








# “Digital governance as a tool against money laundering: Cross-country evidence for financial crime reduction”

## AUTHORS

Olga Lygina   
Narek M. Kesoyan   
Gaukhar Uvakbayeva   
Nataliia Kovshun   
Ekaterina Dmitrieva   
Rostyslav Shchokin   
Liudmyla Zakharkina 

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© Olga Lygina, Narek M. Kesoyan,  
Gaukhar Uvakhbayeva, Nataliia  
Kovshun, Ekaterina Dmitrieva,  
Rostyslav Shchokin, Liudmyla  
Zakharkina, 2026

Olga Lygina, Ph.D., Rector, Associate  
Professor in Education at the Higher  
School of Social and Technical  
Sciences, Baishiev University, Republic  
of Kazakhstan.

Narek M. Kesoyan, Ph.D. in Economics,  
Associate Professor, Dean of the  
Faculty of Marketing and Business  
Administration, Armenian State  
University of Economics, Armenia.

Gaukhar Uvakhbayeva, Ph.D. in  
Economics, Associate Professor,  
Department of Finance and  
Accounting, Kazakh National Al-Farabi  
University, Republic of Kazakhstan.  
(Corresponding author)

Nataliia Kovshun, Doctor of  
Economics, Professor, Director  
of the Institute of Economics and  
Management, Professor at the  
Department of Enterprise Economics  
and International Business, National  
University of Water and Environmental  
Engineering, Ukraine.

Ekaterina Dmitrieva, Investor Relations  
Expert in Alternative Investments,  
Columbia Business School, USA.

Rostyslav Shchokin, Doctor of Law,  
Professor of the Department of  
Administrative, Financial and Banking  
Law, Interregional Academy of  
Personnel Management, Ukraine.

Liudmyla Zakharkina, Ph.D. in  
Economics, Associate Professor of the  
Department of Financial Technologies  
and Entrepreneurship, Sumy State  
University, Ukraine.



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Olga Lygina (Republic of Kazakhstan), Narek M. Kesoyan (Armenia),  
Gaukhar Uvakhbayeva (Republic of Kazakhstan), Nataliia Kovshun (Ukraine),  
Ekaterina Dmitrieva (USA), Rostyslav Shchokin (Ukraine),  
Liudmyla Zakharkina (Ukraine)

# DIGITAL GOVERNANCE AS A TOOL AGAINST MONEY LAUNDERING: CROSS-COUNTRY EVIDENCE FOR FINANCIAL CRIME REDUCTION

## Abstract

Money laundering threatens global financial integrity, while digital governance is increasingly seen as a tool to enhance transparency and regulatory capacity. This study operationalized digital governance through the United Nations E-Government Development Index, which captures the scope and quality of online public services, telecommunications infrastructure, and human capital. The paper aims to examine whether improvements in e-government development are associated with measurable reductions in systemic money-laundering vulnerabilities at the country level. The study uses an unbalanced panel of 171 countries for 2012–2024 (982 observations). Fixed- and random-effects models with Box–Cox transformations were estimated, with the Hausman test guiding model selection and cluster-robust and Driscoll–Kraay standard errors ensuring reliable inference. The results demonstrate a statistically significant and economically meaningful inverse relationship between e-government development and money-laundering risk, measured by the Basel AML Index. In the preferred fixed-effects specification, the coefficient on the transformed EGDI is  $-1.56$  ( $p < 0.001$ ), indicating that within-country improvements in digital governance capacity are associated with substantial reductions in AML vulnerability over time. This effect remains robust across alternative error structures, with 95% confidence intervals of  $[-1.96, -1.17]$  under cluster-robust estimation and  $[-1.75, -1.38]$  under Driscoll–Kraay correction. The inclusion of country-specific fixed effects reveals considerable structural heterogeneity in baseline AML risk (approximately 1.15–3.90), while time effects display limited variation over the sample period (approximately 2.11–2.19), confirming that the risk-reducing role of digital governance is not driven by specific countries or particular years.

## Keywords

e-government development, anti-money laundering,  
digital governance, panel data analysis, Basel AML index

## JEL Classification

G28, H83, K42, O38

## INTRODUCTION

Global illicit finance continues to pose a systemic challenge to financial stability, sustainable development, and institutional credibility. The United Nations Office on Drugs and Crime estimates that a non-negligible share of global economic activity is associated with laundering processes, highlighting the macroeconomic relevance of the problem (UNODC, n.d.). International financial institutions increasingly stress that effective anti-money laundering and counter-terrorist financing (AML/CFT) frameworks are not merely compliance instruments but core pillars of financial system integrity.

In recent years, regulatory momentum has intensified, particularly within Europe. In 2024, the European Union adopted a comprehensive AML legislative package, including the AMLA Regulation, a new EU AML Regulation, and the 6th AML Directive, and designated

Frankfurt as the seat of the Anti-Money Laundering Authority. The appointment of the Authority's first chair in January 2025 marked a further step toward centralized supervision and harmonized enforcement across Member States (AMLA, n.d.). At the global level, the Financial Action Task Force (FATF, 2021) has emphasized the growing role of digital tools, such as data pooling, advanced analytics, and digital identity, in strengthening risk detection and supervision, and updated its Recommendations in June 2025 to enhance information-sharing and beneficial ownership transparency. Parallel initiatives led by the World Bank, including GovTech and anticorruption programs and the establishment of a Beneficial Ownership Transparency Working Group, similarly foreground digital public infrastructure as a mechanism for reducing corruption and illicit financial flows.

Despite these reforms, substantial disparities persist in both digital governance capacity and AML outcomes across countries. The United Nations E-Government Survey 2024 documents significant progress in digital public administration while revealing persistent regional and structural gaps (UNDSA, 2024). At the same time, operational cooperation through the Egmont Group of Financial Intelligence Units (now comprising approximately 180 members) has expanded. Yet, jurisdictions differ markedly in workload, institutional capacity, and risk exposure. These asymmetries raise an unresolved empirical question: to what extent does variation in digital government capacity translate into measurable differences in money-laundering vulnerability? Although policy discourse increasingly links digital governance reforms with enhanced transparency and regulatory effectiveness, systematic cross-country evidence on their direct association with AML risk remains limited. Existing debates often treat digitalization as a supporting instrument but do not clarify whether improvements in e-government development are accompanied by statistically significant reductions in systemic money-laundering vulnerabilities. Addressing this gap is essential to understanding whether investments in digital public infrastructure serve merely as administrative modernization tools or as substantive components of the financial integrity architecture.

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## 1. LITERATURE REVIEW

The relationship between digital governance and AML has emerged as a crucial topic in academic and policy debates, reflecting broader concerns about the effectiveness of governance structures in addressing financial crime. Research has increasingly highlighted the transformative potential of e-government systems to enhance transparency, reduce corruption, and strengthen institutional resilience. This emphasis is reinforced by critiques suggesting that conventional AML regimes have often underperformed in practice, thereby increasing interest in technology-enabled, data-driven governance reforms as a route to more effective prevention and enforcement (Pol, 2020). Empirical investigations across diverse settings demonstrate that digital governance is not only a technological innovation but also an institutional lever for mitigating illicit financial flows, strengthening compliance capacity, and reducing opportunities for corruption.

A significant body of scholarship has explored the broader links between e-government and financial

crime. Evidence suggests that improvements in e-government frameworks can reduce opportunities for corruption and money laundering by enhancing compliance, accountability, and oversight effectiveness (Alomari, 2020; Máchová et al., 2018; Bartulovic et al., 2023). The effectiveness of these mechanisms is reinforced by studies connecting governance quality and economic openness to money-laundering vulnerabilities, with particular reference to regional and group-based patterns in the EU, G20, BRICS, and CIVETS economies (AlQudah et al., 2025; Tarasenko et al., 2022). The credibility of digital governance as an AML-relevant reform track is further supported by evidence that targeted digitalization can reshape AML “scenarios” and compliance patterns, including under shock conditions such as the COVID-19 period, when supervisory and transactional processes became more digitally mediated (Vasilyeva et al., 2021). Complementary work has examined the interplay between financial governance, corporate governance, and audit quality in ensuring financial integrity (Amanamah, 2024), as well as the growing role of compliance units within organizations (Abou-Moghli & Shatem, 2024).

Recent contributions emphasize how digital governance enhances state capacity by enabling antifragile organizational responses and adaptive strategies in the public sector (Bartuseviciene & Butkus, 2024; Bian & Wang, 2024). In addition, studies emphasize the behavioral and organizational determinants of e-government adoption, highlighting how digital readiness and cultural or institutional conditions influence the uptake of new technologies (Crăciun et al., 2025; Xanthopoulou et al., 2023; Zambrano-Yépez et al., 2023). A complementary stream foregrounds the role of knowledge, technological capability, and innovation as measurable determinants of integrity gains, positioning digital transformation as both a capacity-building and a corruption-reduction mechanism (Yefimenko et al., 2025). Evidence on the determinants of corruption in government also reinforces the relevance of institutional drivers and non-linear effects, implying that digital governance reforms interact with deeper structural conditions rather than operating as purely technical “plug-ins” (Bozhenko et al., 2022). Bibliometric review further shows that digital governance and AI-enabled public administration have become central research themes, reflecting the rapid diffusion of digital tools in government and growing attention to governance quality, digital divides, and institutional digitalization (Rekunen et al., 2025) alongside Europe’s substantial variation in digital capacity and reform trajectories (Kovac et al., 2024; Zámek & Zakharkina, 2024; Stender et al., 2024). Moreover, structural transformations in public administration systems highlight the integration of digital and economic reforms as complementary drivers of institutional change (Kuanaliyev et al., 2024), with governance frameworks for cross-sector coordination, such as public-private partnerships, presented as an additional channel through which implementation capacity and accountability can be strengthened (Oe et al., 2025).

The literature also documents how digital transformation enhances the effectiveness of anticorruption and AML measures by improving the monitoring of illicit transactions and enhancing fraud detection (Dobrovolska & Rozhkova, 2024; Nonik et al., 2024). Broader perspectives highlight the role of artificial intelligence and machine learning in enhancing institutional capacity to

detect and prevent financial crime, with implications for the organized criminal use of AI in laundering operations (Lyeonov et al., 2024, 2025). Related evidence suggests that the diffusion of AI across public-sector functions is accelerating and increasingly measurable through bibliometric mapping, which strengthens the case for treating AI-enabled governance as a distinct component of modern state capacity rather than an auxiliary innovation (Rekunen et al., 2025). At the same time, research on societal perceptions of AI indicates that fear, hope, and indifference coexist, implying that adoption trajectories and the legitimacy of AI-assisted oversight may vary across countries and institutional contexts (Yarovenko et al., 2024). Increasing expectations placed on financial institutions regarding openness and responsibility, alongside ESG reporting obligations arising within a context of stricter regulatory frameworks and intensified reputational scrutiny, have positioned AI as a core element of contemporary financial architectures. When implemented appropriately, AI streamlines information handling while improving precision and practical relevance; however, its deployment requires robust governance mechanisms and clearly articulated limits, particularly given the associated regulatory, legal, and reputational exposures. At the organizational level, AI and FinTech adoption in banking is also shown to depend on inclusivity considerations and cultural alignment, suggesting that the effectiveness of technology-enabled compliance and monitoring can be conditioned by workforce readiness, customer trust, and context-specific innovation pathways (Othman, 2025). These contributions align with studies analyzing the relationship between financial fraud, tax tools, and overall economic security (Asare & Samusevych, 2023; Klochan & Filipov, 2023; Salnikova et al., 2019).

A growing body of work links AML effectiveness to the changing risk landscape created by fintech, digital assets, and new payment infrastructures. Fintech development is associated with both enhanced efficiency and novel compliance challenges, requiring governance models that keep pace with innovation and market restructuring (Polishchuk, 2023). This challenge is particularly pronounced for crypto-assets, where evolving legislative and regulatory approaches expand the scope of money-laundering prevention obligations while leav-

ing countries at different stages of readiness and enforcement capability (Muraviov et al., 2023; Tonkykh et al., 2023; Soana, 2022). These insights reinforce the central premise of digital governance research: the effectiveness of AML increasingly depends on digital supervisory capacity, interoperable data systems, and adaptive regulation that can respond to innovation-driven shifts in laundering typologies.

Scholarly contributions connect money laundering risks to corruption, shadow-economy dynamics, and socio-economic vulnerabilities. The interaction between corruption and laundering has been shown to exacerbate governance failures (Bartulovic et al., 2023; Pulungan et al., 2024; Masyk et al., 2023), while the shadow economy remains a critical determinant of illicit financial activities (Czapkiewicz et al., 2025; Lyeonov et al., 2025; Yakushev et al., 2023). Importantly, illicit flows can also be generated through subnational governance failures and fraudulent actions by local authorities, emphasizing that AML risk is not only a national-level compliance matter but can also be rooted in regional public-sector integrity and budgetary governance (Kuzior et al., 2024). These findings are supported by empirical evidence showing that digital readiness enhances European countries' ability to combat both corruption and cyber threats (Yarovenko et al., 2025). In parallel, research focusing on transparency and trust in the public sector underscores that institutional benchmarks and credibility mechanisms can support macroeconomic stability and, by extension, improve the enabling environment for AML compliance and enforcement (Vasylieva et al., 2023).

Comparative studies using clustering methods suggest that countries differ significantly in their FATF compliance and effectiveness, highlighting the need for tailored strategies (Kuzior et al., 2025). Related evidence from Central Asia provides granular insight into how financial monitoring operates within specific banking operations, showing that effectiveness can depend on organizational processes, risk typologies, and supervisory practice rather than on formal rules alone (Abzhalelova et al., 2025). Evidence from Bangladesh likewise illustrates that AML outcomes reflect not only policy intent but also the

practical configuration of instrumentalities, compliance routines, and control capacity (Zafarullah & Haque, 2021). Methodologically, the broader financial-sector literature also signals an increasing use of efficiency assessment tools and bibliometric mapping, such as DEA-focused research streams, which can be repurposed to evaluate supervisory and compliance architectures in regulated markets (Druva Kumar & Senthil Kumar, 2024). Bibliometric analyses of insurance market transparency and corporate governance issues further contextualize how institutional structures support or undermine AML measures (Amanamah, 2024).

The broader governance and public management literature offers complementary insights into digitalization and its indirect effects on AML. Digital governance reforms are increasingly intertwined with organizational learning and knowledge management, with evidence suggesting that integrating knowledge management and smart technologies in public organizations can enhance operational effectiveness and strengthen accountability channels relevant to integrity and compliance outcomes (Mahmoud et al., 2025). Studies highlight how governance challenges and strategic opportunities emerge in the implementation of circular economy principles, underscoring the role of institutional design in supporting transparency and accountability (Batlles-delaFuente et al., 2024). Other contributions highlight the socio-economic challenges of governance reforms (Ntshangase et al., 2024; Sidii, 2025; Tossekbayev et al., 2025; Waldman, 2024; Bondar et al., 2024), while research on InsurTech and e-commerce integration demonstrates how technological advancements intersect with compliance requirements (Khrais, 2025). In parallel, AI applications in adjacent public policy domains, such as energy equity and municipal services, illustrate how algorithmic tools are being embedded into public decision-making, further strengthening the argument that governance capacity is increasingly defined by digital and AI readiness (Kirichok et al., 2025; Kajda & Karwot, 2025). The challenges of cyber-fraud and emerging threats, such as pig-butcher scams, underline the need for adaptive governance models to counter evolving risks (Burton & Moore, 2024).

Macro-level conditions and geopolitical pressures shape the risk environment in which AML and digital governance operate. Unconventional mon-

etary policies can influence liquidity conditions, financial intermediation incentives, and cross-border capital movements, thereby indirectly altering the opportunity structure for illicit flows and complicating monitoring demands (Jabiyev et al., 2025). Likewise, intensifying geopolitical competition can amplify sanctions-related compliance pressures and incentives for circumvention through complex trade and financial channels, or cross-border transactions, thereby increasing the importance of digitally enabled oversight, information sharing, and resilient governance systems (Ahmed, 2025). While these macro dynamics are not AML policies per se, they reinforce the practical relevance of state digital capacity for sustaining effective compliance under rapidly changing external constraints.

The literature presents a comprehensive landscape that links digital governance with the mitigation of money laundering risk. Empirical evidence shows that digitalization can reduce vulnerabilities to corruption, shadow economy activities, and cyber-enabled financial crimes. At the same time, methodological innovations highlight the importance of tailored AML strategies and robust digital governance capacities. Nevertheless, the reviewed studies also emphasize heterogeneity across countries in digital readiness and institutional quality, underscoring the importance of comparative, cross-country analyses. These insights justify the present study's focus on evaluating whether improvements in e-government development contribute to measurable reductions in money-laundering risks across a large panel of nations.

The study aims to assess the impact of advancements in e-government on reducing systemic money-laundering risks in a global panel of 171 countries between 2012 and 2024, thereby providing evidence on the role of digital governance in enhancing financial integrity and supporting international regulatory frameworks.

## 2. METHODOLOGY

This study employs a panel data approach to investigate the relationship between e-government development and money-laundering risks across countries. The dataset comprises 171 countries from

2012 to 2024, yielding an unbalanced panel of 982 observations due to varying data availability across countries and years. The empirical analysis is based on an unbalanced panel of 171 countries observed from 2012 to 2024. The full list of countries included in the sample is provided in Appendix A.

The explanatory variable is the E-Government Development Index (EGDI), obtained from the United Nations E-Government Knowledgebase (UN, n.d.). The EGDI measures the scope and quality of online services, the development status of telecommunication infrastructure, and human capital, and is widely used as an indicator of digital governance capacity. The dependent variable is the Basel Anti-Money Laundering (AML) Index, provided by the Basel Institute on Governance (n.d.), which assesses countries' vulnerabilities to money laundering and terrorist financing based on multiple dimensions, including corruption, financial transparency, political risk, and legal frameworks.

Both variables were subjected to normality tests and transformation procedures before estimation. The Shapiro–Wilk test was applied to assess distributional properties. Since the EGDI is bounded between 0 and 1, and the Basel AML Index is strictly positive, a Box-Cox transformation was employed to stabilize variance and approximate normality. The estimated  $\lambda$  was 1.18 for the EGDI, indicating near-linearity, and 0.65 for the Basel AML Index, suggesting a log-like transformation. The transformed variables were used in subsequent econometric models.

The core empirical strategy relies on fixed-effects (FE) and random-effects (RE) panel models estimated with the `plm` package in R. The country-fixed effects specification controls for unobserved, time-invariant heterogeneity across countries, such as institutional traditions, legal systems, enforcement cultures, and the structural characteristics of financial systems. This allows the analysis to focus on within-country changes over time in digital governance and AML risk. The random effects model, which incorporates both within- and between-country variation, is estimated for comparison under the assumption that unobserved country effects are uncorrelated with the explanatory variable. The Hausman test is used to assess this assumption and guide model selection.

To account for global shocks and common temporal dynamics, such as international regulatory reforms, geopolitical developments, or global financial trends, an additional specification incorporating time-fixed effects is estimated. This approach isolates the effect of digital governance from year-specific influences that affect all countries simultaneously, thereby strengthening causal interpretation.

Standard diagnostic tests reveal violations of classical panel assumptions. The Wooldridge test indicates first-order serial correlation, the Breusch-Pagan test confirms heteroskedasticity, and the Pesaran CD test provides evidence of cross-sectional dependence. To ensure reliable statistical inference under these conditions, the analysis employs robust variance-covariance estimators, including country-level cluster-robust standard errors and Driscoll-Kraay standard errors, which jointly correct for heteroskedasticity, serial correlation, and cross-sectional dependence.

All estimations and diagnostic procedures were conducted in R Studio, using the `plm`, `lmtest`, and `sandwich` packages. This methodological framework enables a rigorous assessment of the relationship between e-government development and money laundering risk, while explicitly accounting for both persistent country-specific characteristics and common global time effects.

### 3. RESULTS

The dataset comprises 982 observations spanning 171 countries from 2012 to 2024. The average year is close to 2018, indicating a balanced distribution of time.

For the EGDI ( $x$ ), the mean value is 0.60 with a standard deviation of 0.21, while the median (0.62) is slightly above the mean. The distribution is slightly left-skewed ( $-0.29$ ) and moderately platykurtic ( $-0.85$ ), indicating a relatively symmetric but somewhat flat distribution compared to a normal distribution. The index ranges widely from 0.06 to 0.98, indicating significant disparities in digital governance development between countries.

The Basel AML Index ( $y$ ) has an average of 5.53 and a standard deviation of 1.21. The median (5.46) is close to the mean, and the distribution is nearly symmetric ( $\text{skew} = 0.17$ ) and platykurtic ( $\text{kurtosis} = -0.42$ ). The values span from 2.36 to 8.61, reflecting noticeable but not extreme cross-country variation in money laundering risks.

Although both variables show distributions that are relatively close to normal (with slight skewness and kurtosis), transformation may still be required. The E-Government Index ( $x$ ) is bounded between 0 and 1, which can introduce non-linearity and heteroscedasticity in regressions; a logit or arcsine-square-root transformation could stabilize variance. Despite being more normally distributed, the Basel AML Index ( $y$ ) is strictly positive and has a limited range; therefore, a log or Box-Cox transformation may improve normality and linearity in econometric models.

**Table 1.** Descriptive statistics with all the variables (Country, Year, EGDI, Basel AML Index)

Variable	EGDI ( $x$ )	Basel AML Index ( $y$ )
N	982	982
Mean	0.6	5.53
SD	0.21	1.21
Median	0.62	5.46
Trimmed	0.61	5.5
MAD	0.24	1.26
Min	0.06	2.36
Max	0.98	8.61
Range	0.93	6.25
Skewness	$-0.29$	0.17
Kurtosis	$-0.85$	$-0.42$
SE	0.01	0.04

The Shapiro-Wilk test was applied to assess the normality of the variables. The results indicated that the EGDI ( $W = 0.97$ ,  $p < 0.01$ ) deviates from normality, whereas the Basel AML Index ( $W = 0.99$ ,  $p = 0.08$ ) does not differ significantly from normality. Therefore, transformations were considered for  $x$ , while  $y$  was retained in its original form.

The Box-Cox transformation was applied to ensure the normality and homoscedasticity of the data. The estimated  $\lambda$  was 1.18 for the EGDI, indicating that the variable is close to linear and requires no substantial transformation. For the Basel AML Index, the estimated  $\lambda$  was 0.65, suggesting

a log-like transformation to stabilize variance and approximate normality. The transformed values were used in robustness checks.

The FE model results indicate a statistically significant negative relationship between the transformed EGDI and the Basel AML Index. Specifically, the coefficient for  $x\_trans$  is  $-1.56$  ( $p < 0.001$ ), indicating that improvements in e-government development are associated with a reduction in AML risks over time within countries. However, the  $R^2$  (within) is relatively low (0.159), indicating that while the relationship is significant, the model explains only a modest portion of the within-country variation.

The RE model also shows a strong, highly significant negative effect, with a coefficient of  $-1.99$  ( $p < 0.001$ ). Unlike the FE model, RE includes both within- and between-country variation, resulting in higher explanatory power ( $R^2 = 0.452$ ). The significant intercept (2.38) suggests that there are systematic cross-country differences in AML risks that are not captured by the explanatory variable.

The Hausman test strongly rejects the null hypothesis ( $\chi^2 = 33.18$ ,  $p < 0.001$ ), indicating that the RE assumption of uncorrelated individual effects is violated. Thus, the FE model is consistent and preferred for interpreting causal within-country effects.

Both models confirm that higher e-government development is associated with lower AML risks;

however, the FE specification is more reliable for drawing policy conclusions.

The diagnostic tests reveal several specification issues in the fixed-effects model. The Wooldridge test for serial correlation strongly rejects the null of no autocorrelation ( $F = 95.72$ ,  $p < 0.001$ ), indicating the presence of first-order autocorrelation in the panel residuals. Similarly, the Breusch–Pagan test for heteroskedasticity confirms significant variance heterogeneity across units ( $BP = 307.78$ ,  $df = 171$ ,  $p < 0.001$ ), suggesting that error variances are not constant. Furthermore, the Pesaran CD test ( $z = 6.72$ ,  $p < 0.001$ ) and the alternative Breusch–Pagan LM version ( $\chi^2 = 24,464$ ,  $p < 0.001$ ) both provide strong evidence of cross-sectional dependence, which is common in macro-level panels where countries are affected by shared shocks and global dynamics. Taken together, these findings indicate that the classical FE assumptions are violated. To obtain reliable inference, it is therefore essential to employ robust estimation techniques, such as country-cluster robust standard errors or Driscoll–Kraay standard errors, which correct for serial correlation, heteroskedasticity, and cross-sectional dependence.

Across all specifications, the coefficient for  $x\_trans$  (Box–Cox-transformed EGDI) is consistently negative and statistically significant, with a value of approximately  $-1.56$ . This confirms that improvements in e-government development are associated with lower Basel AML Index values (i.e., reduced money-laundering risk):

**Table 2.** Panel regression results: Effect of e-government development on AML risk

Specification	Fixed Effects (FE)	Random Effects (RE)
Coefficient ( $x\_trans$ )	-1.564	-1.994
Std. Error	0.126	0.102
Test-statistic	$t = -12.37$	$z = -19.55$
p-value	$< 0.001$	$< 0.001$
Intercept	–	2.377***
$R^2$ (Within)	0.159	0.452
$R^2$ (Between)	–	Reported
$R^2$ (Overall)	–	Reported
Observations	982 ( $n = 171$ ; $T = 2-7$ )	982 ( $n = 171$ ; $T = 2-7$ )
F/Chi <sup>2</sup> -statistic	$F(1,810) = 152.9$ , $p < 0.001$	$\chi^2(1) = 382.4$ , $p < 0.001$
Hausman Test	$\chi^2 = 33.18$ , $df = 1$ , $p < 0.001 \rightarrow$ FE preferred	

Note: The Basel AML Index (Box–Cox transformed) is the dependent variable. Explanatory variable – EGDI (Box–Cox transformed). FE model controls for unobserved time-invariant heterogeneity across countries; no intercept reported. The RE model assumes uncorrelated country effects and includes an intercept of 2.38 ( $p < 0.001$ ). The Hausman test strongly favors the FE specification ( $p < 0.001$ ). Signif. codes: ‘\*\*\*’ – 0.001; ‘\*\*’ – 0.01; ‘\*’ – 0.05; ‘.’ – 0.1; ‘no symbol’ – insignificant.

- with cluster-robust SEs by country, the estimated effect is  $-1.56$  ( $SE = 0.20$ ,  $t = -7.69$ ,  $p < 0.001$ ), and the 95% confidence interval  $[-1.96, -1.17]$  confirms a robust negative association.
- with Driscoll–Kraay SEs, which correct simultaneously for heteroskedasticity, serial correlation, and cross-sectional dependence, the estimate remains  $-1.56$ , but the standard error falls to  $0.095$ , leading to an even stronger  $t$ -statistic ( $-16.52$ ,  $p < 0.001$ ). The 95% confidence interval  $[-1.75, -1.38]$  further strengthens evidence of a stable effect.
- the finite-sample corrected Driscoll–Kraay SEs produce nearly identical results to the clustered SEs ( $SE \approx 0.20$ ,  $t = -7.66$ ,  $p < 0.001$ ), supporting robustness across alternative estimators.

The findings are consistent across all error structures, indicating that the observed adverse effect of e-government development on AML risk is both statistically robust and substantively meaningful.

The empirical analysis consistently demonstrates a significant and robust negative association between e-government development and money laundering risks. Across fixed effects, random effects, and robustness-corrected specifications, higher levels of digital governance are associated with lower Basel AML Index scores, underscoring the role of e-government as an institutional mechanism for reducing vulnerabilities to financial crime. The effect remains stable across different model corrections, with coefficients around  $-1.56$ , confirming the substantive impact of e-government reforms on strengthening anti-money laundering resilience.

At the same time, diagnostic tests revealed important violations of classical panel assumptions, including serial correlation, heteroskedasticity, and cross-sectional dependence. Using cluster-robust

and Driscoll–Kraay standard errors ensured that the estimates remained statistically valid under these conditions. The robustness of the results across alternative corrections strengthens confidence in the findings' reliability. The evidence suggests that improvements in e-government infrastructure play a meaningful, statistically significant role in lowering AML risks, both within and across countries, thereby highlighting the importance of digitalization in advancing financial integrity.

The estimated country-specific fixed effects reveal substantial heterogeneity in baseline AML risk across countries after controlling for AI readiness and other modelled factors (Table 4 and Table B1, Appendix B). Higher fixed-effect values indicate persistently higher AML risk that is not explained by observed technological or institutional variables, pointing to deep-rooted structural vulnerabilities. At the upper end of the distribution, countries such as Iran, Afghanistan, Kenya, Cambodia, the Democratic Republic of the Congo, and Myanmar exhibit the largest positive effects, suggesting that entrenched AML challenges persist even when accounting for AI readiness. These results indicate that in such jurisdictions, structural issues related to governance capacity, enforcement effectiveness, or political and economic instability continue to dominate AML outcomes.

In contrast, countries with the lowest fixed effects demonstrate comparatively strong structural resilience. Nordic and advanced European economies, including Finland, Estonia, Slovenia, Lithuania, Norway, Sweden, and San Marino, consistently show the smallest baseline AML risks. This pattern suggests that long-established institutional frameworks, regulatory quality, and administrative capacity play a decisive role in limiting AML vulnerabilities beyond what can be captured by observable indicators alone. Even when AI readiness is held constant, these countries benefit from favorable unobserved characteristics that systematically reduce AML exposure.

**Table 3.** Fixed effects estimates with robust standard errors

Specification	Coefficient (x_trans)	Std. Error	t-value	p-value	95% CI (Lower)	95% CI (Upper)
FE with Cluster-Robust SEs (country)	-1.564	0.203	-7.69	< 0.001	-1.962	-1.165
FE with Driscoll–Kraay SEs	-1.564	0.095	-16.52	< 0.001	-1.749	-1.378
FE with DK Finite-Sample Correction	-1.564	0.204	-7.66	< 0.001	-1.962	-1.165

**Table 4.** Countries with the highest and lowest fixed effects (Baseline AML risk)

Rank	Top 10 countries (highest fixed effects)		Bottom 10 countries (lowest fixed effects)	
	Country	FE estimate	Country	FE estimate
1	Iran, Islamic Rep.	3.898	Andorra	1.147
2	Afghanistan	3.517	San Marino	1.176
3	Kenya	3.414	Finland	1.413
4	Congo, Dem. Rep.	3.393	Estonia	1.465
5	Myanmar	3.400	Slovenia	1.647
6	Cambodia	3.355	Lithuania	1.665
7	Vietnam	3.288	Bulgaria	1.845
8	Lao PDR	3.288	Norway	1.818
9	Mozambique	3.286	New Zealand	1.808
10	Sudan	3.248	Sweden	1.855

A notable insight from the results is that high income status alone does not guarantee a low baseline AML risk. Several economically advanced or financially open countries, such as the United Arab Emirates, Argentina, China, and the Bahamas, exhibit relatively high fixed effects, indicating persistent vulnerabilities linked to financial complexity, openness, or geopolitical factors. Conversely, some middle-income economies show moderate effects, reflecting more balanced structural conditions. This underscores that AML risk is shaped by a multidimensional set of factors that extend beyond income level or technological adoption.

Figure 1 illustrates the distribution of country-specific fixed effects from the fixed-effects panel model, capturing time-invariant, unobserved heterogeneity in AML risk after controlling for AI readiness and common temporal dynamics. The wide dispersion of estimates highlights substantial cross-country differences in baseline AML vulnerability that cannot be explained solely by observable technological or institutional variables. Countries located at the upper end of the distribution consistently exhibit a persistently higher AML risk, indicating deep-seated structural challenges in governance, enforcement capacity, or the financial system. In contrast, countries with lower fixed effects demonstrate strong structural resilience, reflecting favorable institutional arrangements and long-standing regulatory effectiveness.

Figure 1 also underscores that AML risk is not solely determined by income level or technological advancement. Several financially developed or highly open economies appear among countries with relatively elevated fixed effects, while several smaller or less prominent economies show comparatively low

baseline risk. This visual evidence reinforces the econometric findings by demonstrating that, although AI readiness significantly reduces AML risk on average, persistent country-specific factors continue to shape outcomes. Figure 1, therefore, complements the regression results by emphasizing the importance of addressing long-term structural and institutional determinants alongside technological solutions in strengthening AML frameworks.

The fixed effects highlight that while AI readiness significantly reduces AML risk on average, its effectiveness is conditioned by deep, time-invariant country characteristics. The persistence of high baseline risks in certain countries implies that technological solutions must be complemented by long-term institutional strengthening. At the same time, the strong performance of structurally resilient countries highlights the potential benefits of aligning AI-enabled AML tools with robust governance and enforcement systems.

The time-fixed effects specification (Table 5) confirms a strong and robust negative relationship between AI readiness and AML risk, after controlling for global shocks common to all countries. The coefficient on the transformed AI readiness variable is large and highly statistically significant ( $-2.565$ ,  $p < 0.001$ ), indicating that improvements in AI readiness are associated with substantial reductions in AML vulnerability, even after accounting for worldwide regulatory, macroeconomic, and geopolitical developments through time dummies. Compared with country-only specifications, the coefficient magnitude increases, suggesting that failing to control for global time trends would underestimate the true effect of AI readiness on AML risk.



**Table 6.** Estimated time fixed effects

Year	Time Effect	Year	Time Effect	Year	Time Effect
2012	2.162	2018	2.143	2022	2.164
2014	2.109	2020	2.148	2024	2.190
2016	2.163	–			

Note: Time effects capture global AML-related shocks common to all countries in a given year. Higher values indicate periods of elevated baseline AML risk.

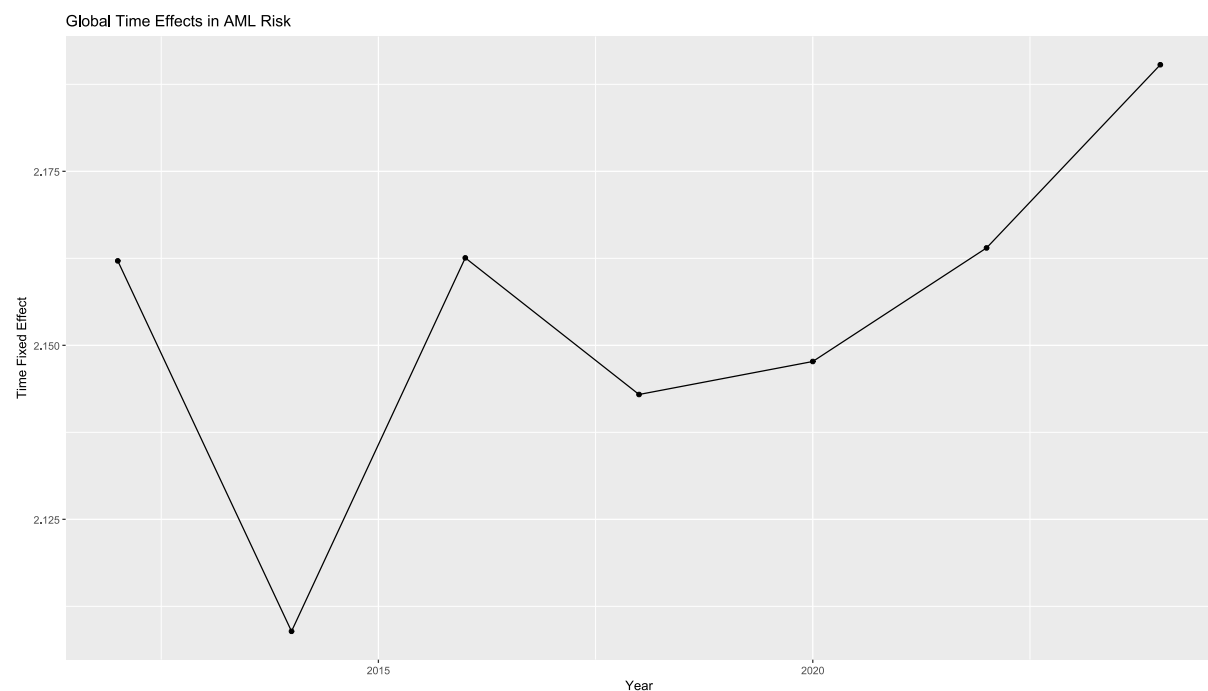
Figure 2 visualizes the estimated time-fixed effects from the panel model and illustrates the evolution of global and year-specific AML risk after controlling for AI readiness and country-specific heterogeneity. The trajectory is relatively flat over the observation period, indicating that common global AML pressures remained broadly stable rather than exhibiting sharp structural breaks. Minor fluctuations are observable, with slightly lower effects around the mid-2010s and a gradual increase toward the later years, culminating in the highest value in 2024. This pattern suggests a modest upward shift in baseline AML risk at the global level, potentially reflecting the growing complexity of international financial flows, accelerated digitalization of financial services, and heightened geopolitical and macroeconomic uncertainty.

Importantly, the limited dispersion of the time effects confirms that the strong negative impact of AI readiness identified in the regression results is

not driven by particular years or temporary global shocks. Instead, AI readiness consistently reduces AML risk across different global environments. Figure 2, therefore, supports the interpretation that technological capacity operates as a structurally stabilizing factor, mitigating AML vulnerabilities even as global conditions evolve, and reinforces the robustness of the estimated relationship between AI readiness and money-laundering risk.

## 4. DISCUSSION

The findings of this study provide strong empirical confirmation that e-government development significantly reduces money-laundering risks, as reflected in the robust negative coefficient of  $-1.56$  in the fixed effects estimations. This aligns with prior research, which shows that digital governance frameworks enhance compliance mechanisms, accountability, and the transparency of financial



**Figure 2.** Evolution of global AML risk: Time fixed effects from the panel model (2012–2024)

transactions, thereby constraining the channels through which illicit finance operates (Alomari, 2020; Máchová et al., 2018; Bartulovic et al., 2023). The present results strengthen the view that digitalization is not merely a supportive governance tool but a structural driver of financial integrity.

The empirical evidence also resonates with studies that emphasize the importance of governance quality and institutional readiness in achieving AML effectiveness. The within-country reductions in AML risk parallel findings that governance reforms and economic openness can shape vulnerabilities to illicit finance across regions and economic blocs (AlQudah et al., 2025). The result that e-government reduces AML risk, even after correcting for serial correlation, heteroskedasticity, and cross-sectional dependence, underscores its robustness and complements studies on compliance units and internal control mechanisms that highlight organizational capacity as an intervening factor (Abou-Moghli & Shatem, 2024; Amanamah, 2024).

Moreover, the results confirm the research insights that digital governance contributes to antifragility and dynamic capabilities in public institutions. By demonstrating that improvements in e-government are consistently linked to lower AML risk, this study empirically validates the conceptual argument that digital transformation enhances the adaptive capacities of governance systems (Bartuseviciene & Butkus, 2024; Bian & Wang, 2024). The findings also align with research on behavioral economics and e-government adoption, which emphasizes the role of digital readiness in shaping governance outcomes (Crăciun et al., 2025; Zambrano-Yépez et al., 2023).

Importantly, this study provides empirical support for the literature documenting how digitalization strengthens monitoring and detection capacities against cyber-fraud and financial crime. Prior works demonstrate that AI, machine learning, and blockchain analytics can uncover illicit flows in cryptocurrency transactions and beyond (Dobrovolska & Rozhkova, 2024). The significant and stable negative relationship between e-government and AML risk suggests that these technological advancements translate into measurable macro-level outcomes when embedded in national governance infrastructures.

The robustness of the results also supports findings that digital readiness enhances resilience against corruption, shadow economies, and cyber threats. The consistent effect across model specifications is in line with evidence from European contexts showing that digitalization and transparency reforms bolster states' ability to curb corruption and illicit markets (Yarovenko et al., 2025; Czapkiewicz et al., 2025; Lyeonov et al., 2025). In this respect, the results extend prior research by demonstrating that these relationships are not limited to specific regional settings but hold globally across 171 countries.

The findings also reinforce the importance of tailored, context-sensitive AML strategies, as emphasized in work on FATF compliance clusters and on institutional determinants of system effectiveness (Kuzior et al., 2025). By empirically demonstrating that digital governance consistently increases AML risk, this study suggests that countries with weaker institutional capacity or lower digital readiness may face greater challenges in translating formal compliance into actual effectiveness.

This study's results align with, but extend, the existing literature by providing robust cross-country econometric evidence on the institutional role of digital governance in mitigating AML risks. The consistency of the findings across robustness checks highlights digital governance as a reliable and scalable tool for advancing financial integrity, providing empirical support for the policy emphasis placed by international organizations on digital transformation in AML/CFT strategies.

This study is subject to several limitations that should be acknowledged. First, the analysis relies on an unbalanced panel covering 171 countries from 2012 to 2024, and data availability constraints, particularly for e-government indicators, may limit the comparability of results across countries and years. Second, although transformations and robust estimation techniques were applied, measurement errors in both the EGDI and the Basel AML Index could affect the precision of estimates. Third, the fixed effects approach captures within-country dynamics but does not fully address potential endogeneity, such as reverse causality between governance reforms and AML risks. The macro-level indicators

do not reflect institutional or enforcement heterogeneity at the sectoral or micro level, which may influence the observed relationships. These limitations suggest that while the results provide strong evidence of a negative association be-

tween e-government development and AML risk, they should be interpreted cautiously and complemented by future studies using micro-level data, instrumental variable approaches, or case-specific analyses.

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## CONCLUSION

This study aimed to assess whether the development of e-government reduces systemic money-laundering risks in a global setting. By examining the relationship between digital governance and financial integrity, the paper sought to provide empirical evidence on the role of e-government in strengthening resilience against illicit financial activities.

The study analyzes an unbalanced panel of 171 countries over 2012–2024, using the E-Government Development Index as the explanatory variable and the Basel AML Index as the dependent variable. Fixed- and random-effects models with Box–Cox transformations were estimated, with the Hausman test guiding model selection and cluster-robust and Driscoll–Kraay standard errors ensuring reliable inference.

The results reveal a strong and statistically significant negative association between e-government development and AML risk. In the preferred fixed-effects model, the coefficient equals  $-1.56$  ( $p < 0.001$ ), with robust confidence intervals confirming stability of the effect. Substantial country-specific heterogeneity persists (approximately 1.15–3.90), while time effects remain relatively stable (approximately 2.11–2.19), indicating that the risk-reducing impact of digital governance is structural rather than year-specific.

The findings have broader strategic implications for public policy and institutional reform. Strengthening financial integrity cannot rely solely on formal compliance with international AML/CFT standards; it must also address the state's structural capacity to generate, process, and exchange reliable digital information. Investments in digital governance infrastructure, such as interoperable e-services, secure ICT architecture, digital identity systems, data analytics capabilities, and citizen digital literacy, appear to function not only as administrative modernization tools but as core components of risk prevention and supervisory effectiveness. By enhancing transparency, traceability, and cross-agency coordination, advanced e-government systems reduce informational asymmetries and limit opportunities for regulatory arbitrage, concealment of beneficial ownership, and cross-border illicit financial flows. In this sense, digital public infrastructure strengthens both preventive and detective dimensions of AML frameworks. For international organizations, development banks, and standard-setting bodies, these results suggest that digital governance indicators may serve as meaningful complementary benchmarks in assessing AML resilience. Embedding digital capacity metrics into country evaluations, technical assistance programs, and peer-review mechanisms could help align technological transformation strategies with financial-sector stability objectives and long-term institutional credibility.

## AUTHOR CONTRIBUTIONS

Conceptualization: Olga Lygina, Narek M. Kesoyan, Gaukhar Uvakhbayeva, Nataliia Kovshun, Ekaterina Dmitrieva, Rostyslav Shchokin, Liudmyla Zakharkina.

Data curation: Liudmyla Zakharkina.

Formal analysis: Liudmyla Zakharkina.

Funding acquisition: Ekaterina Dmitrieva.

Investigation: Liudmyla Zakharkina.

Methodology: Liudmyla Zakharkina.

Project administration: Liudmyla Zakharkina.

Resources: Narek M. Kesoyan, Rostyslav Shchokin.

Software: Rostyslav Shchokin, Liudmyla Zakharkina.

Supervision: Olga Lygina, Gaukhar Uvakbayeva.

Validation: Ekaterina Dmitrieva, Liudmyla Zakharkina.

Visualization: Nataliia Kovshun, Liudmyla Zakharkina.

Writing – original draft: Olga Lygina, Narek M. Kesoyan, Gaukhar Uvakbayeva, Nataliia Kovshun, Ekaterina Dmitrieva, Rostyslav Shchokin, Liudmyla Zakharkina.

Writing – review & editing: Olga Lygina, Narek M. Kesoyan, Gaukhar Uvakbayeva, Nataliia Kovshun, Ekaterina Dmitrieva, Rostyslav Shchokin, Liudmyla Zakharkina.

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## APPENDIX A. Countries included in the sample

Afghanistan; Albania; Algeria; Andorra; Angola; Antigua and Barbuda; Argentina; Armenia; Australia; Austria; Azerbaijan; Bahamas; Bahrain; Bangladesh; Barbados; Belarus; Belgium; Belize; Benin; Bhutan; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Burkina Faso; Cabo Verde; Cambodia; Cameroon; Canada; Chile; China; Colombia; Comoros; Costa Rica; Croatia; Cuba; Cyprus; Czechia; Côte d'Ivoire; Congo, Democratic Republic; Denmark; Dominica; Dominican Republic; Ecuador; Egypt (Arab Republic); El Salvador; Estonia; Eswatini; Ethiopia; Fiji; Finland; France; Gambia; Georgia; Germany; Ghana; Greece; Grenada; Guatemala; Guinea; Guinea-Bissau; Guyana; Haiti; Honduras; Hungary; Iceland; India; Indonesia; Iran (Islamic Republic); Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kazakhstan; Kenya; Kuwait; Kyrgyz Republic; Lao People's Democratic Republic; Latvia; Lebanon; Lesotho; Liberia; Liechtenstein; Lithuania; Luxembourg; Madagascar; Malawi; Malaysia; Mali; Malta; Marshall Islands; Mauritania; Mauritius; Mexico; Mongolia; Montenegro; Morocco; Mozambique; Myanmar; Namibia; Nepal; Netherlands; New Zealand; Nicaragua; Niger; Nigeria; North Macedonia; Norway; Oman; Pakistan; Panama; Papua New Guinea; Paraguay; Peru; Philippines; Poland; Portugal; Qatar; Republic of Korea; Moldova; Romania; Russian Federation; Rwanda; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Samoa; San Marino; Sao Tome and Principe; Saudi Arabia; Senegal; Serbia; Seychelles; Sierra Leone; Singapore; Slovak Republic; Slovenia; Solomon Islands; South Africa; Spain; Sri Lanka; Sudan; Suriname; Sweden; Switzerland; Syrian Arab Republic; Tajikistan; Thailand; Timor-Leste; Tonga; Trinidad and Tobago; Tunisia; Türkiye; Uganda; Ukraine; United Arab Emirates; United Kingdom; Tanzania; United States; Uruguay; Uzbekistan; Vanuatu; Venezuela (RB); Viet Nam; Yemen (Republic); Zambia; Zimbabwe.

## APPENDIX B

**Table B1.** Country-specific fixed effects

Country	FE	Country	FE	Country	FE
Afghanistan	3.517	Ghana	2.437	Oman	2.072
Albania	2.427	Greece	2.403	Pakistan	2.644
Algeria	2.771	Grenada	2.119	Panama	2.968
Andorra	1.147	Guatemala	2.336	Papua New Guinea	2.272
Angola	2.739	Guinea	2.859	Paraguay	3.123
Antigua and Barbuda	2.102	Guinea-Bissau	3.225	Peru	2.100
Argentina	3.189	Guyana	2.507	Philippines	2.853
Armenia	2.207	Haiti	3.199	Poland	2.115
Australia	2.283	Honduras	2.466	Portugal	1.996
Austria	2.454	Hungary	2.219	Qatar	2.535
Azerbaijan	2.619	Iceland	2.028	Romania	2.154
Bahamas	2.724	India	2.410	Russian Federation	2.927
Bahrain	2.735	Indonesia	2.493	Rwanda	2.767
Bangladesh	2.570	Iran, Islamic Rep.	3.898	Saint Kitts and Nevis	2.789
Barbados	2.444	Ireland	2.165	Saint Lucia	2.082
Belarus	2.421	Israel	2.224	Saint Vincent and the Grenadines	2.063
Belgium	2.305	Italy	2.615	Samoa	2.176
Belize	2.821	Jamaica	2.100	San Marino	1.176
Benin	2.755	Japan	2.864	São Tomé and Príncipe	2.987
Bhutan	2.406	Jordan	2.266	Saudi Arabia	2.667
Bolivia	3.003	Kazakhstan	2.771	Senegal	2.504
Bosnia and Herzegovina	2.483	Kenya	3.414	Serbia	2.587
Botswana	2.295	Korea, Republic	2.644	Seychelles	2.656
Brazil	2.660	Kuwait	2.878	Sierra Leone	2.845

**Table B1 (cont.).** Country-specific fixed effects

Country	FE	Country	FE	Country	FE
Brunei Darussalam	2.477	Kyrgyz Republic	2.872	Singapore	2.503
Bulgaria	1.845	Lao PDR	3.288	Slovak Republic	2.132
Burkina Faso	2.838	Latvia	2.209	Slovenia	1.647
Cabo Verde	2.936	Lebanon	2.842	Solomon Islands	2.355
Cambodia	3.355	Lesotho	2.817	South Africa	2.386
Cameroon	2.974	Liberia	2.919	Spain	2.328
Canada	2.478	Liechtenstein	2.261	Sri Lanka	2.922
Chile	1.983	Lithuania	1.665	Sudan	3.248
China	3.191	Luxembourg	2.707	Suriname	2.764
Colombia	2.160	Madagascar	3.044	Sweden	1.855
Comoros	2.756	Malawi	2.192	Switzerland	2.645
Congo, Dem. Rep.	3.393	Malaysia	2.614	Syrian Arab Republic	2.424
Costa Rica	2.614	Mali	3.114	Tajikistan	3.230
Côte d'Ivoire	2.630	Malta	2.280	Tanzania	2.836
Croatia	2.132	Marshall Islands	2.501	Thailand	2.999
Cuba	2.404	Mauritania	2.701	Timor-Leste	2.461
Cyprus	2.397	Mauritius	2.461	Tonga	2.897
Czechia	2.008	Mexico	2.575	Trinidad and Tobago	2.451
Denmark	2.053	Moldova	2.404	Tunisia	2.210
Dominica	1.857	Mongolia	2.861	Türkiye	2.901
Dominican Republic	2.707	Montenegro	1.922	Uganda	3.084
Ecuador	2.640	Morocco	2.483	Ukraine	2.842
Egypt, Arab Rep.	2.158	Mozambique	3.286	United Arab Emirates	3.123
El Salvador	2.196	Myanmar	3.400	United Kingdom	2.300
Estonia	1.465	Namibia	2.694	United States	2.613
Eswatini	3.111	Nepal	3.053	Uruguay	2.223
Ethiopia	2.610	Netherlands	2.540	Uzbekistan	2.505
Fiji	2.128	New Zealand	1.808	Vanuatu	2.431
Finland	1.413	Nicaragua	2.715	Venezuela, RB	2.997
France	2.167	Niger	2.682	Viet Nam	3.288
Gambia	2.307	Nigeria	2.983	Yemen, Rep.	2.893
Georgia	2.288	North Macedonia	1.933	Zambia	2.853
Germany	2.550	Norway	1.818	Zimbabwe	2.914

Note: FE estimates sorted alphabetically by country name.