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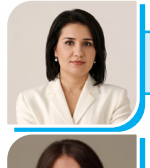
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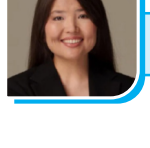
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MEASURING WHAT HIDES IN PLAIN SIGHT: A HYBRID, TRANSACTION-LEVEL FRAMEWORK FOR ASSESSING THE SHADOW ECONOMY IN A DIGITALISING ECONOMY

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Abstract: Conventional estimates of the shadow economy were designed for cash-based economies and increasingly misread a reality in which value is created and concealed through platforms, e-commerce and digital intermediaries. This paper develops and tests a hybrid, transaction-level framework for assessing the shadow economy in a digitalising economy. Following a classification of direct, indirect, model-based and digital transaction-level methods, the paper specifies a triangulation design in which a macro top-down estimate, a micro bottom-up estimate built from e-invoice, online-cash-register and QR/POS data, and an institutional calibration layer are reconciled into an estimate band with a documented structural residual. The framework is operationalised for Uzbekistan with a 2017–2024 regional panel and a six-indicator risk-scoring module. The share of the informal and hidden economy in GDP fell from 45.6% to 34.3%, while its nominal volume rose 3.13-fold and grew 2.5–3.9-fold in every region. The decline in the informal component reduced the potential volume by 187.0 trillion UZS, whereas the rising share of the hidden component added a structural residual of 13.8 trillion UZS, concentrated in Samarkand, Namangan, Fergana and Khorezm regions. The paper contributes a four-family taxonomy of methods, a reproducible triangulation protocol that reports bands rather than point estimates, a regional indicator panel and risk-scoring architecture that connect measurement to risk-based enforcement, and evidence that relative and absolute measures of informality must be reported together.

Key words: shadow economy measurement; non-observed economy; MIMIC; tax gap; e-invoicing; digital footprints; risk scoring; triangulation; regional analysis; Uzbekistan.

Аннотация: Традиционные методы оценки теневой экономики разрабатывались для экономики, основанной на наличных расчётах, и недостаточно отражают условия, в которых стоимость создаётся и скрывается через платформы, электронную торговлю и цифровых посредников. В статье разработана гибридная система оценки теневой экономики на уровне транзакций. На основе классификации методов на четыре группы предложен протокол триангуляции, сводящий макро-, микро- и институциональные данные в интервальную оценку с документированным структурным остатком; протокол применён к Узбекистану с использованием региональной панели за 2017–2024 годы и модуля риск-скоринга из шести показателей. Доля неформальной и скрытой экономики в ВВП снизилась с 45,6% до 34,3%, тогда как её номинальный объём вырос в 3,13 раза. Снижение доли неформальной составляющей уменьшило потенциальный объём на 187,0 трлн сумов, а рост доли скрытой составляющей сформировал структурный остаток в 13,8 трлн сумов, сосредоточенный в Самаркандской, Наманганской, Ферганской и Хорезмской областях.

Ключевые слова: измерение теневой экономики, ненаблюдаемая экономика, MIMIC, налоговый разрыв, электронные счета-фактуры, цифровые следы, риск-скоринг, триангуляция, региональный анализ, Узбекистан.

INTRODUCTION

Every estimate of the shadow economy is an estimate of something that, by definition, resists observation. The field has therefore advanced not by finding a single correct measure but by multiplying imperfect ones and learning how their biases differ [1; 2; 3]. In an economy where retail is settled through QR codes, where micro-enterprises trade on marketplaces and where income is earned through platforms and settled through

fintech wallets, cash is no longer the main footprint of informality. At the same time, mandatory electronic invoicing, online cash registers, acquiring data from QR/POS terminals and unified identifiers make it possible to compare what an entity reports with what third parties observe about it — in near real time and at the level of the individual taxpayer.

Uzbekistan offers a clear setting for studying this transition. Between 2017 and 2024 the country combined liberalisation with a rapid roll-out of e-invoicing and online cash registers, and the share of the informal and hidden economy in GDP fell from 45.6% to 34.3% (26.9% in 2025 by preliminary data) [4]. Yet the regional picture is uneven — the share fell in every region, but at very different speeds, and in several regions the hidden component grew — while the absolute volume of informal and hidden activity rose more than three-fold. These features reflect the difficulty of measuring a digitalising economy with instruments calibrated on a cash economy.

The purpose of the article is to develop a hybrid, transaction-level framework for assessing the shadow economy that is both credible and actionable in a digitalising economy, and to apply it to the regions of Uzbekistan. The objectives are: to classify assessment methods into four families and specify what each can and cannot see; to formalise a triangulation protocol that reconciles macro, micro and institutional evidence into an estimate band with a documented structural residual; to operationalise the protocol with a regional indicator panel and a six-indicator risk-scoring module; and to show, on Uzbek data, that relative and absolute measures of informality must be reported together.

LITERATURE REVIEW

For three decades the dominant measurement tools were indirect macro proxies. The currency-demand approach of V. Tanzi infers hidden transactions from excess demand for cash [5]; its sensitivity to initial conditions and specification has been examined critically by H. Ahumada, F. Alvaredo and A. Canavese [6]. D. Kaufmann and A. Kaliberda used electricity consumption relative to recorded output [7], and S. Johnson and co-authors applied this logic to the transition economies, showing the scale of the unofficial economy after the collapse of central planning [8]. Latent-variable MIMIC models combine several causes and indicators into a relative index [9]; T. Breusch drew attention to the sensitivity of MIMIC estimates to calibration and benchmarking [10]. The OECD handbook on the non-observed economy set out the statistical framework within which national statistical offices estimate unrecorded activity in national accounts [11].

All of these families rest on an assumption that is now eroding: that hidden activity leaves its trace mainly in cash. In a digitalising economy, currency-demand estimates can fall while hidden activity migrates into digitally intermediated channels; dependent self-employment and platform work blur the line between formal and informal status [12; 13; 14]. Tax administrations have begun to use transaction-level data for risk-based audit [15; 13], and model-based work on trade mis-invoicing has extended measurement to illicit financial flows [16]. However, as V.Yu. Burov and co-authors noted in their systematic review, the literature remains divided between the question of “how much and where” and the question of “what to do and to whom” [17].

The author’s earlier studies examined methodological aspects of assessing the hidden economy in the digital economy [18], the experience of advanced foreign countries in using digital technologies against the hidden economy [19] and practical aspects of combating the hidden economy in Uzbekistan [20], and these results were generalised in a monograph [21]. The present article develops this line by integrating transaction-level evidence into national and regional estimates and by reporting estimates as bands with a documented structural residual.

RESEARCH METHODOLOGY

Taxonomy of assessment methods

Figure 1 organises the methods into four families. Direct (bottom-up) methods — household and business surveys, tax audits, labour-force modules — observe agents and transactions directly but suffer from non-declaration, selectivity and cost. Indirect (top-down) macro methods infer hidden activity from discrepancies: excess currency demand, electricity or physical-input use relative to recorded output and gaps between the income and expenditure sides of national accounts. Model-based methods treat the shadow economy as a latent variable (MIMIC) or embed it in structural or DSGE simulations and trade-mis-invoicing models of illicit financial flows. The fourth family, digital transaction-level methods, compares reported flows with flows observed by third parties — e-invoice chains, online cash registers, QR/POS acquiring, bank and customs records — and uses AI and Big-Data techniques to score entities by risk. The design principle that follows from the taxonomy is triangulation: no family is universal, and each has a known bias direction.

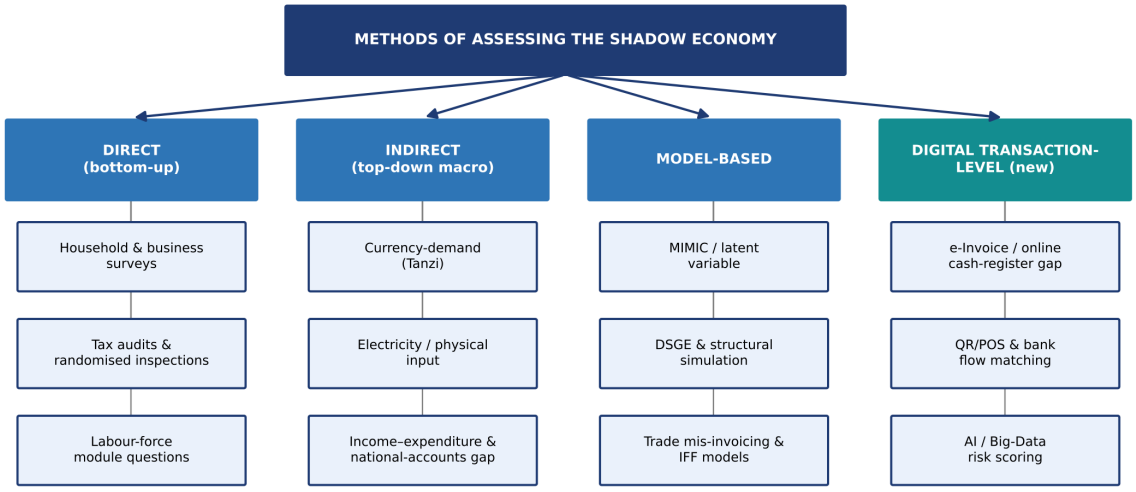


Figure 1. Four-family taxonomy of shadow-economy assessment methods
Source: developed by the author.

The historical sequence of the families is shown in Figure 2 as four waves. Each wave added granularity, timeliness and data integration; none fully displaced its predecessor. The present framework belongs to the fourth, hybrid wave. The properties of the families relevant to a digitalising economy are summarised in Table 1.

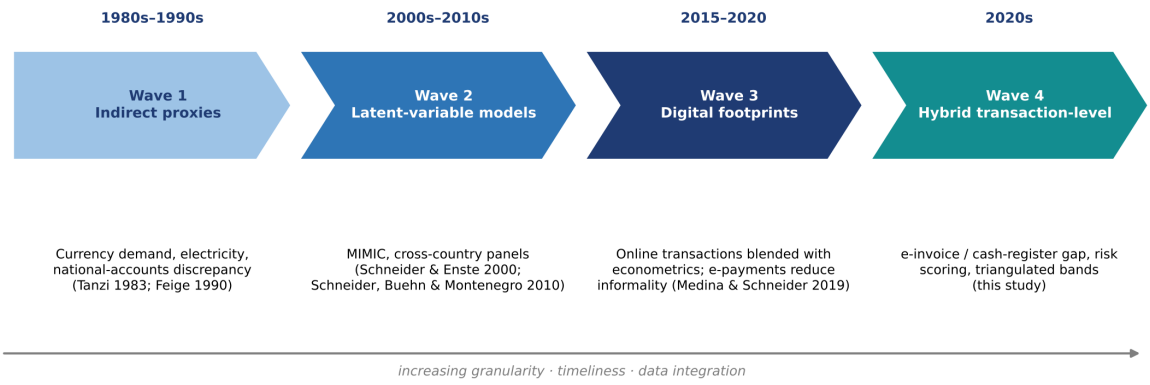


Figure 2. Four waves in the evolution of shadow-economy measurement
Source: developed by the author on the basis of the literature cited.

Table 1. Properties of the four method families relevant to a digitalising economy

Family	Unit of observation	Known bias direction	Visibility of digital-era informality
Direct	Agent / transaction	Downward (non-declaration)	Low unless surveys ask about platform income
Indirect macro	Economy / region	Unstable: the cashless shift breaks the proxy	Low; currency demand falls while platform informality rises
Model-based (MIMIC, DSGE)	Country panel	Relative index; calibration-dependent	Medium; depends on inclusion of digital indicators
Digital transaction-level	Entity / invoice / payment	Covers only entities inside the digital perimeter	High inside the perimeter; blind to fully off-grid activity

Source: compiled by the author.

The triangulation protocol

The protocol (Figure 3) has three vertices. The macro top-down vertex uses the official estimate of the informal and hidden economy, supported by currency- and energy-based checks and a MIMIC-style band. The micro bottom-up vertex constructs a tax-gap-type estimate from transaction data: declared sales versus e-invoice chains, cash-register receipts versus acquiring volumes, and sectoral value added implied by third-party data versus declared value added. The institutional calibration vertex uses audit outcomes, AML/CFT alerts and labour- and migration-register data to anchor the two estimates and to supply regional controls. The three are reconciled into an estimate band [lower; central; upper], and the part of the change in volume that is not explained by nominal scale effects is reported as a structural residual. Reporting bands rather than points makes methodological uncertainty explicit in the estimate itself [17].

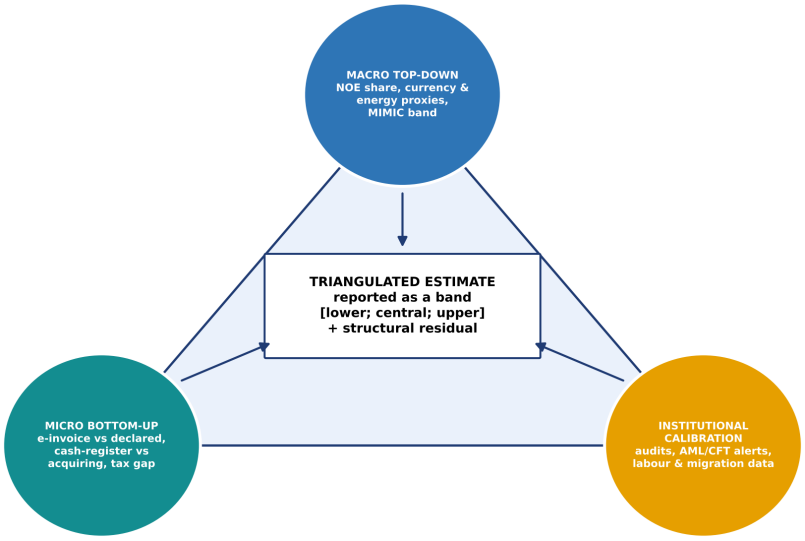


Figure 3. Triangulation protocol: three evidence vertices reconciled into an estimate band

Source: developed by the author.

Regional indicator panel and decomposition

For the empirical application, a regional panel for the Republic of Karakalpakstan, 12 regions and Tashkent city was assembled for 2017–2024. The outcome block uses the official estimates of the National Statistics Committee of the Republic of Uzbekistan, which distinguish the informal economy (activity carried out without registration) and the hidden economy (activity deliberately concealed from the authorities), in volume and as a share of GDP and GRP [4; 22; 23]. Table 2 lists the indicator blocks. Monetary variables are log-transformed; shares are in per cent of GDP or GRP.

Table 2. Indicator panel used to operationalise the framework

Indicator block	Indicators	Frequency / level	Source
Outcome	Share of informal and hidden economy in GRP; volume of informal and hidden components (bln UZS)	Annual / region	National Statistics Committee
Digital perimeter	e-invoice coverage; share of cashless turnover; QR/POS terminals per 1,000 firms; ICT-services GVA	Annual / region	Tax Committee; Central Bank; National Statistics Committee
Economic structure	Wholesale and retail turnover; active small-business entities; foreign-trade turnover; sector GVA	Annual / region	National Statistics Committee; Customs Committee
Institutional calibration	Audit yield; AML/CFT alerts; registered versus insured employment; migration outflows	Annual / region	Department for Combating Economic Crimes; Ministry of Employment
Infrastructure instruments	Mobile-internet subscribers; fibre-optic density	Annual / region	Ministry of Digital Technologies

Source: compiled by the author.

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The structural residual is obtained by decomposing the change in volume V = s·GDP between 2017 and 2024 into a scale component attributable to nominal GDP growth at the constant 2017 share and a share component:

$$\Delta V = s_0 \cdot (GDP_1 - GDP_0) + (s_1 - s_0) \cdot GDP_1, \qquad (1)$$

where s is the share in GDP (GRP) and the indices 0 and 1 denote 2017 and 2024. The share component is calculated separately for the informal and the hidden components; a positive share component of the hidden economy is interpreted as new structural hidden activity.

Risk-scoring module

The micro vertex is implemented as a five-step pipeline — ingest, link, derive, score, act — that resolves entities through unified identifiers, derives six indicators (cash share of receipts, e-invoice chain breaks, mismatch between reports and third-party data, tax-discipline history, cash-register-versus-acquiring gap and related-party anomalies), scales each to 0–100 and combines them into a weighted composite with sector-specific thresholds. The scores feed both the measurement layer (as inputs to the bottom-up estimate) and the action layer (risk-based audit, automated notices, incentives). Weights are calibrated on historical audit outcomes and re-estimated annually; the weights reported below are design values and serve as a calibration starting point.

ANALYSIS AND RESULTS

One national trend, several regional stories

The share of the informal and hidden economy in GDP fell from 45.6% in 2017 to 34.3% in 2024 and 26.9% in 2025 [4]. Figure 4 shows that this average is the net of very different regional trajectories. Navoi region, whose economy is dominated by large industrial and mining enterprises operating inside the digital reporting perimeter, cut the share from 37.2% to 17.5% of GRP; its hidden component is also the lowest in the country (2.5%). In Namangan (63.5% → 53.0%) and Samarkand (57.6% → 49.5%) regions the total share also declined, but much more slowly, and the hidden component moved in the opposite direction — from 9.2% to 14.6% in Namangan and from 6.0% to 10.6% in Samarkand [23]. The institutional calibration layer relates these increases to unregistered domestic trade, migration-related income flows and incomplete reporting in tourism-related small business — segments that lie largely outside the digital perimeter and are therefore invisible to transaction-level methods but visible to labour- and migration-register data. In 2024 the highest total shares were recorded in Surkhandarya (56.2%), Khorezm (54.9%), Namangan (53.0%) and Kashkadarya (52.9%) regions.

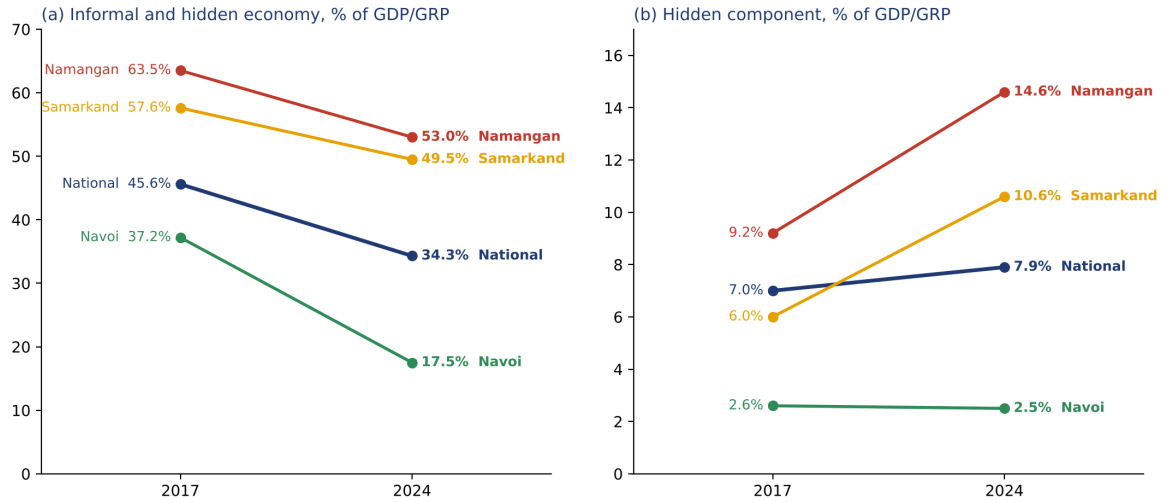


Figure 4. Informal and hidden economy and its hidden component, % of GDP/GRP, 2017 and 2024: national level and three contrasting regions

Source: compiled by the author on the basis of [4; 22; 23].

Relative decline, absolute growth

Measured in volume rather than share, informal and hidden activity grew in every region between 2017 and 2024, by 2.5–3.9 times (Figure 5). In Kashkadarya region the volume rose from 15.5 to 44.5 trln UZS, in Namangan from 11.8 to 38.1, in Fergana from 15.0 to 46.0, in Samarkand from 17.8 to 51.4 and in Tashkent city

from 19.6 to 76.4 trln UZS [23]. Nationally the volume rose from 168.6 to 527.4 trln UZS, a 3.13-fold increase [4].

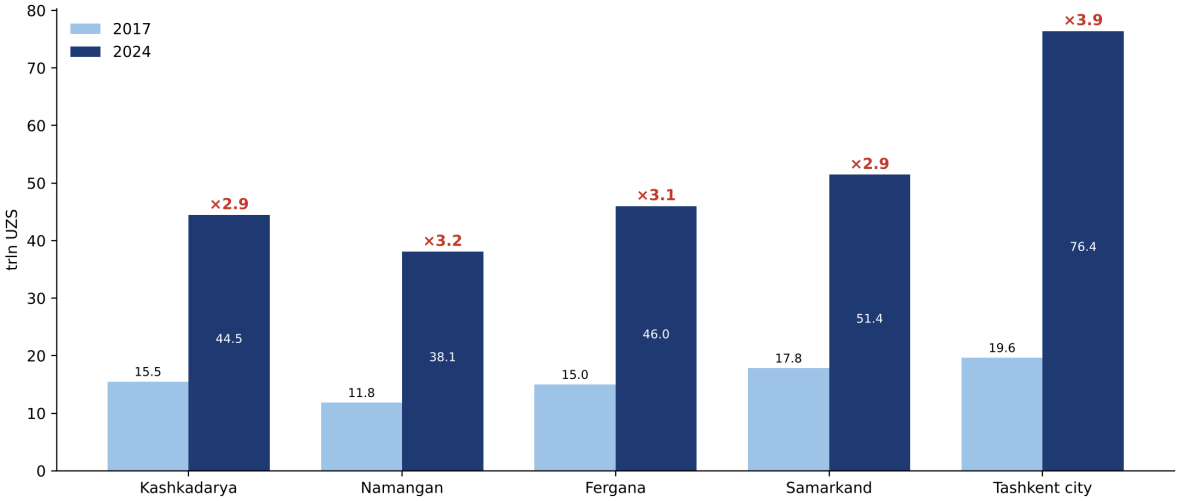


Figure 5. Volume of the informal and hidden economy in five regions, 2017 and 2024, trln UZS, with growth multiples
Source: author's calculations on the basis of [23].

Decomposition (1), based on nominal GDP of 369,612.8 bln UZS in 2017 and 1,535,431.7 bln UZS in 2024 [24], shows that at the constant 2017 share nominal GDP growth alone would have raised the volume by 531.9 trln UZS. The decline in the share of the informal component subtracted 187.0 trln UZS from this counterfactual, whereas the increase in the share of the hidden component from 7.0% to 7.9% of GDP added 13.8 trln UZS [22]. This 13.8 trln UZS is the structural residual — new hidden activity that escapes digital control; it equals about 3.8% of the nominal increase in volume (358.7 trln UZS). Regional calculation of the same residual for the hidden component (Table 3) shows that it is concentrated in Samarkand, Namangan, Fergana and Khorezm regions, which together account for about 13 trln UZS, while in Tashkent city, Karakalpakstan and Navoi region the share of the hidden component slightly decreased.

Table 3. Structural residual of the hidden component by region, 2017–2024

Region	Hidden share 2017, % of GRP	Hidden share 2024, % of GRP	Structural residual $(s_1 - s_0)\cdot GRP_1$, trln UZS
Samarkand	6.0	10.6	4.78
Namangan	9.2	14.6	3.89
Fergana	10.0	12.7	2.53
Khorezm	8.0	11.4	1.82
Jizzakh	6.2	8.4	0.96
Andijan	7.8	8.8	0.93
Kashkadarya	10.7	11.7	0.84
Surkhandarya	8.0	9.1	0.62
Other regions	—	—	from −0.60 to 0.29

Source: author's calculations on the basis of [23]; GRP for 2024 is derived as the ratio of the hidden-economy volume to its share. Because shares are published rounded to 0.1, the sum of regional residuals differs from the national value.

The reading for measurement practice is that relative and absolute indicators answer different questions and must be reported together: the share measures reform effectiveness, while the structural residual measures the frontier of new hidden activity and shows where it is located.

Digital growth and hidden activity

The information and communication sector is the core of the digital perimeter. In 2023 its gross value added amounted to 21,103 bln UZS, or 2.1% of GDP, having grown by 24.2% in real terms compared with 2022 [25]. Over 2017–2025 the share of the informal and hidden economy declined steadily, and the decline was driven by the informal component, while the hidden component remained at 7.0–7.9% of GDP (Figure 6).

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A naïve reading would attribute the whole decline to digitalisation. The triangulation protocol cautions against this: in the sectoral regressions underlying this research the coefficient on ICT-services value added was initially large and positive (+2.06), consistent with digital services themselves being a locus of unrecorded activity; a Durbin–Wu–Hausman test (3.14, p = 0.076) indicated endogeneity, and an instrumental-variable re-estimation using mobile-internet subscribers and fibre-optic density as instruments reduced the coefficient to +0.87. The corrected estimate implies that digital growth reduces informality only when digital flows are bound to compulsory reporting; otherwise part of the growth is itself hidden. This is precisely the segment that macro proxies miss and transaction-level methods capture.

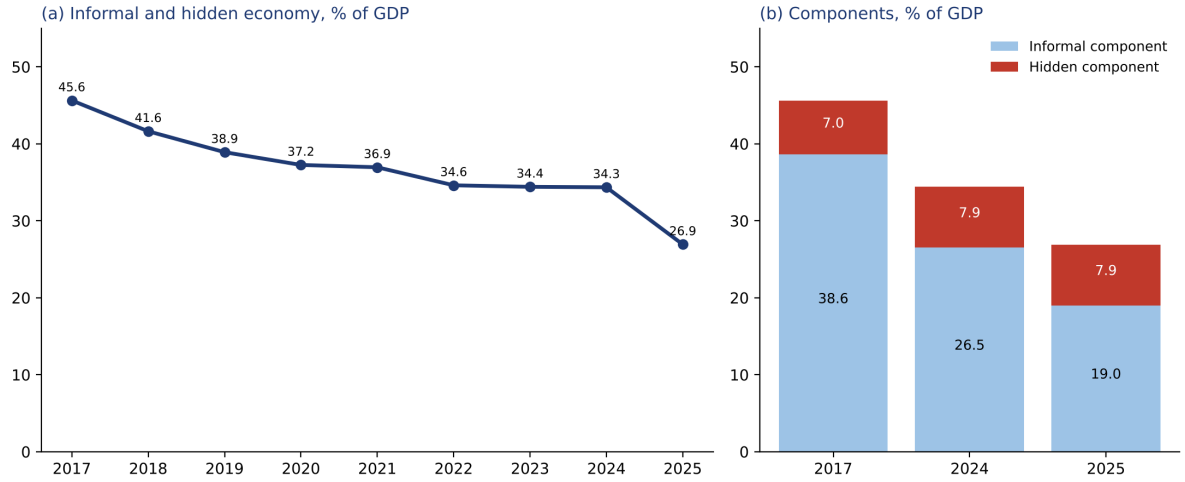


Figure 6. (a) Share of the informal and hidden economy in GDP, 2017–2025, %; (b) its informal and hidden components, % of GDP

Source: author's calculations on the basis of [4; 22; 24]; 2025 data are preliminary.

The micro vertex: indicators and risk scores

Table 4 reports the six indicators of the risk-scoring module, their derivation and the design weights. Figure 7 illustrates the pipeline and contrasts two stylised indicator profiles: a high-risk entity with a high cash share, broken e-invoice chains and large report-to-third-party mismatches, and a compliant entity whose profile stays below 25 on every axis. Aggregating entity scores by sector and region yields the bottom-up estimate of unreported turnover that enters the triangulation band, while the same scores direct audits towards the top risk decile. In this way measurement and enforcement draw on one data pipeline, which is the practical meaning of "hybrid" in the framework.

Table 4. Risk-scoring indicators of the micro vertex (design weights; calibrated annually on audit outcomes)

Indicator	Derivation	Design weight	Primary data
Cash share of receipts	Cash receipts / total receipts, compared with sector median	0.20	Online cash registers, acquiring
e-Invoice chain breaks	Invoices without matching counter-party invoice / total	0.20	e-Invoice system
Report versus third-party mismatch	|Declared turnover − observed inflows| / declared turnover	0.20	Tax returns, bank, customs
Tax-discipline history	Late filings, arrears, prior adjustments (index)	0.15	Tax Committee
Cash-register versus acquiring gap	Registered sales − card/QR settlements (normalised)	0.15	Cash registers, Central Bank
Related-party anomalies	Share of turnover with affiliated or newly created firms	0.10	Registers, e-ID

Source: developed by the author.

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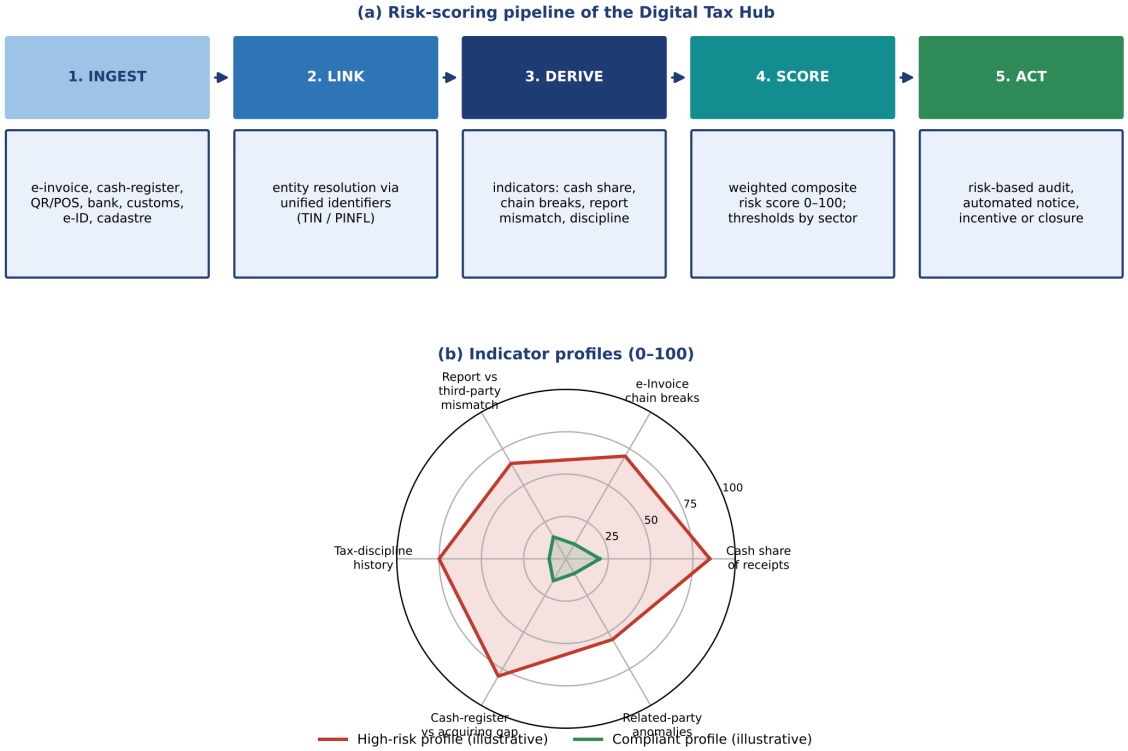


Figure 7. (a) Five-step risk-scoring pipeline; (b) stylised indicator profiles of a high-risk and a compliant entity (0–100 scale, illustrative)

Source: developed by the author.

Implications for measurement methodology

Three implications follow. First, the cash footprint is no longer a sufficient statistic for informality. In Navoi region and Tashkent city, where digital payments are deepest, the share of the informal and hidden economy is lowest; yet in the regions where the hidden component is growing, part of new activity takes place in digitally intermediated services. This is consistent with the dual effect of the digital economy — digital platforms both create new channels for concealment and new tools for detection [13; 18] — and it supports the move from currency-based to transaction-based proxies.

Second, point estimates should give way to bands with a documented structural residual. The decomposition reported here would have been impossible from a single top-down number; it required confronting the macro change with a scale counterfactual and attributing the remainder to the informal and hidden components. Reporting the residual turns a headline such as “informality tripled” into actionable magnitudes: the reforms reduced the potential volume by 173.2 trln UZS, while about 13.8 trln UZS of new hidden activity emerged, concentrated in four regions. This answers the call in the systematic reviews for estimates that state their scope and present their uncertainty [17; 3].

Third, measurement and enforcement should share one data pipeline. Transaction-level data dissolve the classical division of labour between statisticians and tax administrations: the same e-invoice chain break that lowers a firm’s compliance score also raises the bottom-up estimate of unreported turnover in its sector and region. The practical corollaries are a minimum analytical infrastructure — unified identifiers, interoperable tax, customs, payment and statistical registers and regulated data exchange — and a governance rule that risk scores are used for targeting, not for automatic sanction. The regional results also show that, within one country, under one legal framework and one statistical methodology, the hidden component moved in opposite directions in different regions; cross-country indices that treat a country as a single observation necessarily average over such heterogeneity, whereas the proposed framework is designed to be run at the regional level, where the policy levers are applied.

The results should be interpreted taking into account that the official estimate is itself model-based, the regional panel is short, the 2025 data are preliminary, the risk-scoring weights are design values pending calibration on audit outcomes, and regional residuals are calculated from shares published with one decimal place.

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CONCLUSIONS AND RECOMMENDATIONS

A four-family taxonomy — direct, indirect, model-based and digital transaction-level — shows that transaction-level methods complement rather than replace classical approaches; each family has a known bias direction, and triangulation is the appropriate design principle in a digitalising economy.

The proposed protocol reconciles macro top-down, micro bottom-up and institutional-calibration evidence into an estimate band with a documented structural residual, replacing contested point estimates with transparent ranges.

Applied to Uzbekistan, the framework shows that the share of the informal and hidden economy in GDP fell from 45.6% in 2017 to 34.3% in 2024 (26.9% in 2025), while its nominal volume rose 3.13-fold. Nominal GDP growth fully explains this rise; the decline in the informal component reduced the potential volume by 187.0 trln UZS, and the rising share of the hidden component added a structural residual of 13.8 trln UZS, concentrated in Samarkand, Namangan, Fergana and Khorezm regions.

Digital growth reduces informality only when digital flows are bound to reporting obligations; uncorrected for endogeneity, the ICT effect is overstated more than two-fold.

On this basis it is recommended: to publish official estimates of the shadow economy together with the decomposition of volume changes and the structural residual by region; to operate the six-indicator risk-scoring module on a single data pipeline shared by statistical and tax authorities and to calibrate its weights annually on audit outcomes; to extend e-reporting obligations to platform-mediated services and domestic trade in the regions where the hidden component is growing; and to test the pipeline on firm-level e-invoice and acquiring microdata in one or two sectors before national roll-out.

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