tyvonchuk and Khusnullin (2024), Kononenko et al. (2024), and Budnyk et al. (2024) demonstrate that digital technologies may simultaneously contribute to de-shadowing and create new forms of the so-called "digital shadow economy." This is particularly relevant during the period of full-scale war, when the stability of electronic payment systems becomes an element of the state's economic security. Our research similarly indicates that, in Ukraine, digital payment instruments may serve not only as tools of transparency but also as additional platforms for shadow economic activity.

Furthermore, Fang et al. (2026) show that crime and shadow economic activity significantly hinder the development of digital financial inclusion in China. At the microeconomic level, Rahman et al. (2022) demonstrate that the adoption of cashless payment systems by enterprises depends on technological compatibility, organisational competence, managerial support, and competitive pressure. In turn, a low level of technological acceptance among employees constrains the macroeconomic impact of digitalisation.

Therefore, under conditions of effective institutional governance, the development of the cashless economy can contribute to reducing the scale of shadow economic processes and narrowing certain tax gaps. Nevertheless, it cannot be regarded

as a single decisive factor capable of eliminating the informal sector entirely. Rather, the transition to a cashless economy should be viewed as an important component of a broader and comprehensive state strategy that combines the development of digital infrastructure, improvements in tax administration, the strengthening of legal frameworks, cybersecurity measures, and other institutional reforms.

CONCLUSIONS

Under the conditions of ongoing military aggression, combating the shadow economy represents one of the key ways to strengthen the financial autonomy of the state. Expanding financial inclusion and promoting the use of cashless payments, therefore, remain among the priority directions of economic reform in Ukraine.

The study managed to prove the theoretical dependencies of the parameters of the development of the cashless economy and the shadow economy, while also revealing a number of unexpected correlations. The calculations indicate a moderate inverse relationship (Fechner coefficient -0.5) between the development of payment infrastructure, including self-service payment terminals, POS terminals, and banking self-service devices, and the scale of GDP shadowing. That is, the automation of financial services acts as an effective mechanism for weakening cash-based channels of economic transactions, which constitute one of the fundamental elements of the shadow sector. The digitalisation of banking services and the transparency of financial transactions create tangible barriers to the concealment of real incomes by both households and business entities. At the same time, the analysis revealed an unexpected positive correlation (Fechner coefficient $+0.75$) between the growth in the number of electronic payment instruments in circulation and the level of the shadow economy. Such results point to a certain institutional distortion in the processes of banking digitalisation in Ukraine. In conditions of declining tax discipline, partly driven by military aggression, financial instability among economic agents, and imperfect legislative regulation of cooperation between banking institutions and tax authorities, electronic financial instruments become new channels for conducting shadow transactions. At the same time, internationally, in countries such as Poland, the development of the cashless economy correlates with the level of the shadow economy. Consequently, the expansion of cashless banking payments and the corresponding financial infrastructure can serve as a key lever in combating the illegal sector of the economy.

For Ukraine, however, the potential role of payment digitalisation in de-shadowing processes is currently weakened by the absence of a comprehensive approach to the fiscalisation of digital financial flows and by the insufficient adaptation of the institutional environment to effective cooperation between banks and tax authorities. At the same time, taking into account the results obtained, the priority areas of the state policy of de-shadowing the economy should be the stimulation of the cashless economy. In a systemic combination, the transparency of financial transactions, the expansion of financial inclusion, and the automation of tax monitoring are key driving forces in reducing the size of the informal economy and a strategic tool for increasing tax revenues to the state budget. The patterns identified in this study highlight the need not only to stimulate technological innovations in cashless payments but also to shift the financial monitoring system and integrate digital control tools into the overall tax reform strategy of the state.

The subject of further scientific research will be the assessment of the possibilities of expanding the use of digital payment instruments to reduce the shadow economy and the study of the risks of cyber threats and financial fraud in this context in different countries, as well as other economic and financial factors of de-shadowing. Since the digitalisation of the payment space is a powerful, but not self-sufficient factor in the shadow economy, it is necessary to expand the horizon of research into the possibilities of minimising the informal economy in the era of technological transformations.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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The Authors declare that there is no conflict of interest.

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ОЦІНКА ВПЛИВУ РОЗВИТКУ ЦИФРОВИХ ПЛАТІЖНИХ ІНСТРУМЕНТІВ НА РІВЕНЬ ТІНІЗАЦІЇ ЕКОНОМІЧНИХ ПРОЦЕСІВ: МІЖНАРОДНИЙ ТА НАЦІОНАЛЬНИЙ КОНТЕКСТ

Стрімкий розвиток цифровізації платіжної царини та зростання її ролі в досягненні прозорості фінансових потоків і в світі, і в Україні актуалізує дослідження в цьому напрямі для вироблення рекомендацій щодо формування ефективної державної фінансової та фіскальної політики. Метою нашого дослідження є оцінити ефективність упровадження цифрових фінансових інструментів у послабленні тіньових економічних процесів для визначення пріоритетних напрямів державної політики в галузі цифровізації платіжної царини.

Досліджено взаємозв'язок між поширенням цифрових платіжних інструментів і динамікою тіньової економіки на прикладі України та Польщі. Для оцінювання щільності та напряму зв'язку між цими показниками застосовано метод кореляції Фехнера, що дозволило визначити узгодженість тенденцій змін відповідних показників у досліджуваних країнах. Результати дослідження свідчать про наявність оберненого статистичного зв'язку між зростанням частки безготівкових операцій і скороченням рівня тіньової економіки, що підтверджує детінізаційний потенціал цифровізації платіжної інфраструктури. Величина коефіцієнтів кореляції (0,5) доводить, що для боротьби з тіньовою економікою необхідно вживати заходів також у податковій галузі, галузі інституційного забезпечення, правової бази та фінансів загалом. Водночас виявлено значне використання електронних платіжних засобів і депозитних банкоматів у неформальній економіці в Україні, що потребує підвищення ефективності контролю за використанням цих інструментів.

У дослідженні враховано також рівень доходів у країнах і чітко простежено, що в країнах із вищими доходами вища частка безготівкових розрахунків і нижчий рівень тіньової економіки.

Ключові слова: тіньова економіка, цифрові платіжні інструменти, безготівкова економіка, платіжні термінали, банківські пристрої самообслуговування, детінізація, фінансова інклюзія

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