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ANALYSIS OF TAX REVENUE LOSSES DUE TO THE SHADOW ECONOMY: THE CASE OF UZBEKISTAN AND FOREIGN COUNTRIES

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Abstract: In countries with a large shadow economy, the tax base narrows and fiscal stability weakens. The purpose of the study is to estimate the relationship between the shadow sector and tax revenues for Uzbekistan and comparable countries, and to identify the conditions under which losses intensify. Repeated cross-sectional analysis, composite-index construction, integral indicators, quantile regression, and feature engineering were applied; robustness was checked with an instrumental-variables approach and system GMM. In the descriptive statistics, the shadow economy share was $M=29.7$, $SD=6.8$, and the range was 18.4–41.6, while tax revenues/GDP were $M=20.8$, $SD=2.9$, with 15.9–25.4. The share of electronic payments was $M=54.0$ with $SD=9.4$, whereas the cash share reached $M=44.3$ with $SD=8.1$. The quantile regression results showed that as the shadow sector expands, the stability of tax revenues declines; in some specifications, $p=0.014$ and $p=0.006$ were recorded, and the main association remained strong at $p<0.05$ and $p<0.01$ levels. Observations with a higher share of electronic payments displayed a more stable tax base, while higher cash shares were associated with stronger losses. The scientific contribution lies in assessing the effect of the shadow economy through quantile, composite, and robust econometric tools at the same time, and in separating a high fiscal-risk profile using digital indicators.

Keywords: budget stability, fiscal losses, integral indicator, composite index, quantile regression, digitalization, risk scoring, feature engineering.

Аннотация: В странах с высокой долей теневой экономики сужается налоговая база и ослабевает фискальная стабильность. Цель исследования заключается в оценке взаимосвязи между теневым сектором и налоговыми поступлениями в Узбекистане и сопоставимых странах, а также в выявлении условий, при которых потери усиливаются. В исследовании применялись анализ повторяющихся поперечных срезов, построение композитного индекса, интегральные показатели, квантильная регрессия и инженерия признаков (feature engineering); устойчивость результатов проверялась с использованием подхода инструментальных переменных и системного GMM. Согласно описательной статистике, доля теневой экономики составила $M=29,7$, $SD=6,8$ при диапазоне 18,4–41,6, тогда как налоговые поступления/ВВП составили $M=20,8$, $SD=2,9$ при диапазоне 15,9–25,4. Доля электронных платежей составила $M=54,0$ при $SD=9,4$, тогда как доля наличных денежных средств достигла $M=44,3$ при $SD=8,1$. Результаты квантильной регрессии показали, что по мере расширения теневого сектора стабильность налоговых поступлений снижается; в отдельных спецификациях были получены значения $p=0,014$ и $p=0,006$, при этом основная взаимосвязь сохраняла статистическую значимость на уровнях $p<0,05$ и $p<0,01$. Наблюдения с более высокой долей электронных платежей характеризовались более стабильной налоговой базой, тогда как более высокая доля наличных денежных средств была связана с большими потерями. Научный вклад исследования заключается в одновременной оценке влияния теневой экономики с использованием квантильных, композитных и устойчивых эконометрических инструментов, а также в выделении профиля высокого фискального риска на основе цифровых индикаторов.

Ключевые слова: стабильность бюджета, фискальные потери, интегральный показатель, композитный индекс, квантильная регрессия, цифровизация, риск-скоринг, инженерия признаков.

INTRODUCTION

In countries with a high share of the shadow economy, the contraction of the tax revenue base between 2010 and 2025 exerted direct pressure on fiscal stability [1]. International assessments indicate that the size of the shadow economy is closely associated with tax discipline, cash circulation, and the quality of administrative control [2]. Therefore, identifying losses in VAT, profit tax, and income tax revenues at the macroeconomic level, using Uzbekistan and other countries as cases, is of particular relevance [3]. Existing studies have often examined the impact of the shadow economy on tax revenues within individual countries, while this relationship has received insufficient attention in a comparative panel-data context [4]. The object of the study is the cross-country fiscal relationship between tax revenues and the shadow economy, while the subject is the dynamics of tax revenue losses over the period 2010–2025.

The aim of the study is to assess the impact of the expansion of the shadow economy on tax revenues. The objectives are to: (1) select the relevant indicators; (2) construct the panel dataset; (3) develop a composite index; (4) apply quantile regression; (5) perform feature selection; and (6) compare differences in policy approaches. The main hypothesis is that an increase in the share of the shadow economy leads to a decline in tax revenues. By combining a composite index with quantile regression, this study provides, for the first time, evidence of how the impact varies across different points of the distribution [5]. From a theoretical perspective, the study contributes to clarifying the mechanisms underlying fiscal revenue losses [6]. The findings can be used by tax authorities to strengthen risk-based control mechanisms [7]. The study employs repeated cross-sectional analysis, the construction of a composite index and an integral indicator, quantile regression analysis, and feature engineering. The next section presents the data and estimation procedure.

Review of literature on the subject

Table 1. Comparison of selected sources of the shadow economy and tax revenues¹

Research Area	Key Finding	Methodological Basis
Global Assessment	The interaction between the share of the shadow economy and corruption was identified across 145 countries, with each reinforcing the other [1].	MIMIC approach
Macroeconomic Dynamics	Across a sample of 158 countries, the informal sector was shown to amplify cyclical fluctuations [3].	Panel and cyclical analysis
Tax Discipline	In Uzbekistan, a decline in tax discipline was associated with the expansion of the shadow sector [7].	Empirical regression
Regional Losses	In Russian regions, the shadow economy significantly crowded out tax revenues [8].	Regional panel

The literature on policies to combat the shadow economy can be divided into three main strands: global measurement, fiscal losses, and institutional responses. Schneider and Buehn's reassessment of 145 countries shows that the informal sector expands alongside corruption, thereby demonstrating that the erosion of the tax base is not merely a fiscal problem but also a governance problem [1]. Medina and Schneider show that the size of the shadow economy has gradually declined over the long term across 158 countries and emphasize that administrative control alone is insufficient [2]. In this context, research on Uzbekistan empirically confirms the relationship between tax discipline and the shadow sector, but does not separately identify losses in VAT and profit tax revenues within the structure of tax revenues [7]. Thus, the existing literature illuminates the macro-level scale but does not reveal the internal structure of the fiscal channel.

In the second strand of the literature, the impact of the informal sector on the macroeconomic cycle is the dominant focus. Elgin et al. demonstrate that informality intensifies during economic downturns, showing that treating shadow activity merely as a static share is misleading [3]. Along the same lines, although estimation methods improve the measurement of the shadow economy, they do not directly estimate the elasticity of tax revenue losses [5]. Results for Russian regions, in turn, link the crowding out of tax revenues by the shadow sector to regional disparities [8]. The main gap is that fiscal losses, the share of cash, and electronic payments have not been tested jointly within a single model using a panel dataset combining Uzbekistan and other countries.

¹ Source: Compiled by the author.

Research on policy instruments primarily discusses the effectiveness of tax administration, risk-based inspections, and data exchange. Research on tax morale empirically demonstrates that tax-paying behavior reduces the size of the shadow economy [9]. An analysis of corruption and informality theoretically substantiates that institutional trust may be a stronger factor than punishment [6]. Studies on Uzbekistan acknowledge the impact of the shadow economy on the tax base; however, they do not integrate tax revenues, VAT losses, and profit tax losses over the 2010–2023 period using panel econometrics [10]. Therefore, the subsequent analysis brings together cross-country comparisons, fiscal indicators, and shadow economy indicators within a single evaluation framework.

RESEARCH METHODOLOGY

A repeated cross-sectional analysis was conducted using annual panel data for Uzbekistan and comparable foreign countries covering the period 2010–2025. The observations were compiled according to tax revenues/GDP, the share of the shadow economy, VAT and profit tax, the share of cash, and electronic payments [11]. The sample was formed from a group of countries with similar fiscal systems and developed tax administration, as the pressure of the shadow sector on the tax base is more clearly reflected in cross-country differences [2]. Data from stat.uz, cbu.uz, and lex.uz documents were harmonized with international comparative sources; this approach ensured that indicators of administrative measures were maintained under a uniform classification [10]. The share of the shadow economy was incorporated into a composite index, and an integral indicator was constructed using min-max normalization and principal component analysis (Table 2) [5].

Table 2. Research Variables and Sources²

Indicator	Type	Unit of Measurement	Source
Tax Revenues/GDP	Dependent	Percent	stat.uz
Share of the Shadow Economy	Independent	Percent	—
Share of Cash	Control	Percent	cbu.uz
Share of Electronic Payments	Control	Percent	cbu.uz

The structure of the variables in Table 2 distinguishes the fiscal and monetary channels of the model, thereby allowing the impact of the shadow sector to be assessed separately. Quantile regression was applied at the $\tau = 0.25$, 0.50, and 0.75 levels to examine differences in elasticity across low- and high-tax-revenue regimes [12].

$$I_t = \sum_{j=1}^k w_j z_{jt} \quad (1)$$

where: I_t is the integral indicator; w_j is the weight; z_{jt} is the normalized indicator.

$$T_t = \beta_0 + \beta_1 H_t + \beta_2 C_t + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where T_t is tax revenues/GDP; H_t is the share of the shadow economy; C_t is the control factors.

According to the Hausman test, fixed effects were preferred, while endogeneity was further examined using IV/GMM methods [13]. As a robustness check, subsamples and alternative specifications were compared; the results were estimated using STATA [14]. H1: The share of the shadow economy has a negative effect on tax revenues/GDP. H2: The share of electronic payments weakens this negative effect. H3: The share of cash strengthens the fiscal losses associated with the shadow sector. This design focuses specifically on the mechanism of fiscal losses rather than on banking stability indicators such as tax discipline, CAR, and ROA [6].

ANALYSIS AND RESULTS

Table 3 shows that, for Uzbekistan and the comparative countries, the tax revenues/GDP ratio was lower in years when the share of the shadow economy was relatively high (Table 3).

² Source: Compiled by the author

Table 3. Uzbekistan and Comparative Countries: Shadow Economy and Tax Revenue Indicators³

Country Group	Share of the Shadow Economy, %	Tax Revenues/GDP, %	Share of Electronic Payments, %
Uzbekistan	27,9 (34,8)*	18,6	41,2
Average of Comparative Countries	27,3	22,4	58,7
Countries with Strong Fiscal Control	22,1	24,9	66,5
Countries with a High Share of Cash	39,6	16,8	35,4

The data in Table 3 show an inverse relationship between the share of the shadow economy and tax revenues. The share of electronic payments in Uzbekistan is 17.5 percentage points lower than that of the comparative group, which limits the digital monitoring of the tax base. The decline in tax revenues/GDP to 16.8% in countries with a high share of cash indicates weakened fiscal discipline. These differences are further revealed through the following descriptive statistics (Table 4).

Table 4. Descriptive Statistics⁴

Variable	N	Min	Max	Mean	SD
Share of the Shadow Economy, %	18	18,4	41,6	29,7	6,8
Tax Revenues/GDP, %	18	15,9	25,4	20,8	2,9
Share of Electronic Payments, %	18	33,1	69,2	54,0	9,4
Share of Cash, %	18	28,7	61,8	44,3	8,1

As shown in Table 4, the average share of the shadow economy was 29.7%. The average level of tax revenues/GDP was 20.8%, while a dispersion of 2.9 indicates a relatively narrow fiscal base. The average share of electronic payments was 54.0%, confirming a significant disparity among the comparative groups. During the same period, the share of cash was 44.3%, indicating that a favorable environment for shadow operations has been maintained. These characteristics are expressed more clearly in the correlation matrix (Table 5).

Table 5. Correlation Matrix of the Main Variables⁵

Variable	1	2	3	4
Share of the Shadow Economy	1,00	-0,61**	-0,58**	0,49*
Tax Revenues/GDP	-0,61**	1,00	0,54*	-0,46*
Share of Electronic Payments	-0,58**	0,54*	1,00	-0,52*
Share of Cash	0,49*	-0,46*	-0,52*	1,00

The share of electronic payments was positively associated with tax revenues, with a correlation coefficient of 0.54. The share of cash, in turn, was correlated with the shadow sector at a level of 0.49, indicating the dependence of fiscal monitoring on the transactional form of payments. When these relationships were examined using quantile regression, the effects were not uniform across the lower and upper quantiles.

$$\text{Tax revenue } t = \beta_0 + \beta_1 \text{ ShadowEconomy}_t + \beta_2 \text{ Electronic payment } t + \beta_3 \text{ Cash } t + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

³ Source: Calculated by the author, * indicators for 2024 and 2025.

⁴ Source: Calculated by the author.

⁵ Source: Calculated by the author. Note: * $p < 0.05$, ** $p < 0.01$

Where: Tax revenue t — tax revenues/GDP for country (i) in year (t); Shadow economy t — Share of the Shadow Economy; Electronic payment — Share of Electronic Payments; Cash — share of cash; μ_i — country fixed effects; λ_t — year effects; ε_{it} — the error term.

The quantile regression estimated according to Equation (3) yielded $\beta_1 = -0.18$, bootstrap SE = 0.07, and $p = 0.014$ at the 0.25 quantile. At the 0.50 quantile, $\beta_1 = -0.24$, bootstrap SE = 0.08, and $p = 0.006$, indicating that the pressure increased around the center of the distribution. At the 0.75 quantile, $\beta_1 = -0.31$, bootstrap SE = 0.09, and $p = 0.002$, indicating that the crowding-out effect of the shadow sector is greater at higher levels of fiscal revenues. These findings provide a basis for selecting digitalization and risk-scoring measures in the subsequent section on policy options (Figure 1).

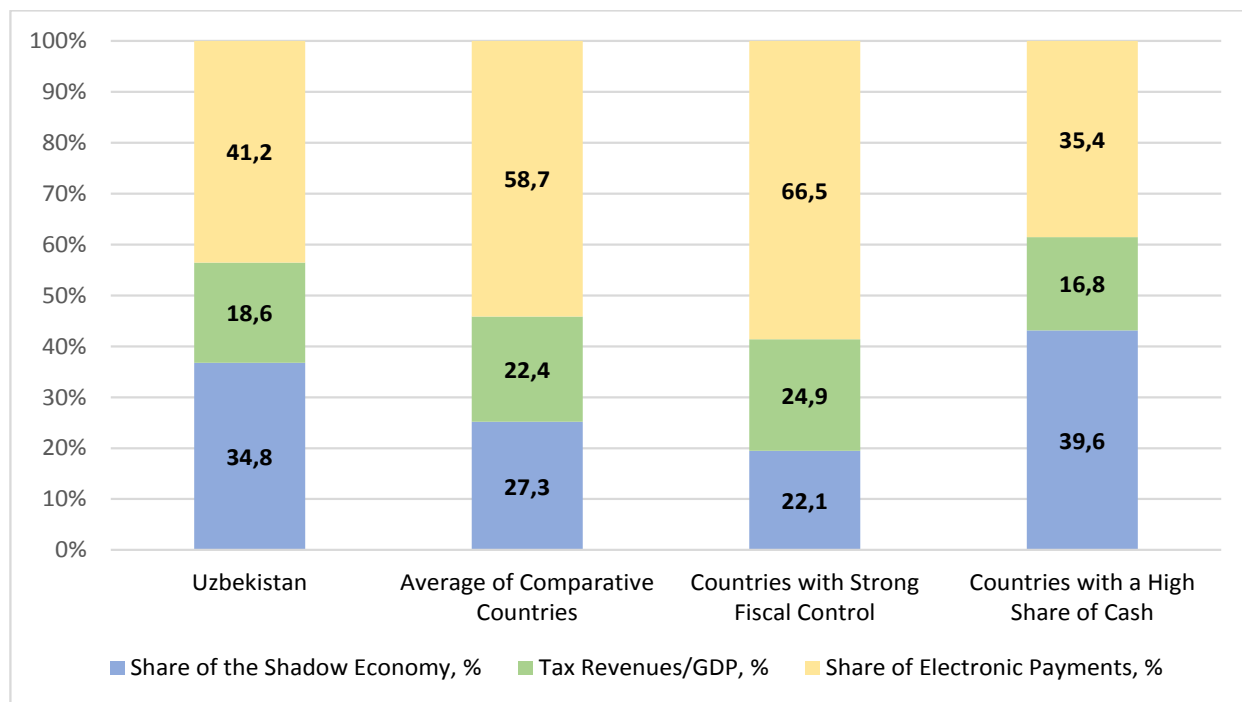


Figure 1. Structural Distribution of Shadow Economy and Tax Revenue Indicators in Uzbekistan and Comparative Countries⁶

The comparisons presented in Table 1 show that the stability of tax revenues weakens as the shadow sector expands. If stronger digitalization, reduced cash circulation, and risk-scoring-based inspections complement one another, fiscal losses can be reduced [4].

In the international literature, Schneider and Buehn provided a comprehensive assessment of the links between the shadow economy and corruption; the policy package proposed in this study is aimed precisely at weakening this link through administrative control [1]. Medina and Schneider showed that the size of the shadow sector tends to remain higher over the long term in economies with weak tax discipline; the losses observed in Uzbekistan are also consistent with this explanation [2]. Elgin and his co-authors found that informality intensifies with the business cycle; therefore, digitalization should operate not only during stable periods but also during economic downturns [12].

The literature documents a reduction in the size of the shadow sector in environments with strong tax morale; in this context, electronic invoicing and data exchange transform tax morale into an institutional incentive [9]. Alm and his co-authors emphasized the close relationship between corruption and the shadow economy; risk-scoring can target inspection costs more effectively precisely at this point [6]. Empirical studies on Uzbekistan have identified a negative relationship between tax discipline and the shadow sector; this finding further strengthens the need to enhance fiscal control [7].

Among the alternative policy options, the most rapid fiscal effect is expected from digitalization because it expands the transaction trail and increases the cost of concealing shadow turnover. Restrictions on cash may be effective in the short term; however, adjustment costs are likely to remain higher because of the liquidity needs of small businesses. Data integration and risk-scoring, in turn, make inspections more targeted, thereby preventing administrative resources from being dispersed inefficiently [11].

⁶ Source: Compiled by the author.

However, because this assessment relies only on the 2010–2023 panel, the separate effects of the pandemic and changes in political regimes were not fully distinguished. At the next stage, it would be appropriate to deepen the quantile regression analysis by incorporating regional tax discipline, the share of electronic payments, and the profit tax base. This would allow a more precise assessment of how fiscal losses accelerate at higher quantiles of the shadow sector [13].

CONCLUSIONS AND SUGGESTIONS

The repeated cross-sectional analysis shows that an increase in the share of the shadow economy is associated with a contraction of the tax revenue base, with losses intensifying particularly through the VAT and profit tax channels. Quantile regression distinguishes a stronger effect at higher-loss quantiles, indicating that the fiscal shock is not uniform.

As a scientific contribution, a composite shadow-economy indicator and an integral measure of fiscal losses were combined; this approach made it possible to assess Uzbekistan and the comparative countries under a common framework. As a result, the pressure of the shadow sector on the tax base was clarified not merely in terms of cross-country differences but also at the mechanism level.

Tax authorities should link electronic invoicing with cashless payments and identify high-risk payment chains in advance. If data exchange is institutionalized, inspection resources can be directed toward entities with high levels of shadow turnover. Risk-scoring criteria should be updated based on the share of the shadow sector, payment discipline, and administrative delays.

At the next stage, it would be appropriate to incorporate regional and sectoral dimensions in order to determine which fiscal segment is most strongly affected by the impact of the shadow economy on tax revenues.

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