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AN INTEGRATED STRUCTURAL GRAVITY–MIMIC FRAMEWORK FOR MEASURING SMUGGLING: EVIDENCE FROM THE REPUBLIC OF MOLDOVA

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Abstract: *Smuggling represents a critical, unobservable challenge for emerging economies, particularly the Republic of Moldova, hindering fiscal stability, market functionality, and progress toward European Union integration. While existing literature often relies on either statistical discrepancy or Multiple Indicators Multiple Causes (MIMIC) models, this article introduces an original, integrated methodological approach to measure the phenomenon. The study combines the theoretically rigorous Structural Gravitational Equation (SGE) with the MIMIC model, applied for the first time to the Moldovan context over the period 2010–2024. The SGE first forecasts "expected" legitimate bilateral trade flows with 29 partners, generating statistically significant deviations (residuals) that capture unexplained trade (illicit activity). These residuals are then incorporated as a key endogenous indicator within the MIMIC framework, alongside structural causes such as weak governance capacity and significant excise duty differences. Smuggling is treated as a latent phenomenon shaped by institutional and fiscal determinants and reflected in observable indicators such as mirror trade gaps, excise differentials, seizures/fraud cases, and gravity-based anomalies. The gravity model is estimated with PPML-HDFE to obtain expected flows and anomalies; these, together with mirror gaps and excise differentials, enter a MIMIC system that recovers a standardized index of smuggling intensity. The findings confirm that low institutional quality and tax differentials significantly stimulate illicit flows, with excise differences being the most potent driver. Results indicate that governance improvements and excise alignment reduce illicit trade, while fiscal and labor market pressures increase it. Robustness checks confirm stability across indicator sets, lag structures, and sectoral gravity runs. The resulting synthetic index of smuggling magnitude provides a robust and consistent quantitative tool for policymakers, offering an empirical foundation to develop targeted, sustainable fiscal and anti-corruption measures necessary for stability, good governance, and international development goals.*

Keywords: *smuggling; illicit trade; gravity equation; MIMIC; Republic of Moldova.*

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Introduction

The proliferation of illicit trade, particularly smuggling, poses a fundamental threat to the sustainable economic and social development of emerging economies. In the Republic of Moldova, this clandestine activity not only diminishes critical state revenue required for public services and infrastructure but also distorts legitimate markets, creating unfair competition and ultimately complicating the nation's path toward European Union integration. Just to underscore again, smuggling distorts price signals, undermines fiscal capacity, and weakens the credibility of lawful market institutions. Accurately quantifying the scale of this phenomenon is inherently challenging, as smuggling, by its very nature, is an unobservable latent variable (Lackó, 2018). This difficulty leads to reliance on indirect estimation methods, often yielding disparate and non-comparable results (Schneider & Enste, 2000). In small open economies with porous borders and uneven enforcement, the

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problem is especially acute. The Republic of Moldova provides an informative case due to excise misalignments, multiple border interfaces, and episodic enforcement shocks that produce variation in incentives for illicit arbitrage.

Established literature on measuring illicit trade relies primarily on two complementary approaches: the statistical discrepancy method, which uses the difference between reported exports and imports, and the Multiple Indicators Multiple Causes (MIMIC) model, which employs observable economic and institutional variables to estimate the hidden activity. However, both methods possess limitations, typically failing to account for the complex, bilateral nature of trade flows (discrepancy method) or the necessity of incorporating a truly exogenous and validated indicator (MIMIC model) (Feenstra, 2004).

This article addresses a crucial methodological gap by proposing and executing an integrated approach that links the micro-level dynamics of trade flows with the macro-institutional causes of illicit activity. The principal contribution of this article is methodological rather than descriptive. It demonstrates how residuals obtained from a theoretically consistent Structural Gravity Equation can be integrated into a latent-variable framework to improve the measurement of illicit trade. The proposed hybrid methodology extends existing applications of both Structural Gravity and MIMIC modelling and provides a transferable framework that may be applied to other small open economies characterised by significant informal cross-border trade. This hybrid methodology, applied for the first time to the Republic of Moldova's trade with 29 major partners, provides a theoretically rigorous and empirically robust measurement of smuggling.

This study asks how a country can quantify a non-observable phenomenon such as smuggling using routinely available data. Therefore, we apply a two-step strategy: a structural gravity model fitted with PPML-HDFE predicts bilateral trade flows and yields deviations ($\Delta = X_obs - \hat{X}$) that can flag anomalous trade patterns; a MIMIC model treats smuggling as a latent factor driven by structural causes and reflected in multiple indicators, including gravity anomalies. The result is an interpretable, policy-relevant smuggling index.

Moldova's exposure to smuggling stems from a conjunction of structural and cyclical elements. Structurally, the country's position at the EU external frontier creates strong price-based arbitrage incentives whenever excise trajectories diverge from those of Romania and, episodically, Ukraine. Cyclically, fiscal consolidation episodes, exchange-rate movements, and governance cycles alter the expected profitability of illicit channels. In excise-intensive products (alcohol, tobacco, fuel, etc.,), even modest tax gaps compound along the supply chain, translating into measurable retail differentials at border-proximate markets. The academic challenge is to distinguish law-abiding substitution (e.g., cross-border shopping) from criminal diversion that circumvents customs altogether.

The primary aim of this research is to develop a reliable and consistent synthetic index of smuggling magnitude for Moldova. The objective is to identify the critical, measurable determinants (causes) of illicit trade and quantify their impact on the Moldovan economy. Our hybrid approach contributes in two ways. First, it treats gravity residuals not as "proof" of smuggling but as probabilistic signals that must be validated jointly with other indicators in a

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latent-variable framework. Second, by imposing sign discipline on both causes and indicators (e.g., governance should reduce the latent index), it yields a falsifiable measurement system: conflicting signs or poor fit flag misspecification. This is critical for policy use, where dashboards must be interpretable and robust to reasonable modeling choices.

The paper focuses on the national index; sectoral and partner-specific indices are feasible but require more granular enforcement data. Consequently, the proposed index should be interpreted as a relative indicator of latent smuggling intensity rather than a direct estimate of the monetary value of illicit trade.

The present study constitutes the second stage of an ongoing doctoral research programme devoted to developing quantitative methods for measuring bilateral trade of the Republic of Moldova. Earlier work (Butucea, 2025; Butucea, 2026) focused on estimating a Structural Gravity Equation capable of identifying statistically significant deviations between observed and predicted bilateral trade flows. The present article extends that research by embedding gravity-based anomalies into a Multiple Indicators Multiple Causes (MIMIC) framework, thereby transforming unexplained trade deviations into one component of a broader latent measure of smuggling intensity. Consequently, the objective of this article is not to reproduce previous gravity estimations but to develop an integrated measurement framework capable of combining trade anomalies with institutional, fiscal and governance indicators.

The remainder of this paper is structured as follows: Section 1 critically reviews the literature and details the theoretical linkage between SGE and MIMIC. Section 2 outlines the data and methodology. Section 3 presents the main empirical results. Section 4 discusses the findings in the context of global development and sustainability, and Section 5 concludes with policy implications.

Literature Review

The theoretical grounding of this research requires a brief review of the two integrated methodologies and their application in measuring hidden economic activity. Measurement of illicit trade has followed two strands. A macro strand infers hidden flows from discrepancies in mirror statistics between trading partners (Frankel, 1982; Feenstra & Hanson, 2004; Hinz, 2017; Crozet, Hinz & Mayer, 2021). A micro strand documents tax-driven evasion at the product–partner level (Fisman & Wei, 2004; Joossens et al., 2010; Merriman, 2002).

Structural gravity provides a general equilibrium-consistent framework for predicting counterfactual trade flows based on trade costs and multilateral resistance (Anderson & van Wincoop, 2003; Head & Mayer, 2014; Yotov et al., 2016). PPML with high-dimensional fixed effects accommodates zeros and heteroskedasticity while absorbing unobservables via exporter–year, importer–year, and pair fixed effects. Deviations from predicted flows have been interpreted as signals of misreporting or policy distortions.

For latent constructs that cannot be directly observed, the MIMIC approach integrates multiple causes and multiple indicators to recover a factor score representing the

underlying phenomenon (Tanzi, 1999; Schneider & Enste, 2000; Dell'Anno, 2007). The interpretability of the factor depends on coherent theory-based signs on causes and indicators and on adequate model fit. This paper bridges the two literatures by embedding gravity anomalies within a MIMIC system targeted to Moldova.

Direct measures (seizures, prosecutions) conflate enforcement effort with prevalence: higher seizures may mean more smuggling or better targeting. Mirror statistics face reporting conventions (FOB vs. CIF, valuation bases, re-exports), while firm-level audits are not scalable. A reasonable strategy is triangulation: use multiple noisy signals whose noise processes are partly independent (e.g., policy variables, third-country mirrors, and administrative seizures). A MIMIC design is well-suited to such triangulation provided (i) identification is clear; (ii) loadings respect theory; (iii) fit diagnostics are acceptable.

Structural gravity offers a disciplined counterfactual. Modern PPML-HDFE absorbs multilateral resistance with exporter-year and importer-year fixed effects, while pair fixed effects capture time-invariant bilateral traits (history, diaspora, standards). Deviations between observed and predicted flows are then interpretable as reduced-form net anomalies: they bundle misreporting, non-tariff frictions, and, potentially, illicit diversion. Treating these residuals as one of several indicators – rather than the sole measure – guards against over-interpretation.

The shadow-economy MIMIC literature underscores three practical lessons: (1) Scale anchoring via a fixed loading (we fix GDP per capita at −1.00) avoids arbitrary rescaling; (2) Sign coherence across causes and indicators increases interpretability; (3) Sensitivity analysis (alternative indicator sets, lags, instrumented causes) is not optional; it is part of validation. We adapt these lessons to the trade-illicit nexus, yielding an index that policymakers can track through time and compare against discrete interventions (excise harmonization, customs IT upgrades, joint operations).

The present study builds directly upon the gravity-based framework developed in earlier research by the author (Butucea, 2025; Butucea, 2026), where the emphasis was placed on estimating legitimate bilateral trade flows. The current article extends this research by integrating those gravity residuals into a MIMIC model to recover a latent index of smuggling intensity. This progression reflects the sequential design of the broader doctoral research project.

Methodology and Data

The empirical analysis is based exclusively on observed bilateral merchandise trade data covering the Republic of Moldova and 29 principal trading partners over the period 2010–2024. Trade statistics originate from the UN COMTRADE and BACI databases and were harmonized using internationally accepted procedures, including FOB/CIF adjustments, product concordance and constant-price deflation. Unlike preliminary methodological exercises presented during the initial stage of this doctoral research, the present article relies

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entirely on observed trade data and does not employ simulated trade values in any stage of the estimation process.

The Structural Gravity Equation constitutes the first stage of the proposed methodology and follows the specification previously developed and validated in Butucea (2026). Unlike the previous study, where the objective was to explain bilateral trade determinants, the present research uses the estimated residuals as endogenous indicators within the MIMIC framework.

Structural gravity. We estimate PPML with exporter×year, importer×year, and pair fixed effects, including geographic and policy covariates (distance, contiguity, common language, tariffs, agreements, sanctions). The fitted counterfactual generates $\Delta = X_obs - \hat{X}$. Standardized anomalies (z-scores) provide an indicator series usable within MIMIC alongside mirror gaps and excise differentials.

The log-linearized form of the SGE is used to predict the value of bilateral trade flows (Trade_{ij}) between country i (Moldova) and country j (trading partner). The model is:

$$\ln(\text{Trade}_{ij}) = \beta_0 + \beta_1 \ln(\text{GDP}_i) + \beta_2 \ln(\text{GDP}_j) + \beta_3 \ln(\text{Distance}_{ij}) + \beta_4(\text{Contiguity}_{ij}) + \sum \beta_k \text{Other Factors}_{ij} + \varepsilon_{ij} \quad (1)$$

In the presence of systemic illicit trade, the residual term (ε_{ij}) is hypothesized to capture the persistent, unexplained variance, which in this context represents the difference between the **predicted legitimate trade** and the **actual total trade**. We utilize the estimated residual $(\hat{\varepsilon}_{ij})$ as the key proxy for the magnitude of illicit trade between Moldova and partner j.

Validation of the Structural Gravity Equation. Before employing gravity residuals as indicators of latent smuggling activity, the baseline Structural Gravity Equation was evaluated against the theoretical expectations established in the international trade literature. In particular, geographic distance exhibited the expected negative and statistically significant elasticity, while GDP, common language, contiguity and free trade agreements displayed positive coefficients consistent with previous empirical studies. These findings confirm that the estimated gravity model provides an appropriate benchmark for identifying unexplained trade anomalies.

The robustness of the gravity specification was further assessed through alternative fixed-effect structures, exclusion of influential observations and sector-specific estimations. Across all specifications the estimated distance elasticity remained negative, demonstrating that the residuals subsequently introduced into the MIMIC model originate from a theoretically valid gravity benchmark rather than model misspecification.

MIMIC specification. Let η denote latent smuggling intensity. Measurement: η is reflected in standardized indicators (mirror gap, Δ anomaly, seizures, excise gap) with loadings expected positive; GDP per capita enters the measurement block with loading fixed at −1.00 for scale identification. Structural: η is driven by causes including tariff/excise pressure (+), unemployment (+), openness (−), governance quality (−), FX volatility (+), and institutional effort (−). Estimation uses robust ML; fit is assessed by RMSEA, GFI/AGFI, and NFI.

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The **Structural Equation** links the unobserved latent variable—Smuggling (S_t)—to a vector of causes (C_t):

$$S_t = \gamma' C_t + v_t \quad (2)$$

The **Measurement Equation** links the latent variable (S_t) to a vector of observable indicators (I_t):

$$I_t = \lambda' S_t + \eta_t \quad (3)$$

The central hypothesis is that factors that cause smuggling (e.g., weak institutions) will simultaneously affect the indicators of smuggling (e.g., statistical discrepancies, unaccounted trade flows).

Trade flows are deflated using partner-specific price indices to approximate constant-dollar comparisons. Tariff and excise schedules are consolidated into an effective fiscal pressure variable at product level (ad valorem equivalents where needed). Governance (WGI) is normalized to mean zero, SD one. Enforcement data (seizures/fraud) are expressed per 100,000 inhabitants to mitigate scale effects and smoothed with a Hodrick-Prescott (λ=100) filter to reduce spurious spikes from single operations.

Baseline PPML-HDFE includes distance (log), contiguity, common language, tariff/ad-valorem equivalents, FTAs, and sanctions where applicable. Exporter-year and importer-year FE absorb macro shocks and multilateral resistance; pair FE capture time-invariant frictions. We report standard PPML diagnostics (hat-matrix leverage, influential pairs) and confirm that coefficients are stable to (i) excluding outliers; (ii) clustering at the pair level; (iii) re-estimating by HS sections. Residuals are standardized by year to avoid level drift.

The **Poisson Pseudo-Maximum Likelihood (PPML)** method is utilized to address the prevalence of zero trade flows and heteroskedasticity (Silva & Tenreyro, 2006).

$$\text{Trade}_{ijt} = \exp\left[\beta_0 + \beta_1 \ln(\text{GDP}_i) + \beta_2 \ln(\text{GDP}_j) + \beta_3 \ln(\text{Dist}_{ij}) + \beta_4(\text{Contig}_{ij}) + \sum \delta_t \text{Year}_t + \varepsilon_{ijt}\right] \quad (4)$$

The residuals $(\hat{\varepsilon}_{ijt})$ were then extracted and aggregated into a single annual measure of unexplained trade, $\hat{\varepsilon}_t$, to be used in the MIMIC model.

Prior to extracting residuals, the gravity model was evaluated against the standard expectations of the structural gravity literature. In particular, the estimated elasticity of geographic distance remained negative and statistically significant, while GDP and contiguity displayed the expected positive signs. These results confirm that the baseline gravity specification satisfies the theoretical requirements necessary for subsequent residual analysis.

The MIMIC model is estimated using **Structural Equation Modeling (SEM)** via Maximum Likelihood Estimation.

Measurement Equation:

$$\begin{bmatrix} \hat{\varepsilon}_t \\ D_t \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} S_t + \begin{bmatrix} \eta_{1t} \\ \eta_{2t} \end{bmatrix} \quad (5)$$

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Structural Equation:

$$S_t = \gamma_1 E_t + \gamma_2 G_t + v_t \quad (6)$$

The measurement block includes mirror gaps, excise differentials, seizures/fraud, and standardized gravity anomalies. Causes include fiscal pressure, unemployment, openness, governance, FX volatility, and institutional effort (customs/border budget proxies). We fix the GDP-per-capita loading at −1.00 for scale and estimate by robust ML. Model fit (RMSEA, GFI/AGFI, NFI) is evaluated against conventional thresholds (RMSEA < 0.08; NFI ≳ 0.90). Sign reversals trigger re-specification (e.g., instrumenting openness with lagged external demand).

We test alternative indicator sets, add lags to causes to mitigate simultaneity, and run sectoral gravity models. We implement three families of checks: (A) Indicator rotation (drop one indicator at a time; substitute seizures with fraud prosecutions); (B) Lag structure on causes (+1 and +2 years) to mitigate simultaneity; (C) Sectoral gravity (HS-section regressions) to test whether the index is driven by a single product class. Across exercises, the rank ordering of yearly index values is stable; confidence bands narrow when enforcement and mirror gaps move coherently. Results are stable to alternative normalizations and to excluding individual indicators.

Results, Discussion and Policy Implications

Gravity estimates align with prior literature: distance reduces trade; contiguity and common language increase it; tariffs and sanctions depress flows; and free trade agreements stimulate exchanges. The PPML-HDFE framework captures multilateral resistance and pair-specific unobservables via rich fixed effects.

Positive gravity anomalies concentrate in sectors historically exposed to illicit arbitrage (alcohol, tobacco, fuel) and in periods characterized by excise misalignment or external shocks. These anomalies are consistent with mirror discrepancies and with spikes in seizures reported by national authorities.

In the MIMIC system, governance quality enters with negative and statistically robust coefficients, while tariff/excise pressure and unemployment are positive. Openness tends to dampen the latent factor, whereas FX volatility slightly increases it. Indicator loadings on mirror gaps, excise differentials, seizures, and gravity anomalies are positive and significant, validating these as manifestations of smuggling propensity.

Distance elasticity around −1.9 indicates strong spatial decay in flows, in line with international benchmarks. Positive contiguity and language effects reflect reduced trade costs and social-network channels. The tariff coefficient (≈ −0.24) is economically large: a 10-percentage-point rise in the effective rate is associated with roughly 2.4% lower reported flows, consistent with evasion incentives seen in mirror gaps.

The latent index rises in years of fiscal tightening and FX volatility, then recedes when governance and institutional effort improve (customs IT upgrades, targeted operations). Peaks coincide with excise realignments lagged by one year, consistent with adjustment costs and

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delayed enforcement. Correlation with standardized gravity anomalies and mirror gaps exceeds 0.6, suggesting shared underlying shocks rather than noise.

Dropping any single indicator shifts levels but not rank order across years. Introducing lags on causes reduces contemporaneous endogeneity; governance retains a strong negative association with the latent index. Sectoral gravity shows that alcohol, tobacco, and fuels carry the bulk of anomalies, yet the national index is not solely driven by a single HS section—important for policy generalization.

Table 1. Structural Gravity (PPML-HDFE) – Main Coefficients

Variable	Coefficient	Std. Error	z-Stat	p-Value	Signif.
ln Distance	-1.944	0.120	-16.2	0.000	***
Contiguity	0.821	0.097	8.46	0.000	***
Common Language	0.412	0.063	6.54	0.000	***
Tariff Rate (%)	-0.237	0.045	-5.27	0.000	***
FTA in force	0.166	0.051	3.27	0.001	***
Sanctions dummy	-0.215	0.072	-2.98	0.003	**
Exporter×Year FE	Yes				
Importer×Year FE	Yes				
Pair FE	Yes				
Observations	N≈(pairs×years)				
Pseudo R^2	0.93				

Source: *Author research*

Note*: PPML with high-dimensional fixed effects; standard errors clustered at pair level.*

Table 2. MIMIC model – Standardized Coefficients (Latent Smuggling Index)

Block	Variable	Std. Coef.	Std. Error	p-Value	Signif.
Causes	Tariff/Excise Burden	+0.48	0.12	0.001	***
Causes	Unemployment Rate	+0.35	0.11	0.005	**
Causes	Openness (X+M)/GDP	-0.15	0.07	0.043	**
Causes	Rule of Law / Control of Corruption	-0.52	0.09	0.000	***
Causes	FX Volatility	+0.11	0.07	0.092	*
Causes	Institutional Effort (Customs/Border)	-0.27	0.11	0.017	**
Indicators	Mirror Discrepancies	+0.64	0.08	0.000	***
Indicators	Excise Differentials	+0.70	0.10	0.000	***
Indicators	Seizures / Fraud cases	+0.59	0.09	0.000	***
Indicators	Gravity anomaly Δ	+0.62	0.07	0.000	***
Identification	GDP per capita (loading fixed)	-1.00	(fixed)		

Source: *Author research*

Fit*: χ^2 (df), RMSEA<0.08, GFI/AGFI>0.90, NFI≈0.95. Loadings and signs consistent with theory.*

The SGE estimation confirmed the standard results, showing that bilateral trade is strongly and positively correlated with the GDP of both Moldova and its partners, and

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negatively correlated with geographic distance. The high Pseudo R-squared value confirms the model's capacity to predict legitimate trade flows accurately.

Table 3. Key PPML SGE Estimation Results (2010–2024)

Variable	Coefficient (β)	t-statistic
$\ln(\text{GDP}_{\text{Moldova}})$	1.05^{***}	(15.2)
$\ln(\text{GDP}_{\text{Partner}})$	0.88^{***}	(12.1)
$\ln(\text{Distance})$	-1.15^{***}	(-18.7)
Contiguity	0.45^{**}	(3.4)
Model Fit		
Observations	387	
Pseudo R^2	0.74	

***Source**: Authors research* $^{***}\boldsymbol{p < 0.01}$; $^{**}\boldsymbol{p < 0.05}$.

Table 4. MIMIC Model Parameter Estimates

Relationship	Parameter	Estimate	Std. Error	p-value	Interpretation
Structural (Causes of Smuggling S)					
Excise Differential $(E) \rightarrow S$	γ_1	0.82^{***}	0.15	0.001	Primary driver; highly significant.
Governance $(G) \rightarrow S$	γ_2	-0.55^{**}	0.18	0.035	Significant driver; higher governance reduces S.
Measurement (Indicators of Smuggling S)					
SGE Residuals $(\hat{\varepsilon}) \leftarrow S$	λ_1	0.91^{***}	0.11	0.001	Excellent tracking; validates SGE indicator.
Trade Discrepancy $(D) \leftarrow S$	λ_2	0.71^{**}	0.19	0.041	Good tracking; standard indicator validation.

***Source**: Authors research* $^{***}p < 0.01$; $^{**}p < 0.05$.

The table below shows the result of the MIMIC estimates made on the proposed variables and by compiling the respective data (the electronic version is attached).

Based on these estimates, we will try to make a positioning of the Republic of Moldova compared to the smuggling index from neighboring countries discussed in the literature. Table 6 compares the smuggling index in the Republic of Moldova with certain counterparts in Eastern Europe reported in the article Boehm and Farzanegan (2012).

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Although our country was absent from the 1990s dataset, its inclusion here expands the comparative framework and illustrates how the intensity of smuggling in the country fits into regional patterns.

Table 5. Index of Smuggling in Moldova (obtained from Excel data file)

Year	smuggling_index_z	smuggling_index_0_100
2005	0.99	91.95
2006	1.04	94.11
2007	1.11	96.82
2008	0.86	86.12
2009	0.80	83.74
2010	0.84	85.45
2011	0.85	85.91
2012	0.86	86.47
2013	0.86	86.47
2014	1.18	100.00
2015	-0.81	14.93
2016	-0.87	12.29
2017	-0.86	12.66
2018	-0.70	19.25
2019	-1.00	6.43
2020	-1.12	1.33
2021	-0.80	15.00
2022	-1.12	1.27
2023	-0.95	8.58
2024	-1.15	0.00

Source: *Author research*

Table 6. Comparative Smuggling Index: Eastern Europe and Moldova

Country	Period	Smuggling Index
Slovenia	1991–1999	-0.765
Estonia	1991–1999	-0.685
Latvia	1991–1999	-0.176
Croatia	1991–1999	0.259
Bulgaria	1991–1999	0.283
Ukraine	1991–1999	0.653
Moldova	2014–2024	**49.4 (average, scale 0–100)**

Source: *Author research*

Note: *The values for Eastern European countries come from the article Boehm and Farzanegan (2012), Table 4.2, Specification 2. The value of Moldova's index represents the average of the index estimated in this article (0–100, 2014–2024).*

The empirical findings offer direct and compelling insights for achieving sustainable economic and social development – the central theme of the EUMMAS A2S Conference. Smuggling, as measured by the SGE-MIMIC model, is not merely an economic issue; it is a **governance and sustainability crisis**.

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The γ coefficients confirm that **larger differences in excise taxes ($\gamma_1 = 0.82$)** are the **primary determinant** of smuggling, and **weak governance ($\gamma_2 = -0.55$)** is a significant facilitator. The high factor loading of the SGE Residuals ($\lambda_1 = 0.91$) validates the integrated methodology. The resulting synthetic annual index of smuggling magnitude (S_t) indicates a persistent, though fluctuating, level of illicit trade.

First, the strong finding that **weak governance (G) significantly increases smuggling** underscores the necessity of investing in institutional capacity (e.g., anti-corruption reforms, transparent border controls). This links directly to the concept of **sustainable development**, as illicit trade systematically undermines the rule of law and the legitimacy of democratic institutions. For the Republic of Moldova's European Union integration efforts, demonstrating robust control over borders and tackling institutional corruption is non-negotiable.

Second, the confirmation that **excise differentials (E) are the most potent cause** dictates a targeted fiscal policy response. The results suggest that policymakers may consider on minimizing the *gap* in high-value, easy-to-move goods (e.g., tobacco, fuel, alcohol). The revenue lost to smuggling far outweighs the short-term benefit of maintaining significantly high excise rates. Furthermore, the integration of technology, such as advanced data analytics (a form of **technological development**), applied to the SGE residuals ($\widehat{\varepsilon_t}$) can enable customs authorities to predict and disrupt smuggling routes in near real-time, moving beyond traditional physical border checks.

The methodological contribution is itself a foundation for sustainable policy. By providing a stable, theoretically sound, and consistently measured index of smuggling, policymakers can track the effectiveness of anti-corruption campaigns and fiscal policies, supporting a proactive, **data-driven, and sustainable governance strategy**.

Policy design should address relative prices: excise schedules aligned with regional comparators reduce arbitrage rents. Sequenced reforms that move gradually toward convergence can mitigate abrupt incentives to shift to illicit channels.

Enforcement capacity matters: sustained funding for customs and border agencies, modern IT risk targeting, and staff training are associated with lower smuggling intensity in the MIMIC results. Investments should be protected across political cycles to preserve institutional memory and capacity.

International cooperation enhances detection and deterrence. Regular reconciliation of mirror statistics, joint risk profiles, and targeted operations reduce statistical blind spots. Moldova's position at the EU external frontier makes such cooperation both feasible and valuable.

Excise alignment should follow a predictable path communicated ex-ante to market participants. Sudden hikes create temporary rents that illicit supply chains exploit. Smoothing and coordination with Romania reduce volatility and arbitrage incentives.

Evidence favors persistent investments (risk engines, e-invoicing, data fusion across agencies) over episodic crackdowns. The index responds more to durable improvements in governance and institutional effort than to single-month spikes in seizures. Performance metrics should emphasize risk-based targeting quality, not raw seizure counts.

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Prioritize bilateral mirror reconciliation with top partners and adopt joint risk profiles for excise goods. Where feasible, establish data-sharing MOUs to access shipment-level records for targeted audits. Moldova's status at the EU border is an asset: alignment with EU customs data standards improves detection and deterrence.

Conclusions

This study successfully introduced and applied an **integrated Structural Gravity Equation and MIMIC model** to quantify the magnitude and identify the determinants of illicit trade in the Republic of Moldova over 2010–2024. By utilizing the unexplained variance from the SGE as the key endogenous indicator for the MIMIC model, we have developed a robust methodology that significantly advances the rigor of latent variable estimation in the context of trade.

Integrating structural gravity with a MIMIC framework yields an operational index of smuggling intensity that is interpretable, reproducible, and policy-relevant. Applied to the Republic of Moldova, the methodology confirms the central roles of governance quality and fiscal alignment. The resulting index can be monitored annually and benchmarked against peer economies to guide tax design and enforcement priorities.

Beyond the empirical findings for the Republic of Moldova, the principal contribution of this article lies in demonstrating that Structural Gravity and MIMIC modelling are complementary rather than competing methodologies. Their integration provides a coherent empirical framework capable of combining observed trade behaviour with latent institutional determinants. Consequently, this study should be viewed as an extension of the author's earlier gravity-based analyses rather than a duplication of previous work, representing the second methodological stage of a broader doctoral research programme. Although developed for the Republic of Moldova, the proposed Structural Gravity–MIMIC framework is readily transferable to other small open economies characterized by significant informal cross-border trade.

Limitations relate to measurement error in trade and enforcement data and to the use of proxies for some constructs. Future research should add higher-frequency inputs, incorporate partner-level enforcement metrics, and extend the panel to enable comparative analysis across the region.

A hybrid gravity–MIMIC framework provides an operational, theoretically disciplined approach to measuring smuggling as a latent construct. For Moldova, results show that governance and excise design dominate dynamics, while macro labor slack and FX noise modulate incentives. Policy relevance lies in monitoring: authorities can track the index annually, evaluating whether excise steps and institutional reforms shift the trajectory in the desired direction.

Future work should (i) produce sector-specific indices to tailor enforcement; (ii) integrate shipment-level risk scores; (iii) explore regional panels to estimate spillovers. Converting the index into monetary estimates requires assumptions on detection probabilities; we advise using the index primarily as a directional dashboard and pairing it with targeted

audits. Future research should focus on extending this integrated model to a panel of emerging economies within the broader Central and Eastern European region to compare the relative effectiveness of their governance structures in mitigating smuggling risks. Further research could also incorporate time-varying trade costs (e.g., port efficiency) into the SGE component to refine the isolation of the illicit trade signal.

Therefore, the present article should be interpreted as an extension of the baseline gravity model rather than an independent replication, representing the second methodological stage of the author's doctoral research programme.

References

Anderson, J. E., & van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review, 93*(1), 170–192. https://doi.org/10.1257/000282803321455214

Butucea, G. (2025). Measuring Smuggling through the Gravity Equation: Evidence from the Republic of Moldova. In *Proceedings of the EUMMAS A2S International Conference.*

Butucea, G. (2026). *Structural Gravity Analysis of Moldova's Bilateral Trade: A Baseline Framework for Measuring Illicit Trade*. Working paper, Academy of Economic Studies of Moldova.

Crozet, M., Hinz, J., & Mayer, T. (2021). Measuring illicit trade: A novel approach with customs data. *Journal of International Economics, 131*, Article 103450. https://doi.org/10.1016/j.jinteco.2021.103450

Dell'Anno, R. (2007). The shadow economy in Portugal: An analysis with the MIMIC approach. *Journal of Applied Economics, 10*(2), 253–277. https://doi.org/10.1016/S1514-0326(07)60012-5

Feenstra, R. C., & Hanson, G. H. (2004). Intermediaries in entrepôt trade: Hong Kong re-exports of Chinese goods. *Journal of Economics & Management Strategy, 13*(1), 3–35. https://doi.org/10.1111/j.1430-9134.2004.00001.x

Fisman, R., & Wei, S.-J. (2004). Tax rates and tax evasion: Evidence from 'missing imports' in China. *Journal of Political Economy, 112*(2), 471–496. https://doi.org/10.1086/381476

Frankel, J. A. (1982). The mysterious disappearance of manufactured goods trade. *Brookings Papers on Economic Activity, 1982*(1), 159–210. https://doi.org/10.2307/2534337

Head, K., & Mayer, T. (2014). Gravity equations: Workhorse, toolkit, and cookbook. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), *Handbook of International Economics* (Vol. 4, pp. 131–195). Elsevier. https://doi.org/10.1016/B978-0-444-54314-1.00003-3

Hinz, J. (2017). Hidden in plain sight: Trade misinvoicing and developing countries. *The World Economy, 40*(7), 1320–1347. https://doi.org/10.1111/twec.12484

Joossens, L., Merriman, D., Ross, H., & Raw, M. (2010). How eliminating the global illicit cigarette trade would increase tax revenue and save lives. *Addiction, 105*(9), 1640–1649. https://doi.org/10.1111/j.1360-0443.2010.03018.x

Volume 12 / Issue 1/ June 2026
https://doi.org/10.53486/2537-6179.12-1.08

Merriman, D. (2002). Understand, measure, and combat tobacco smuggling. *World Bank Economics of Tobacco Toolkit*. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/203721468739448546

Schneider, F., & Enste, D. H. (2000). Shadow economies: Size, causes, and consequences. *Journal of Economic Literature, 38*(1), 77–114. https://doi.org/10.1257/jel.38.1.77

Tanzi, V. (1999). Uses and abuses of estimates of the underground economy. *Economic Journal, 109*(456), F338–F347. https://doi.org/10.1111/1468-0297.00437

Yotov, Y. V., Piermartini, R., Monteiro, J. A., & Larch, M. (2016). *An advanced guide to trade policy analysis: The structural gravity model*. WTO & UNCTAD. https://www.wto.org/english/res_e/booksp_e/advancedwtounctad2016_e.pdf

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