

E-Government Development, Corruption Perception, and Tax Burden: A Panel Regression Analysis of Shadow Economy Determinants in the EU Countries

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Abstract: The aim of the study is to assess the impact of digitalisation, institutional transparency, and tax burden on the scale of the shadow economy in European Union (EU) countries in order to formulate strategic guidelines for Ukraine. The study employed correlation analysis, multiple regression analysis, robustness testing, and logical structure analysis. The results revealed that an increase in the Corruption Perceptions Index (CPI) by one point reduces the share of the shadow economy by 0.2604 percentage points ($p = 0.0026$), highlighting the critical role of institutional transparency and anti-corruption policy in the de-shadowing process. Tax burden demonstrated a positive and statistically significant relationship with the shadow economy (coefficient = 0.1843; $p = 0.0125$), indicating that excessive fiscal pressure may stimulate informal economic activity. The E-Government Development Index (EGDI) retained a positive but only marginally significant effect (coefficient = 50.3170; $p = 0.0667$), suggesting that digitalisation becomes effective primarily when embedded in public administration systems. In contrast, the overall level of digital development measured by DESI was not statistically significant after controlling for institutional and fiscal factors (coefficient = -0.2476 ; $p = 0.1037$). The constructed multifactor model demonstrated high explanatory power ($R^2 = 0.8503$), while robustness analysis confirmed the stability of the core findings across alternative model specifications. The results

indicate that digitalisation alone is insufficient to reduce informality and that its effectiveness depends on institutional quality and balanced fiscal policy. The practical value of the study lies in identifying policy directions for Ukraine, including the expansion of e-government tools, digital tax administration, integrated data analytics, and anti-corruption measures aimed at reducing the shadow economy.

Index Terms: Informal Economy, Tax Administration, E-Government, Public Administration, Financial Opacity, Corruption Perception, Transparency, Institutional Environment.

1. Introduction

The rapid diffusion of digital technologies has fundamentally reshaped mechanisms for overseeing economic transactions and improving regulatory effectiveness. Within the European context, the advancement of digital transformation has coincided with a persistent decline in shadow economic activities, suggesting that digitalisation serves as an important instrument for strengthening transparency, accountability, and compliance [1]. The COVID-19 pandemic, despite its economic shocks, stimulated the shift to cashless payments and online transactions, making many operations more visible to the state. According to the European Commission (EC), VAT (Value Added Tax) losses in the EU sharply dropped by €38 billion in 2021 compared to 2020 – from €99 billion to €61 billion (i.e. from 9.6% to 5.3% of expected revenue) [2]. This unprecedented improvement is partly attributed to the digital leap: the growth of online sales and e-payments, and the strengthening of electronic tax oversight after 2020. Against this background, countries with a history of significant tax evasion issues made the greatest progress: in Italy, the VAT gap decreased by 10.7 percentage points, and in Poland – by 7.8 percentage points in just 2020–2021, thanks to the active implementation of digital tax administration tools [2].

In this context, studying the experience of European countries gains special importance for Ukraine. The deeply rooted shadow economy, shaped by both historical and current factors, creates a specific basis for analysis [3].

The relevance of this study stems from a contradiction. On one hand, there is an undeniable need to reduce the shadow sector through digital transformation tools. On the other hand, there is a lack of comprehensive understanding as to which determinants of digitalisation play a decisive role in the conditions of Ukraine's wartime economy.

The aim of the study is to identify the main determinants of the impact of digitalisation, institutional transparency, and tax policy on the scale of the shadow economy in the EU countries in order to define strategic guidelines for digital de-shadowing in Ukraine. The aim was achieved through the fulfilment of the following research objectives:

- conduct a quantitative analysis of the interrelationships between the level of digitalisation, institutional transparency, fiscal characteristics, and the scale of the shadow sector based on EU country data;
- construct a multifactor regression model to assess the strength and direction of the influence of key factors on the level of informality, taking into account their interdependencies;
- analyse best European practices in digital tax administration and formulate recommendations for their adaptation in Ukraine under wartime economic conditions.

Recent studies increasingly confirm that digitalisation can reduce the shadow economy, yet this relationship is neither automatic nor institutionally neutral. Syed et al. [4] showed that digital finance may decrease informal economic activity by expanding financial inclusion and making transactions more visible, while Rahman et al. [5] reached similar conclusions for BRICST economies, emphasising the role of financial technologies and financial development. However, these findings mainly explain the financial channel of de-shadowing and do not fully clarify whether general digital maturity is sufficient to reduce informality. Boitan and Ștefoni [6], analysing EU countries, demonstrated that digitalisation affects the shadow economy through both the use and quality of digital technologies, whereas Bojan and Achim [7] confirmed that ICT infrastructure may reduce tax avoidance in EU countries. At the same time, these studies mostly treat digitalisation as a broad technological environment, leaving less attention to the distinction between general digital development and digitalisation embedded specifically in public administration. A more institutionally focused perspective is offered by studies on e-government and public digital services. Doan et al. [8] showed that e-government can reduce the shadow economy by strengthening administrative transparency, simplifying interaction with public authorities, and increasing trust in formal procedures. Sacchi et al. [9] also found that e-participation contributes to reducing the shadow economy because it creates a more collaborative environment between the state, citizens, and businesses. Brici and Achim [10] further demonstrated that the digitalisation of public services is associated with a lower level of economic and financial crime, although this effect may differ between developed and developing countries. These findings are important because they suggest that digital tools are more effective when they are not isolated technological solutions, but part of governance systems, administrative control, and public accountability. Another important line of research concerns the institutional conditions under which digitalisation operates. Yamen et al. [11] showed that digitalisation reduces tax evasion more effectively in countries with lower levels of corruption, which means that corruption can weaken the anti-shadow effect of digital transformation. Similarly, Achim et al.

[12] confirmed that technology matters for combating economic and financial crime, but its effectiveness depends on the broader institutional and regulatory environment. Zhanabekov [13], using a robust determinants approach, also showed that better institutional quality reduces the shadow economy, whereas complicated regulation and excessive bureaucratic burden increase it. These findings indicate that the shadow economy cannot be explained only by technological indicators: institutional transparency, corruption control, and regulatory quality remain central explanatory factors. The fiscal dimension of de-shadowing is also ambiguous. Alm [14] argued that technology may strengthen tax enforcement and reduce evasion, but it can also deepen inequality or create new compliance asymmetries if institutional capacity is weak. Uyar et al. [15] demonstrated that education and digitalisation jointly reduce tax evasion, suggesting that technological reforms require complementary social and administrative conditions. Therefore, excessive fiscal pressure without trust, administrative convenience, and digital control may stimulate informal behaviour rather than reduce it.

Thus, the literature shows two unresolved issues. First, previous studies usually confirm a negative association between digitalisation and the shadow economy, but they do not sufficiently distinguish between general digital development, digital finance, ICT infrastructure, and e-government capacity. Second, many studies examine digital, institutional, or fiscal determinants separately, while their combined effect within one empirical framework remains less developed. This study addresses this gap by simultaneously assessing digitalisation, e-government development, institutional transparency, and tax burden, thereby identifying which determinants retain explanatory power after controlling for their interrelationships. The main contribution of the study is the empirical demonstration that the anti-shadow effect of digitalisation is conditional rather than universal: digitalisation becomes more relevant when embedded in public administration and supported by institutional transparency and balanced fiscal policy.

2. Methodology and Empirical Data

For the analysis, statistical data for 2023–2025 were collected using official reports from Schneider [16], Tax Justice Network [17], Transparency International [18], United Nations [19], European Commission [20], Heritage [21], World Bank Group [22, 23]. The structure of the database was formed in a way to cover the main indicators reflecting digitalisation, transparency levels, tax characteristics, and the scale of the shadow economy in the EU countries. Each of the included indicators had a clear analytical purpose.

- 1) GDP – Gross domestic product per capita (USD), used as a basic indicator of the country's economic development level, which influences the level of participation in the shadow economy.
- 2) LossGDP (% of GDP) – an indicator of tax revenue losses due to shadow economic activity, used to assess the fiscal consequences of economic informality.
- 3) CPI – Corruption Perceptions Index, chosen as an indicator of institutional quality, directly influencing the scale of the shadow sector.
- 4) TB (% of GDP) – tax burden as a share of gross domestic product, considered for the analysis of fiscal incentives or deterrents for participation in the shadow economy.
- 5) EGDI – UN E-Government Development Index, selected to assess the digital capacity of public administration.
- 6) TR (% of GDP) – total level of tax revenues as a percentage of GDP according to World Bank data, used to assess the effectiveness of the fiscal system.
- 7) SS – Financial Secrecy Index, chosen as an indicator of favourable conditions for tax opacity and evasion.
- 8) SE (% of GDP) – estimate of the shadow economy volume as a share of GDP, which served as the main dependent variable in the study.
- 9) DESI – the EC's Digital Economy and Society Index considered for a comprehensive assessment of the digital maturity of society.

Table 1 presents the baseline parameters used as the foundation for constructing a multifactor regression model aimed at identifying the determinants of national economic informality.

Table 1. Baseline Data for Assessing the Impact of Digitalisation and Transparency on the Shadow Economy in EU Countries.

Country	GDP	LossGDP	CPI	TB	EGDI	TR	SS	SE	DESI
Austria	46338.96	0.30	67	46.3	0.9065	25.79	55	7.05	54.7
Belgium	44731.04	0.90	22	50.6	0.8145	22.71	53	16.03	50.3
Bulgaria	9819.57	0.20	43	94.2	0.8356	21.73	53	33.05	37.7
Greece	21139.19	0.30	49	45	0.8618	27.64	53	20.93	38.9
Denmark	61295.98	0.10	90	80.8	0.9847	30.42	49	9.73	69.3
Estonia	20123.42	0.20	76	77.6	0.9727	20.76	44	24.44	56.5
Ireland	91647.77	0.10	77	72.6	0.911	16.79	47	10.13	62.7
Spain	28569.84	0.60	56	57.4	0.9206	15.5	57	15.81	60.8
Italy	34088.09	0.40	54	79.9	0.8415	24.5	55	20.32	49.3

Cyprus	32341.3	0.10	56	76.2	0.8886	23.33	62	23.9	48.4
Latvia	16703.9	0.30	59	76.9	0.8852	24.23	55	19.94	49.7
Lithuania	18685.55	0.20	63	73.5	0.9118	21.1	51	22.36	52.7
Luxembourg	106342.8	0.20	81	62.7	0.8446	25.97	55	8.25	58.9
Malta	33000.59	0.10	46	70	0.8886	22.34	54	23.37	60.9
Netherlands	51305.63	1.10	78	54	0.9382	23.26	65	8.21	67.4
Germany	44336.78	0.90	75	60.5	0.9382	11.01	57	8.81	52.9
Norway	78912.33	0.10	81	62.4	0.9315	31.27	53	10.4	64.3
Poland	17391.14	0.60	53	73.8	0.8618	17.12	46	21.89	40.5
Portugal	22292.42	0.90	57	59.8	0.8466	22.89	57	15.71	50.8
Romania	12399	0.50	46	93.7	0.7636	16.16	59	29.03	30.5
Slovak Republic	19238.76	0.40	59	76.7	0.8021	19.44	53	13.06	43.4
Slovenia	25708.87	0.20	60	56.6	0.8744	18.18	36	22.08	53.4
Hungary	16282.83	0.30	41	85.3	0.8121	23.43	55	25.44	43.8
Finland	37970.13	0.20	88	68.2	0.9577	21.2	52	10.83	69.6
France	39117.48	0.70	67	54.3	0.8674	24.47	48	14.21	53.3
Croatia	17147.17	0.20	47	77.3	0.8818	21.65	53	29.67	47.5
Czech Republic	20245.66	0.60	56	78.9	0.8239	12.64	50	14.9	49.1
Sweden	54449.8	0.70	81	51.6	0.9326	27.6	27	10.8	65.2

Source: Schneider [16], Tax Justice Network [17], Transparency International [18], United Nations [19], European Commission [20], Heritage [21], World Bank Group [22, 23], Centre of Economic Strategy [24]

The study employed a correlation analysis using the Pearson coefficient. The assessment of relationships preliminarily determined which factors are most associated with changes in the shadow sector. The method of multiple linear regression was also applied. The model was built with the shadow economy level as the dependent variable and included several independent variables: DESI, EGDI, CPI, SS, TR, TB, GDP, and LossGDP. The regression analysis quantitatively assessed the degree of influence of each factor individually while controlling for other variables. The model parameters were estimated using the least squares method. The statistical significance of the coefficients was tested at the $p < 0.05$ level. During the model construction, multicollinearity was checked by calculating variance inflation factors (VIF), which helped to avoid distortions in the regression analysis results (Table 2).

Table 2. Variance Inflation Factor Diagnostics.

Variable	VIF
GDP	2.91
DESI	4.89
CPI	3.48
TB	1.99
EGDI	4.68
LossGDP	1.77
TR	1.35
SS	1.15

Source: calculated by the authors

The calculated VIF values ranged from 1.15 to 4.89 and remained below the commonly accepted threshold of 5.0. The highest values were observed for DESI (4.89) and EGDI (4.68), reflecting the conceptual similarity of these indicators as measures of digitalisation. Nevertheless, the results do not indicate problematic multicollinearity, suggesting that the estimated coefficients are sufficiently stable and reliable for interpretation. Therefore, all explanatory variables were retained in the final regression specification.

The correlation analysis made it possible to identify statistically significant relationships between the shadow economy size and a number of macroeconomic and institutional variables. However, despite the informativeness of the correlation matrix, it did not account for interdependencies among the independent variables and their combined effect on the outcome. For this reason, the study moved on to constructing a multiple regression model, which made it possible to assess not only the strength but also the direction of the influence of each factor while controlling for other parameters.

$$SE = \beta_0 + \beta_1GDP + \beta_2DESI + \beta_3CPI + \beta_4TB + \beta_5EGDI + \beta_6LossGDP + \beta_7TR + \beta_8SS + \varepsilon$$

A total of 28 EU Member States were selected for the study. This choice was determined by the fact that EU countries operate within a harmonised regulatory environment, share common approaches to the development of digital technologies, e-governance, and the fight against the shadow economy. This creates the necessary conditions for an

objective comparative analysis without significant distortions because of differences in legal or economic systems.

The sample included all 28 EU Member States available at the time of data collection, representing the full cross-sectional population of the European Union rather than a randomly selected subset. Therefore, the study was designed as an exploratory cross-sectional analysis aimed at identifying the key determinants of shadow economy variation across EU countries. Although the limited number of observations may constrain the generalisability of the findings, the risk of overfitting was mitigated through multicollinearity diagnostics, which confirmed acceptable VIF values for all explanatory variables, and by maintaining a theoretically grounded model specification.

A potential limitation of the study is the possibility of endogeneity between certain variables. In particular, digitalisation, institutional transparency, and the shadow economy may influence each other simultaneously. However, the primary objective of the study was to identify cross-sectional associations and assess the relative importance of the selected determinants rather than establish strict causal relationships. Therefore, the estimated coefficients should be interpreted as indicative of statistically significant relationships rather than definitive causal effects.

3. Results

3.1. Assessment of the Impact of Digitalisation on the Shadow Economy of European Countries

The dataset presented in Table 1 was used for a correlation analysis to examine the associations among core economic, institutional, and digital variables (Table 3).

Table 3. Correlation Matrix of the Relationships between Digitalisation, Transparency of Governance, and the Level of the Shadow Economy.

	<i>GDP</i>	<i>LossGDP</i>	<i>CPI</i>	<i>TB</i>	<i>EGDI</i>	<i>TR</i>	<i>SS</i>	<i>SE</i>	<i>DESI</i>
<i>GDP</i>	1								
<i>LossGDP</i>	-0.102	1.000							
<i>CPI</i>	0.597	-0.133	1.000						
<i>TB</i>	-0.346	-0.399	-0.184	1.000					
<i>EGDI</i>	0.347	-0.153	0.737	-0.294	1.000				
<i>TR</i>	0.336	-0.286	0.221	-0.231	0.220	1.000			
<i>SS</i>	-0.073	0.128	-0.232	0.162	-0.211	-0.071	1.000		
<i>SE</i>	-0.716	-0.298	-0.670	0.588	-0.422	-0.162	0.040	1.000	
<i>DESI</i>	0.646	-0.043	0.730	-0.394	0.791	0.294	-0.196	-0.684	1.000

Source: calculated by the authors

The results of the correlation analysis confirmed a clear link between economic development, the use of digital governance tools, tax transparency, and the scale of the shadow economy. The most noticeable inverse relationship was observed between GDP per capita and the size of the shadow economy ($r = -0.716$), which supports existing theoretical views: in wealthier countries, people are generally less likely to rely on informal economic activities. This can be explained by better living conditions, wider access to public services, and fewer reasons to avoid formal employment. A comparable pattern was found for the CPI, which showed a similarly strong correlation with the shadow economy ($r = -0.670$), underlining the significant role of institutional factors. In societies with high levels of corruption, informal work often becomes a way to cope with administrative barriers or to secure basic income.

The role of digitalisation indices – both EGDI and the broader DESI – is significant. In particular, EGDI showed a noticeable negative correlation with SE ($r = -0.422$), while DESI demonstrated a stronger one: $r = -0.684$. This finding is consistent with the view that digital governance may contribute to lower levels of informality. DESI also demonstrated strong correlations with CPI ($r = 0.730$) and EGDI ($r = 0.791$), suggesting a close association between digital development, institutional transparency, and e-government capacity. However, the subsequent regression analysis indicates that this relationship becomes less pronounced once other institutional and fiscal factors are simultaneously considered.

Special attention should be paid to the SS indicator of tax secrecy. Its correlation with SE was almost absent ($r = 0.040$), which at first glance contradicts expectations. However, such a weak correlation suggests that SS has different effects – not on the domestic informal economy, but rather on international evasion, financial optimisation, and losses from transnational capital flows. However, SS demonstrated a negative correlation with CPI ($r = -0.232$), EGDI ($r = -0.211$), and DESI ($r = -0.196$), allowing the assumption that in more digitalised and transparent countries, tax secrecy decreases. The findings are consistent with the view that digital platforms, open registries, and automatic information exchange may contribute to fiscal transparency.

Another trend identified was the positive correlation between TB and the size of SE – $r = 0.588$. This result pointed to the risk of overload: in cases where tax pressure is high but unsupported by digital infrastructure, the population and businesses are more likely to go underground. This was further supported by a moderately negative correlation between TB and EGDI ($r = -0.294$) and DESI ($r = -0.394$): a digital state relies less on crude rate increases and more on effective

administration, evasion detection, and analytics.

Another important group of relationships should also be highlighted. The level of tax revenues (TR) moderately correlated with GDP ($r = 0.336$) and DESI ($r = 0.294$), indicating that not tax rates, but rather the quality of administration, trust in the state, and digital convenience are the drivers of fiscal efficiency. TR also showed a negative correlation with TB ($r = -0.231$), which confirmed the idea that excessive tax pressure is not always a path to higher revenues, especially under weak digital capacity. These findings suggest that fiscal effectiveness may depend more on administrative quality, transparency, and digitalisation than on increasing tax pressure alone.

The results of estimating the multivariate linear regression model are presented in Table 4.

Table 4. Determinants of the Regression Model of the Impact of Digital Transformation, Transparency and Institutional Quality on the Shadow Economy Size in the EU Countries

Regression Statistics					
Multiple R	0.922139				
R Square	0.850341				
Adjusted R Square	0.787327				
Standard Error	3.386058				
Observations	28				
ANOVA					
	Df	SS	MS	F	Significance F
Regression	8	1237.751	154.7189	13.49443	2.371E-06
Residual	19	217.8424	11.46539		
Total	27	1455.594			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-2.0004	19.9561	-0.1002	0.9212	
GDP	-0.0001	0.0000	-1.4990	0.1503	
DESI	-0.2476	0.1449	-1.7092	0.1037	
CPI	-0.2604	0.0751	-3.4676	0.0026	
TB	0.1843	0.0668	2.7584	0.0125	
EGDI	50.3170	25.8718	1.9449	0.0667	
LossGDP	-4.6452	2.9158	-1.5931	0.1276	
TR	0.1100	0.1559	0.7057	0.4890	
SS	-0.1208	0.0943	-1.2814	0.2155	

Source: calculated by the authors

The obtained values confirmed the high quality of the model: the explanatory power ($R^2 = 0.85$) indicated that 85% of the variation in the shadow economy level is explained by the selected factors. The F-statistic = 13.49, and with a p-value < 0.001 , this suggests the model is statistically significant as a whole.

The regression results identified corruption perception and tax burden as the strongest statistically significant determinants of shadow economy variation across EU countries. In particular, a one-point increase in the Corruption Perceptions Index (CPI) was associated with a 0.26 percentage-point reduction in the shadow economy, highlighting the importance of institutional transparency and governance quality. Conversely, tax burden demonstrated a positive and statistically significant relationship with the shadow economy, suggesting that excessive fiscal pressure may encourage informal economic activity.

The role of digitalisation appeared more nuanced. EGDI exhibited a positive coefficient and was marginally significant ($p = 0.0667$), suggesting a complex interaction between e-government development and the size of the shadow economy. By contrast, the Digital Economy and Society Index (DESI) showed the expected negative coefficient; however, its effect did not reach conventional levels of statistical significance ($p = 0.1037$). Therefore, the results do not provide sufficient evidence to conclude that the overall level of digital economy development independently influences the shadow economy once institutional and fiscal factors are taken into account.

The remaining variables (GDP, LossGDP, TR, and SS) did not demonstrate statistically significant effects in the estimated specification. Consequently, their influence should be interpreted with caution and regarded as indicative rather than

conclusive

To verify the stability of the estimated relationships and assess the sensitivity of the results to model specification, a robustness analysis was conducted using an alternative regression model based on the strongest predictors identified in the baseline estimation (Table 5).

Table 5. Robustness Analysis of the Regression Results.

Variable	Baseline Model	Robustness Model
CPI	-0.2604**	-0.3716***
TB	0.1843**	0.2910***
EGDI	50.3170*	44.7681*
R ²	0.850	0.724
Adjusted R ²	0.787	0.689
F-statistic	13.49	20.98
p-value (F)	<0.001	<0.001

Note: *** p < 0.01; ** p < 0.05; * p < 0.10.

Source: calculated by the authors.

The results confirmed the stability of the core findings. Corruption perception remained negatively associated with the shadow economy, whereas tax burden and e-government development preserved the direction of their estimated coefficients. The simplified model retained substantial explanatory power ($R^2 = 0.724$; Adjusted $R^2 = 0.689$) and remained statistically significant ($F = 20.98$; $p < 0.001$). Consequently, the principal conclusions of the study remained stable across alternative model specifications, supporting the robustness of the estimated relationships.

Overall, the empirical results suggest that reducing the shadow economy depends not only on the level of digitalisation itself, but also on the quality of public governance and institutional transparency. The findings indicate that digital tools are most effective when integrated into tax administration and anti-corruption mechanisms.

3.2. Directions for the Implementation of European Digitalisation Practices to Reduce the Shadow Economy in Ukraine

Although the empirical model was estimated using EU-country data, the obtained relationships may provide useful analytical benchmarks for Ukraine. The purpose of the empirical analysis was not to directly forecast the size of the Ukrainian shadow economy, but rather to identify institutional and digital determinants that demonstrated consistent associations with lower levels of informality across countries operating within a developed regulatory environment. Therefore, the policy recommendations proposed for Ukraine should be interpreted as adaptation-oriented rather than directly transferable solutions, taking into account the specific economic and wartime conditions of the country.

Analysing the directions for implementing European experience in Ukrainian practice, it is important to systematise the key digital and institutional strategies that have proven effective in the field of de-shadowing. Table 6 presents a comparative overview of digital innovations in tax administration across selected EU countries that have demonstrated the highest efficiency in curbing informal economic activity.

Table 6. Institutional and Digital De-shadowing Strategies of the EU Countries in the Field of Tax Transformation.

Item No.	Country	Key digital instrument	Main result
1	Estonia	Digital ID, X-Road data exchange platform, fully digital tax administration	More than 98% of entrepreneurs submit tax reports online; the shadow economy declined from approximately 30% to 18% of GDP [25].
2	Italy	Mandatory e-invoicing through the SDI platform	VAT gap decreased from 21.6% in 2019 to 10.6% in 2021; additional budget revenues reached approximately €15 billion annually [26; 27].
3	Poland	SAF-T reporting, split-payment mechanism, KAS analytics platform	VAT gap fell from 24% in 2015 to 10.4% in 2021, making Poland one of the most successful de-shadowing cases in the EU [2; 28].
4	Greece	myDATA platform, online cash registers, incentives for cashless payments	The shadow economy declined from about 30% to approximately 21% of GDP, accompanied by improved taxpayer compliance [29–32].

Source: Kokkinidis [30], Cui and Yao [31], OECD [32], Newsroom [29], Boerhof [2], Sauka and Putniņš [25], Rödl & Partner [26], Ptak [28], European Commission [27]

The analysed EU experience demonstrates that successful de-shadowing is achieved not through digitalisation alone, but through the integration of digital tools into tax administration, data exchange systems, and compliance monitoring mechanisms. Despite differences in national approaches, all successful cases combined three common elements: digital transaction traceability, automated analytical control, and reduced reliance on cash-based economic activity.

According to official estimates by the Ministry of Economy of Ukraine [33], the shadow economy size showed relative stability during 2019–2022 with a tendency to increase up to 2021 and partial decline in 2022. In particular, in 2019 the share of the shadow sector amounted to 28% of GDP, in 2020 – 30%, in 2021 – 32%, and in 2022 – 30% of GDP (Figure 1). It should be emphasised that following the start of the full-scale invasion of Ukraine by the Russian

Federation in February 2022, the Ministry of Economy ceased publishing official quarterly reports on the shadow economy size.

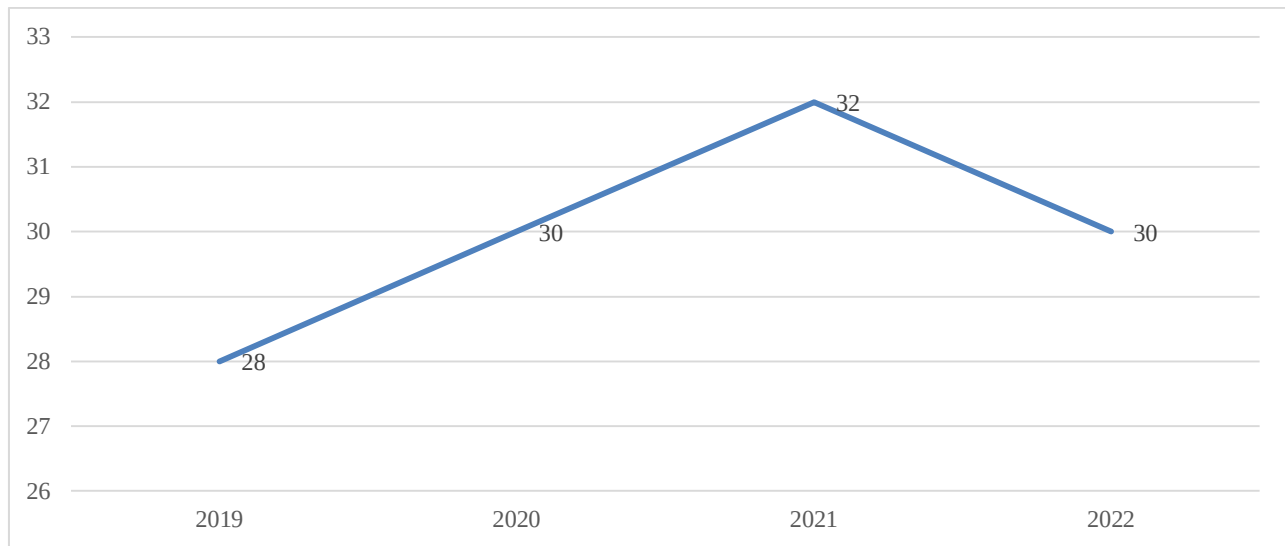


Fig. 1. Dynamics of the Shadow Economy Market in 2019-2022, % of GDP.
Source: Ministry of Economy of Ukraine [33]

Despite the progress achieved in digital transformation, Ukraine continues to demonstrate one of the highest levels of shadow economic activity in Europe. According to World Economics [34], the shadow economy accounted for 43.4% of GDP in 2023, substantially exceeding the average levels observed across EU countries.

It is worth noting that Ukraine has made a qualitative leap in the field of e-government. In the global UN EDGI 2022, Ukraine ranked somewhere in the middle of the first hundred, but by 2024 it had risen to 30th place, improving its position by 16 points [19]. In the E-Participation Index (citizen engagement in e-democracy), Ukraine ranked first in the world in 2024, a jump of 56 positions compared to 2022. This progress became possible due to the systematic work of the Ministry of Digital Transformation and the support of international partners. The development of online services has grown significantly: in the Online Services Index (OSI) subindex, Ukraine entered the top five countries in the world.

In this context, identifying the strategies implemented in EU countries becomes particularly valuable for Ukraine, which is actively developing a systemic policy of digital shadow economy reduction (Table 7).

Table 7. Strategic Directions for Reducing the Shadow Economy in Ukraine Based on Empirical Findings and European Experience.

Item No.	Empirical finding	Strategic direction for Ukraine	Practical implementation measures
1	Corruption perception (CPI) demonstrated the strongest negative association with the shadow economy	Strengthening digital transparency and reducing discretionary interactions between taxpayers and public authorities	Expansion of digital public services, integration of state registers, automation of tax procedures, electronic audit trails, open-data solutions, and minimisation of direct contact between businesses and tax officials
2	Tax burden (TB) showed a positive relationship with the shadow economy	Shifting from fiscal pressure to compliance-oriented tax administration	Simplification of tax reporting procedures, reduction of administrative barriers, expansion of risk-based tax monitoring, and wider use of automated compliance tools instead of increasing tax rates
3	EGDI showed a marginally significant and complex relationship with the shadow economy, indicating that e-government tools require targeted integration into tax administration rather than general digital expansion alone.	Further digitalisation of tax administration and public financial control	Mandatory e-invoicing for VAT transactions, full deployment of online cash registers, expansion of electronic taxpayer services, and development of integrated digital tax platforms
4	European experience (Italy, Poland, Estonia, Greece) confirmed the importance of data-driven supervision	Creation of a national analytical ecosystem for detecting tax evasion risks	Establishment of a Data Analytics Centre under the Ministry of Finance or State Tax Service, integration of customs, tax, banking and property databases, and implementation of big-data risk assessment mechanisms
5	Successful EU practices highlighted the importance of broad digital participation	Increasing digital inclusion and trust in digital public services	Digital literacy programmes for citizens and SMEs, expansion of broadband infrastructure, strengthening cybersecurity, and protection of personal data

Source: author's own developments

The empirical findings suggest that digitalisation should not be viewed as an isolated technological solution to the shadow economy problem. The results indicate that the effectiveness of digital reforms depends on their integration with institutional transparency and balanced fiscal policy. Consequently, the most promising strategy for Ukraine involves the simultaneous strengthening of e-government instruments, anti-corruption mechanisms, and compliance-oriented tax administration.

4. Discussion

The empirical results indicate that corruption perception is the most decisive factor explaining cross-country differences in the shadow economy, while high tax burden encourages informality and the contribution of digitalisation depends on its institutional context.

Several studies confirm that weak institutions and burdensome regulations underpin informality. A cross-country analysis by Schneider and Asllani [35], covering six EU states for 2003–2022, identified poor institutional quality, complex tax and regulatory systems and pervasive corruption as primary drivers of the shadow economy; the authors note that stronger institutions and simplified tax rules were responsible for reducing informality from 22.6 % to 17.3 % of GDP. Similarly, Achim and Mare [36], using panel data for 50 countries over thirteen years, found that income inequality and unemployment increase the shadow economy, whereas better governance is associated with lower informality; their GMM estimates suggest that institutional reforms are more effective than purely economic adjustments. These results are consistent with the strong negative coefficient of CPI in the present study and underscore that anti-corruption reforms and institutional strengthening should accompany digitalisation.

The empirical evidence on digitalisation is more nuanced. Haruna and Alhassan [37] report, for 42 African countries, that digitalisation – particularly telecom infrastructure and online service uptake – reduces the shadow economy; they argue that policymakers should prioritise digital technology to formalise hidden activity. Semaniuk and Kuchciak [38] highlight that modern accounting technologies and blockchain, if integrated with ethical standards, enhance transparency and reduce opportunities for corruption and shadow transactions. However, these studies do not explicitly separate general digital maturity from digital government capacity. The present analysis demonstrates that while the overall digital economy index (DESI) is not a significant determinant of informality, the e-government development index (EGDI) shows a marginally significant effect. This suggests that digital tools become effective only when embedded in public administration and accompanied by institutional reforms. The LASSO-based study by Agafitei et al. [39] on Central and Eastern European countries supports this interpretation: their results indicate that rule of law and governance indicators have stronger and more robust effects on reducing the shadow economy than digitalisation proxies; they conclude that digitalisation contributes to informality reduction but is secondary to institutional quality. The present findings align with this hierarchy.

The positive relationship between tax burden and the shadow economy is consistent with the classic “fiscal pressure” hypothesis and supported by the literature. Mara [40] argues that excessive taxation without efficient administration stimulates informal activity, while digital reforms in tax collection – such as e-invoicing – are only effective when combined with moderating tax rates. The Hungarian case examined by Ván et al. [41] reveals that digital fiscal devices (online cash registers) increase declared turnover mainly among small firms, leaving the tax contribution of larger firms mostly unaffected. The present results, where tax burden remains positively associated with informality even after controlling for digitalisation, corroborate the need to shift from fiscal pressure towards compliance-oriented tax administration.

Studies that integrate financial development and institutional quality yield similar messages. Ameer et al. [42] find that financial development decreases the shadow economy in both developed and developing countries only when accompanied by strong institutional quality; their comparative analysis shows that financial depth without institutional strength can instead widen informal activity. Silalahi [43] reports that ICT usage and tax policy interact with corruption to influence the shadow economy in G20 countries: digitalisation reduces informality only if corruption is low and tax systems are transparent. The current model’s results echo these findings: DESI alone does not reduce informality unless combined with corruption control and moderate tax burden.

While there is broad consensus that digitalisation can support de-shadowing, several works caution that its effect is conditional. Mastac, Trandafir and Nicodim [44] demonstrate that digitalisation and institutional quality are complements; when institutions are weak, digitalisation may even substitute for formal mechanisms and inadvertently sustain informal networks. This non-linearity may explain why EGDI displays a positive coefficient in the present study after controlling for other factors: e-government reforms may be more prevalent in high-informality contexts, making it difficult to detect their independent effect. Panel cointegration analysis for EU countries by Mara [40] likewise finds that digitalisation has a long-run de-shadowing effect only when coupled with legal enforcement and business compliance incentives.

There is also evidence that digitalisation interacts with human capital and education. Obelovska et al. [45], using DESI 2024 data, show that countries with stronger digital skills and infrastructure have higher tax compliance and lower informality; however, they stress that institutional reforms must accompany digital investments. Koeswayo, Handoyo and Hasyir [46] emphasise that public governance and corruption perception are closely related;

improvements in governance can strengthen the link between digitalisation and shadow economy reduction. Munteanu et al. [47] underline that education and governance improvements correlate with lower corruption and higher institutional trust, which indirectly reduce informal activity. These studies reinforce the present conclusion that digital tools must be part of broader institutional and educational programmes.

Cross-regional studies also point to the conditional nature of digital effects. Ajide and Dada [48] report that ICT investment reduces the shadow economy in West Africa, but the magnitude is modest compared with institutional factors. Eng and Lim [49] find that the informal economy's influence on GDP growth varies across ASEAN countries depending on governance and regulatory environments. Thus, generalising digitalisation effects without considering regional institutional contexts can be misleading; the present research supports this caution.

The present study faces limitations that mirror those noted in the literature. The cross-sectional design with 28 European countries provides a snapshot but cannot capture dynamic effects or reverse causality; countries with large shadow economies may invest more aggressively in digital reforms, producing positive EGDI coefficients. Endogeneity remains a concern, and future research could employ dynamic panel methods, instrumental variables or structural equation models.

The digital indices used (DESI, EGDI) are broad composites; disaggregating their components – such as internet access, open data portals or digital tax services – could reveal more specific mechanisms. Despite these limitations, the findings contribute to the debate by showing that digitalisation alone does not guarantee de-shadowing; instead, the combination of digital tools with transparent institutions and moderate fiscal pressure is the crucial pathway for reducing informal activity.

Empirically grounded policy implications follow from these comparisons. First, anti-corruption and transparency measures should be prioritised alongside digital reforms. Second, tax administration should move from increasing rates to simplifying procedures and adopting risk-based monitoring. Third, investment in e-government should focus on specific tools such as mandatory e-invoicing, online cash registers and integrated registers, complemented by national analytics centres for data-driven control. Finally, digitalisation strategies should include human capital development and digital literacy to ensure that businesses and citizens can participate effectively in formal economic channels. This analysis strengthens the argument that digital reforms are necessary but insufficient; their success depends on the institutional and fiscal environment in which they are implemented.

5. Conclusions

The study examined the relationship between digitalisation, institutional transparency, fiscal factors, and the shadow economy across European Union countries. The empirical analysis demonstrated that institutional quality remains the most influential determinant of shadow economy variation. In particular, an increase of one point in the Corruption Perceptions Index was associated with a reduction of the shadow economy by 0.26 percentage points, confirming that anti-corruption measures and transparent governance constitute the primary mechanisms for reducing informality. At the same time, tax burden exhibited a positive and statistically significant relationship with the shadow economy ($\beta = 0.1843$; $p = 0.0125$), indicating that excessive fiscal pressure may encourage economic agents to operate outside the formal sector.

The results also revealed that the impact of digitalisation is conditional rather than automatic. Although both DESI and EGDI demonstrated negative correlations with the shadow economy, only e-government development retained a marginally significant effect within the multivariate model, while the overall level of digital development was not statistically significant after controlling for institutional and fiscal factors. These findings suggest that digital technologies alone are insufficient for reducing informality. Their effectiveness depends on integration into public administration systems, tax monitoring mechanisms, and anti-corruption policies. The robustness analysis confirmed the stability of these conclusions across alternative model specifications.

The constructed regression model demonstrated high explanatory power ($R^2 = 0.8503$), indicating that the selected set of institutional, digital, and fiscal variables provides a reliable framework for explaining cross-country differences in shadow economy levels. The findings imply that successful de-shadowing strategies should prioritise institutional transparency, efficient tax administration, and the targeted use of digital governance instruments rather than relying solely on broad digital transformation initiatives.

For Ukraine, the results highlight the importance of adapting European practices that combine digital technologies with institutional reforms. Priority measures include the further expansion of electronic tax administration, wider implementation of e-invoicing and digital fiscal control instruments, enhanced integration of public databases, automated exchange of financial information, and risk-based taxpayer monitoring systems. However, the effectiveness of these measures will largely depend on strengthening anti-corruption institutions, improving regulatory transparency, and increasing digital literacy among businesses and citizens. Therefore, digitalisation should be viewed not as an independent solution to the shadow economy problem, but as a component of a broader institutional transformation aimed at increasing transparency, trust, and compliance within the formal economy.

All the Declarations and Statements

Author Contributions Statement

Inna Servatynska Korsun – Conceptualization, Methodology, Drafting - original draft.
Maryana Matveyeva – Conceptualization, Methodology, Writing - proofreading and editing.
Nataliia Tkachova – Data curation, Validation, and Formal analysis.
Svitlana Kustova – Project management, Resources, and Supervision.
Ihor Samsin – Resources, Visualization and Supervision.

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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Data Availability Statement

The data will be available from the corresponding author and will be made available upon request via email.

Ethical Declarations

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

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Declaration of Generative AI in Scholarly Writing

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Abbreviations

The following abbreviations are used in this manuscript:

EU - European Union
CPI - Corruption Perceptions Index
EC - European Commission
VAT - Value Added Tax
GDP - Gross domestic product
CPI - Corruption Perceptions Index
TB - tax burden
TR - tax revenues
EGDI - E-Government Development Index
SS - Financial Secrecy Index
DESI - Digital Economy and Society Index
VIF - variance inflation factors
OSI - Online Services Index
MoF - Ministry of Finance of Ukraine
MCAA CRS - Multilateral Competent Authority Agreement on Automatic Exchange of Financial Account Information
ICT - Information and Communication Technologies

APPENDIX

None.

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