

“Digitalization of tax and customs administration and the oversight of public-private partnership contracts: Cross-country evidence and Kazakhstan’s special-purpose audit context”

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DIGITALIZATION OF TAX AND CUSTOMS ADMINISTRATION AND THE OVERSIGHT OF PUBLIC-PRIVATE PARTNERSHIP CONTRACTS: CROSS-COUNTRY EVIDENCE AND KAZAKHSTAN'S SPECIAL-PURPOSE AUDIT CONTEXT

Abstract

Public-private partnerships are a principal vehicle for infrastructure finance, yet their institutional correlates are poorly measured. This study examines how tax and customs digitalization and the oversight of PPP contracts relate to PPP deal flow, with Kazakhstan as a case. Customs digitalization is measured by WTO Trade Facilitation Agreement commitments and realized implementation in the UN survey, tax digitalization by electronic filing and payment rates, and oversight by contract-management and supreme-audit scores. Poisson and staggered-adoption models use 359 observations across 83 low- and middle-income economies (2020–2024), larger and more PPP-active than the 50 excluded, and 803 across 81 WTO members (2015–2024). Legal commitments to digital customs procedures show no association with financial closures, nor do electronic tax filing and payment. Realized implementation of electronic duty payment is associated with about 0.4 log points more closures per level; the two-year lead is insignificant, and the estimate loses significance without China, India, and Brazil. The three customs measures thus distinguish perceived trade-logistics performance, formal commitment, and realized transactional implementation. Contract-management regulatory quality ($\beta = 0.023$, $p < 0.01$) is associated with closures through accounting for PPP liabilities and the presence of a regulator, whereas post-project audit and supreme-audit oversight are not. In Kazakhstan, customs digitalization was complete by 2019, the 2021 amendments followed the national audit of PPP obligations, and termination rates differ across regions, not cohorts. State audit of budget execution reaches PPP obligations directly, whereas special-purpose audit applies only where the state partner is a quasi-public entity.

Keywords

infrastructure finance, deal flow, trade facilitation, e-government, fiscal risk, contingent liabilities, Central Asia

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G31, H54, H83, L33

INTRODUCTION

Developing economies face an annual SDG-investment gap of about US\$4 trillion (UNCTAD, 2023, 2025). Public-private partnerships (PPPs) are an important channel for mobilizing private capital, yet private participation remains volatile and uneven, reaching about USB 100.7 billion in 2024 across the 137 low- and middle-income economies tracked by the World Bank (World Bank, 2025a).

Three aspects of state capacity bear on that variation. The first is the fiscal interface with investors, since customs procedures are a plausible channel for the import-intensive construction phase of infrastructure projects and tax administrations increasingly operate electronically (Junquera-Varela et al., 2022; World Bank, 2022). Customs digitalization is viewed as a legal commitment in the WTO Trade Facilitation Agreement Database (World Trade Organization, 2026) and as realized implementation in the UN Global Survey on Digital and Sustainable Trade Facilitation (United Nations, 2025). The Logistics Performance Index, by contrast, rates perceived clearance efficiency, an outcome of trade-logistics performance rather than a measure of digitalization (World Bank, 2026). The second aspect is the digitalization of public services more broadly (United Nations, 2024). The third is the oversight of PPP contracts, which generate fiscal risks and contingent liabilities (Irwin et al., 2018; International Monetary Fund & World Bank, 2019) and whose regulatory framework, including the accounting and audit of those liabilities, is scored by the World Bank's Benchmarking Infrastructure Development (World Bank Group, 2020).

These lines of research developed separately, with limited attention to investment outcomes in the e-government stream and to the fiscal interface in the PPP-governance stream (Section 1). This study examines whether tax and customs digitalization and oversight of PPP contracts, including the accounting and audit of the resulting obligations, are associated with PPP deal flow across low- and middle-income economies, holding market size constant. Kazakhstan's registry of 1,324 PPP and concession projects, its early customs digitalization, the 2019 national audit of PPP obligations, the 2021 amendments, and the regional audits that followed allow these institutions to be traced against a national portfolio down to the level of regions. The estimates describe associations rather than causal effects, and the case is an illustration rather than a within-country test.

1. LITERATURE REVIEW

Research on the determinants of private participation has developed around the World Bank Private Participation in Infrastructure (PPI) database and related panels. Partnerships are more common in large markets with high aggregate demand and under macroeconomic stability, and corruption control and an effective rule of law are associated with a larger number of projects (Engel et al., 2014; Hammami et al., 2006). Market size, purchasing power, and regulatory quality relate to the frequency and value of partnerships (Sharma, 2012), and private involvement in transport is greater where corruption is lower and regulation stronger (Percoco, 2014). Practitioners in less mature markets rank legislative instability and the absence of competition among the leading risks (Samoilov et al., 2024). Committed investment in renewable energy partnerships responds to institutional and economic conditions (Fleta-Asín & Muñoz, 2021), and the PPI records have been extended with imputed institutional and conflict variables (Fernández-Olmos et al., 2025). Methodologically, pseudo-maximum likelihood suits non-negative outcomes with many zeros (Santos Silva & Tenreiro, 2006). Two-way

fixed-effects estimates can be biased when adoption dates differ and effects vary across cohorts (Goodman-Bacon, 2021), a problem addressed by two-stage (Gardner, 2022) and local-projections estimators (Dube et al., 2023).

A complementary line examines how partnerships are financed. Transparent procurement, risk allocation, and stakeholder engagement recur as conditions for viable projects (Casady et al., 2024), and financial inclusion is linked to higher private PPP investment in energy (Yi et al., 2025). It has been proposed to use blended finance – combining grants and private funds – for Ukraine's energy sector (Kuzior et al., 2023a), fiscal incentives in special economic zones shape investor calculus (Michalek, 2023), and hybrid governance is advanced as a balance between market efficiency and public accountability (Oe et al., 2025). Broader evidence links infrastructure to long-run growth (Khandelwal et al., 2024) and convergence across the European Union (Mačiulytė-Šniukienė et al., 2023), connects infrastructure and financial technology to migrant employment (Privara, 2025), and treats sustainable investment (Patnaik & Hedau, 2026) and project financing (Berkane et al., 2025) as distinct channels.

The second stream concerns e-government and GovTech maturity. Digital government is associated with higher quality of life through online services and telecommunication infrastructure (Vasylieva et al., 2026), and GovTech is modeled as a technological, institutional, and human system whose association with social progress weakens at higher maturity (Kuzior et al., 2026). Differences in digital readiness across the European Union follow research spending and broadband connectivity (Valaskova et al., 2025) and form national clusters (Pakhnenko et al., 2025). Public-sector digitalization accompanies better health system performance (Hrytsenko et al., 2026), its link with income inequality is asymmetric (Tutar et al., 2025), and e-government indices alone do not determine anti-corruption capacity without institutional safeguards (Yarovenko et al., 2025). Kazakh enterprises show basic digital infrastructure but limited advanced maturity (Satpayeva et al., 2025).

A third stream addresses tax and customs digitalization. Revenue administration is moving to digital-by-default operation, with integrated systems and analytics supporting risk profiling and fraud detection (Junquera-Varela et al., 2022). Automated tax information systems and digital messaging raise revenue in Azerbaijan (Gazanfarli & Zhelev, 2025), and cross-country work finds positive revenue effects once social moderators are modeled (Messono, 2025), whereas tax morale among young taxpayers rests on institutional trust rather than leniency (Erina et al., 2026). Own-revenue growth in rural local governments follows administrative capacity (Mohapatra, 2026), lower corruption accompanies stronger innovation and technological readiness (Yefimenko et al., 2025), and tax revenues in transition economies move with output growth (Shapovalova et al., 2023). In trade facilitation, soft infrastructure such as customs procedures raises export performance by lowering transaction costs (Portugal-Perez & Wilson, 2012), and mandatory electronic invoicing raises reported sales and tax liabilities, especially among small firms (Bellon et al., 2022). Logistics efficiency reflects transport-sector characteristics relevant for customs performance (Hamidova et al., 2024), and environmental regulation interacts with the informal economy in ways that complicate collection (Lyeonov et al., 2025).

Auditing, oversight, and contract management form the fourth stream. Eroding horizontal accountability accompanies rent-seeking and institutional drift (Ugulava, 2026); transparency benchmarks relate to public-sector trust and macroeconomic stability, with strength varying by cultural context (Vasylieva et al., 2023); and innovation in public financial management is undercut by political capture (Ntuli et al., 2026). For partnerships, the standards of supreme audit institutions govern the audit of public-private finance and concessions, emphasizing value for money, risk transfer, and the reporting of long-term obligations (INTOSAI, 2007). Audit scholarship supplies the procedural counterpart through anti-corruption audit as an internal-audit function (Bezverkhyy et al., 2024), analytical procedures for integrated reporting (Bezverkhyy et al., 2023), digital formats such as SAF-T and XBRL as the database for audit (Shygun et al., 2023), and convergence toward common ethical standards in consulting (Kyzenko et al., 2026). Institutional and technological maturity conditions financial monitoring of bank investment in Kazakhstan (Abzhalelova et al., 2025) and lower bank default risk (Fakhrunnas et al., 2025); transparency has been mapped in insurance markets (Kuzior et al., 2023b), and institutions condition government health expenditure commitments (Megbowon & Zerihun, 2025).

Evidence on Kazakhstan and other transition economies provides the immediate context. Regional income inequality follows unemployment and household income structure (Kurmanov et al., 2026), responsible production in manufacturing is driven by environmental and resource strategies (Zhidebekkyzy et al., 2025), and five-helix cooperation has been proposed for Industry 4.0 settings in the region (Megits et al., 2022). Work on enterprise investment attractiveness and regional smart specialization (Vakhovych et al., 2014, 2021), on trade openness and foreign direct investment (Aleksandravičienė et al., 2024; Manaf et al., 2025) and on cluster-based inclusive growth (Saher et al., 2025) completes the investment-determinants background.

The four streams have developed in parallel. The PPP literature models determinants of private participation, the digital government literature exam-

ines service delivery and social outcomes, and the revenue-administration literature measures collection rather than investment. They rarely meet at the level of measured tax, customs, and contract-oversight capacity and observed partnership activity; only limited cross-country evidence links customs performance to private participation, and Kazakhstan illustrates the gap, its audit framework and its PPP registry having been studied separately. This study therefore examines how tax and customs digitalization and the oversight of PPP contracts, including the accounting and audit of the resulting obligations, are associated with the scale of private participation across low- and middle-income economies, with Kazakhstan as a complementary case. It uses two cross-country panels, the national PPP registry and the estimators noted above. Three hypotheses follow. *H1* states that customs digitalization, measured as legal commitment and as realized implementation, is positively associated with the number of PPP financial closures, with perceived clearance efficiency entering as a measure of trade-logistics performance rather than of digitalization. *H2* states that the digitalization of tax administration, measured by electronic filing and payment, is positively associated with financial closures. *H3* states that the regulatory framework for the oversight of PPP contracts and for the accounting and audit of the resulting obligations is positively associated with financial closures. The hypotheses concern associations rather than causal effects.

2. DATA AND METHODOLOGY

2.1. Data, variables and population

PPP outcomes come from the World Bank Private Participation in Infrastructure (PPI) database, namely the annual number of projects reaching financial closure and private investment commitments in USD million. Three populations are distinguished. The PPI-active universe comprises the 133 economies recording at least one project in 1990–2024, for which a year without a closure is a genuine zero. The broader eligible population adds six economies that never record a project (Eritrea, the Marshall Islands, Mauritius, Micronesia, Turkmenistan and Tuvalu), entering with zero outcomes only in the two-part speci-

cations (Table C1). The complete-case estimation sample is the part of the PPI-active universe with every regressor observed: 83 economies in the preferred specification.

Table 1 lists the variables, definitions, and sources. Digital public-service provision is the Online Service Index of the UN E-Government Development Index, with the GovTech Maturity Index and its tax and customs sub-indices as alternatives. Because those lie near their ceiling, tax and customs administration are also measured directly. Customs digitalization is measured as legal commitment, the date by which a WTO member undertook to implement each of six Trade Facilitation Agreement measures, and as realized implementation, the level from 0 to 3 recorded in the 2015 to 2025 waves of the UN trade-facilitation survey, carried forward at most two years between waves and used as levels rather than dated adoption events. Perceived clearance efficiency in the Logistics Performance Index is not a measure of digitalization and enters as overall trade-logistics performance.

PPP oversight is measured by the Benchmarking Infrastructure Development (BID) scores for preparation, procurement, and contract management, the latter referred to as contract-management regulatory quality, and by nine yes-or-no questionnaire items (World Bank, 2020, 2023, 2025b). Five items on monitoring, the regulator, and the regulation of modification and termination form an oversight index; four on post-project audit and the accounting, reporting, and online disclosure of PPP liabilities form an audit and fiscal-liability index, each the share of items answered yes. Supreme-audit oversight is the Open Budget Survey sub-score (International Budget Partnership, 2025), available for 61 of the 83 economies and not for Kazakhstan.

Controls are Government Effectiveness (Kaufmann & Kraay, 2025), GDP per capita at purchasing power parity, trade openness, and population, the last in logarithms, since the outcomes are absolute counts that GDP per capita does not scale.

The preferred specification uses an unbalanced 2020–2024 panel, the window set by the joint availability of the institutional measures, which

are published in waves and carried forward within an economy for at most three years. Complete cases yield 359 country-year observations across 83 economies, 446 across 91 without the customs measure, and 246 across 59 with the ISORA measures (Table A1). A second panel for 2015–2024, with 803 observations across 81 WTO members, serves the fixed-effects specifications.

The complete-case sample is selective. The 50 economies of the PPI-active universe without complete data record 0.26 projects a year against 3.14 in the sample and have lower Online Service Index scores (0.34 against 0.56), contract-management scores (51 against 67) and clearance ratings (2.25 against 2.45), and much smaller populations (Table A2), with exclusion being concentrated in East Asia and Pacific and Sub-Saharan Africa. The estimation sample therefore represents the larger, more digitalized and more PPP-active part of the universe; an inverse-probability-weighted specification is reported alongside the preferred estimates (Table C1), and the conclusions are confined to that part. Of the six never-PPP economies, only Mauritius has complete regressors, with four of the others lacking BID scores and Eritrea GDP per capita, so the eligible-population specification

adds one economy and offers a limited test of the never-PPP concern.

The Kazakhstan case draws on the national PPP registry (Kazakhstan Center for Public-Private Partnership, 2026), which lists 1,324 projects as of 1 April 2026 with signing date, level, region, sector, status, contract type and cost, deflated to 2021 prices. The institutional context comes from legal acts and official statements (Republic of Kazakhstan, 1998, 2015a, 2015b, 2021, 2022, 2024; President of the Republic of Kazakhstan, 2019; Government of the Republic of Kazakhstan, 2021; Supreme Audit Chamber of the Republic of Kazakhstan, 2023, 2024), from the OECD (2019) and Asian Development Bank (2022) assessments and from published audit conclusions, of which the Almaty audit is the only full regional text (Revision Commission of Almaty Region, 2023).

2.2. Model specification

The project count is an over-dispersed integer with a large share of zeros, and investment is a non-negative, highly skewed amount (Table B1), so both outcomes are modeled multiplicatively rather than with a log-linear specification that would

Table 1. Variables, definitions and sources

Variable	Definition	Source
PPP projects (count)	Number of PPP projects reaching financial closure, by country-year	World Bank PPI
PPP investment	Total private investment commitments, US\$ million	World Bank PPI
EGDI Online Service Index	Online provision of government services (0–1); GTMI and its tax (I-7) and customs (I-8) sub-indices (0-2) as alternatives	UN E-Government Survey; World Bank GTMI
Tax e-filing and e-payment rates	Shares of returns filed and of payments made electronically (%)	ISORA
TFA implementation indicators	One from the definitive implementation date of a TFA measure (Articles 1.2, 7.1, 7.2, 7.4, 7.5, 10.4); category A treated as implemented throughout	WTO TFA Database
UN implementation scores	Level of implementation of digital customs measures, 0 to 3, by survey wave; paperless-trade composite (0-1)	UN Global Survey on Digital and Sustainable Trade Facilitation
LPI customs clearance efficiency	Efficiency of the customs clearance process (1-5), trade-logistics performance	World Bank LPI (WDI)
BID Contract Management	Quality of regulation governing PPP contract management (0-100); preparation and procurement scores as alternatives	World Bank BID
BID oversight index; audit and fiscal-liability index	Shares of five oversight items and of four audit and fiscal-liability items answered yes (0–100)	World Bank BID, question level
SAI oversight	Open Budget Survey sub-score for supreme-audit oversight (0-100)	International Budget Partnership
Controls	WGI Government Effectiveness; ln GDP per capita, PPP; trade, % of GDP; ln population	World Bank WGI and WDI

Note: PPI, Private Participation in Infrastructure; EGDI, E-Government Development Index; GTMI, GovTech Maturity Index; ISORA, International Survey on Revenue Administration; TFA, Trade Facilitation Agreement; LPI, Logistics Performance Index; BID, Benchmarking Infrastructure Development; SAI, Supreme Audit Institution; WGI and WDI, Worldwide Governance and World Development Indicators.

discard zero-valued observations (Santos Silva & Tenreiro, 2006). The preferred conditional mean is given by equation (1),

$$E[Y_{it} | X_{it}, \delta_t] = \exp\left(\beta_1 OSI_{it} + \beta_2 BID_{it} + \beta_3 CUST_{it} + \gamma' Z_{it} + \delta_t\right), \quad (1)$$

where Y_{it} is the number of PPP projects (Poisson) or total PPP investment (Poisson pseudo-maximum likelihood, PPML) in economy i and year t , OSI_{it} the Online Service Index, BID_{it} the contract-management score, and $CUST_{it}$ the LPI customs clearance rating, a measure of trade-logistics performance. X_{it} collects all regressors, Z_{it} is the vector of controls (Government Effectiveness, ln GDP per capita, trade openness, and ln population) with coefficient vector γ , β_1 to β_3 are the focal coefficients, and δ_t are year fixed effects. Within the short window, the institutional regressors are nearly time-invariant, so a within-economy specification adds economy fixed effects α_i , as in equation (2),

$$E[Y_{it} | X_{it}, \alpha_i, \delta_t] = \exp\left(\alpha_i + \delta_t + \beta_1 OSI_{it} + \beta_2 BID_{it} + \beta_3 CUST_{it} + \gamma' Z_{it}\right), \quad (2)$$

which is estimated as a robustness check, with regional fixed effects as an intermediate variant. Equation (1) is also estimated with the GTMI sub-indices, the ISORA measures, and the BID question-level indices added to X_{it} , and the effect sizes in Figure 1 use standardized regressors.

The commitment dates and the implementation scores vary within economies, so they are analyzed with economy fixed effects over 2015–2024. For each TFA measure, the indicator D_{it} equals one from the year of the definitive implementation date onward. Category A commitments, already implemented at entry into force, are treated as implemented throughout; category B and C commitments dated 2016–2024 form the implementation cohorts, and later or undetermined dates are not yet implemented within the window. The specification is given by equation (3),

$$E[Y_{it} | X_{it}, \alpha_i, \delta_t] = \exp\left(\alpha_i + \delta_t + \theta D_{it} + \gamma' Z_{it}\right), \quad (3)$$

where θ is the coefficient of interest and the other terms are as in equation (2). Pre-arrival processing enters as a comparison measure, because it concerns the timing of document submission rather than a digital system. Because staggered adoption can bias two-way fixed-effects estimates when effects vary across cohorts (Goodman-Bacon, 2021), the average effect is also estimated with the two-stage estimator of Gardner (2022) and dynamic effects with the local-projections estimator of Dube et al. (2023), on the inverse hyperbolic sine of the count with three pre-treatment periods. The UN scores enter equation (3) in place of D_{it} as intensities. A two-year lead of the score is added as a check that future scores are not associated with current closures; because the scores are survey-wave levels carried forward between waves rather than dated adoption events, this check is not an event-study test of anticipation.

Two further specifications address the sample and the durability question. A two-part model over the eligible population separates a logit for hosting at least one project from a Poisson model truncated at zero (Cameron & Trivedi, 2013). The Kazakhstan registry records project status at a single date but not the date of termination, so under a constant hazard λ_c for signing cohort c , the probability that project j is observed as terminated follows equation (4),

$$P(T_j = 1) = 1 - \exp(-\lambda_c E_j), \quad (4)$$

where T_j equals one if project j is terminated and E_j is the exposure window in years, namely the planned duration for expired projects, the age at the snapshot date for operating projects and the smaller of the two for terminated projects. Equation (4) is a complementary log-log model of T_j with $\ln E_j$ as an offset, in which cohort, sector, government-level, and region indicators enter the log hazard, and exponentiated coefficients are termination-rate ratios; regional rates use a rule-of-three upper bound where no termination is observed. Duration dependence is not identifiable from a single snapshot, so the estimates are read as exposure-adjusted comparisons.

2.3. Estimation and diagnostics

The count models are estimated by Poisson quasi-maximum likelihood, consistent under misspecification provided the conditional mean is cor-

rect, with economy-clustered standard errors that accommodate over-dispersion. Over-dispersion is quantified by the Pearson statistic; a negative binomial serves as an alternative; multicollinearity is assessed with variance inflation factors; and correlations appear in Table B2. Two tests are pre-specified. Equation (1) with the clearance rating (Table 2, column 2) tests the hypotheses across economies, and equation (3) with the single-window, electronic-payment, and post-clearance-audit indicators tests them within economies. All other specifications are sensitivity analyses and are not used to select results.

2.4. Limitations

Several limitations remain. The design is associational; within 2020–2024 the institutional measures vary little within economies, so those estimates rely on between-economy variation, and the fixed-effects specifications show which associations survive within economies without identifying effects. The indices are published in waves and carried forward, which understates short-run variation. Each customs measure is limited in its own way, since the LPI rating is closely related to the other LPI components and to governance, the TFA dates record legal commitments rather than operational dates, and the UN scores are self-reported levels. The BID items describe the regulatory framework; audit coverage and findings are not observed cross-nationally, and complete cases cover 83 of the 133 economies, over-representing larger, more digitalized and more PPP-active economies (Table A2). Finally, the PPI database and the registry cover different universes, so the case is illustrative, and durability is assessed under a constant hazard because the registry records no termination dates.

3. RESULTS

3.1. Descriptive statistics

The analysis covers the PPI-active universe of 133 economies (Tables B1 and B2). Both dependent variables are strongly right-skewed with a large share of zeros, the count of closures having a mean of 2.06, a median of zero, and a maximum of 69 projects in a country-year. Population is equally skewed, which motivates the logarithmic scale

control, and the variance far in excess of the mean motivates the count and PPML estimators with over-dispersion-robust inference.

The GTMI tax and customs sub-indices and the ISORA filing and payment rates sit near their ceilings, leaving limited cross-country variation, whereas clearance efficiency and the contract-management score vary more widely. Among the question-level items in 2025, monitoring and the regulation of modification and termination are provided for in about 90% of economies, an economic regulator in 5%, post-project audit in 10%, accounting for PPP liabilities in 40%, and their online disclosure in 14%. Of the 110 WTO members in the PPI universe, 17 hold category A commitments for the single window, 36 have definitive dates in 2016–2024, and 57 have later or undetermined dates, with 23 economies outside the Agreement; the 2015–2024 panel with complete controls contains 803 observations for 81 members, and the cohorts for the other measures appear in the last column of Table 3.

The complete-case sample comprises 359 country-year observations across 83 economies (Table A1). The 50 economies without complete data record 0.26 financial closures a year against 3.14 in the sample and are smaller, less digitalized, and weaker in contract-management regulation (Table A2), so the estimates that follow describe the larger and more PPP-active part of the universe.

3.2. Trade-logistics performance, contract oversight and PPP deal flow, 2020–2024

Table 2 reports the preferred count specification. Country size is the dominant scale variable, with an elasticity of the expected project count of 0.49 ($p < 0.001$) that stays between 0.41 and 0.60 under year or regional fixed effects. Once size is held constant, the Online Service Index is no longer statistically significant ($p = 0.061$), and the coefficient on contract-management regulatory quality is half of its value without size controls (0.023 against 0.046; not tabulated).

Adding the clearance rating (column 2) leaves that estimate unchanged, and efficiency of customs clearance is positively associated with closures (β

= 1.083, $p < 0.05$). One standard deviation of the rating corresponds to about 49% more expected projects, and ten points of the contract-management score to about 26%. Figure 1 summarizes column 2 as standardized coefficients, with 0.32 log points per standard deviation for contract management (SE = 0.11), 0.40 for clearance efficiency (SE = 0.17), 0.64 for population (SE = 0.14), and 0.78 for the Online Service Index (SE = 0.42, $p = 0.063$).

Regional and two-way fixed effects (columns 3 and 4) separate the three focal variables. Clearance efficiency retains its sign and significance in both, reflecting movement between the 2018 and 2022 LPI waves, whereas contract-management regulatory quality loses significance once regional differences are absorbed, so its association is identified across rather than within regions. The Online Service Index is insignificant in both columns.

Direct measures of tax and customs administration do not alter this picture (columns 5 and 6). The GTMI sub-indices and the ISORA rates of electronic filing and payment show no detectable association, although the intervals are wide relative to the variation in these rates. In the investment model, no institutional variable retains significance once population is included, so that model identifies scale rather than institutional correlates, and the remaining analysis concentrates on deal flow.

The identification and sample checks of Table C1 qualify the two cross-national associations. Contract-management regulatory quality stays between 0.021 and 0.032 under governance controls, first-wave values, and inverse-probability weighting, but it is identified across rather than within regions. The customs coefficient survives sample perturbations and within-economy es-

Table 2. Preferred specification: PPP project count (Poisson)

Variable	(1) Baseline + size	(2) + Customs efficiency	(3) + Region FE	(4) Two-way FE	(5) + GTMI tax, customs	(6) + E-filing, e-payment
EGDI Online Service Index	3.796 (2.030)	3.712 (1.994)	2.026 (1.235)	-0.499 (1.624)	3.740 (2.017)	2.187 (1.784)
BID Contract Management	0.023** (0.008)	0.023** (0.008)	0.013 (0.011)	-0.006 (0.044)	0.023** (0.008)	0.021 (0.014)
LPI customs efficiency		1.083* (0.456)	1.448** (0.533)	1.213** (0.378)	1.081* (0.458)	0.912 (0.514)
GTMI tax system (I-7)					-0.068 (0.260)	
GTMI customs system (I-8)					0.035 (0.326)	
Tax e-filing rate (ISORA)						0.001 (0.011)
Tax e-payment rate (ISORA)						0.001 (0.007)
WGI Government Effectiveness	0.020 (0.610)	-0.481 (0.568)	0.021 (0.309)	0.490 (0.699)	-0.478 (0.575)	-0.802 (0.623)
ln GDP per capita	0.040 (0.217)	0.019 (0.208)	-0.411 (0.276)	-0.953 (1.893)	0.019 (0.209)	0.454 (0.357)
Trade, % of GDP	0.002 (0.004)	-0.002 (0.004)	0.001 (0.005)	0.016 (0.010)	-0.002 (0.004)	-0.004 (0.006)
ln population	0.491*** (0.067)	0.414*** (0.091)	0.602*** (0.161)		0.413*** (0.092)	0.497*** (0.128)
Fixed effects	Year	Year	Region, year	Country, year	Year	Year
Observations	446	359	359	291	359	246
Economies (clusters)	91	83	83	65	83	59

Note: Poisson estimates; standard errors clustered by economy in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Column 4 omits ln population, whose within-economy variation over five years is negligible, and drops 68 observations from economies with no financial closure in the window (separation). Customs efficiency is the LPI efficiency of customs clearance (1-5), a measure of trade-logistics performance; e-filing and e-payment are ISORA shares of returns filed and payments made electronically (%).

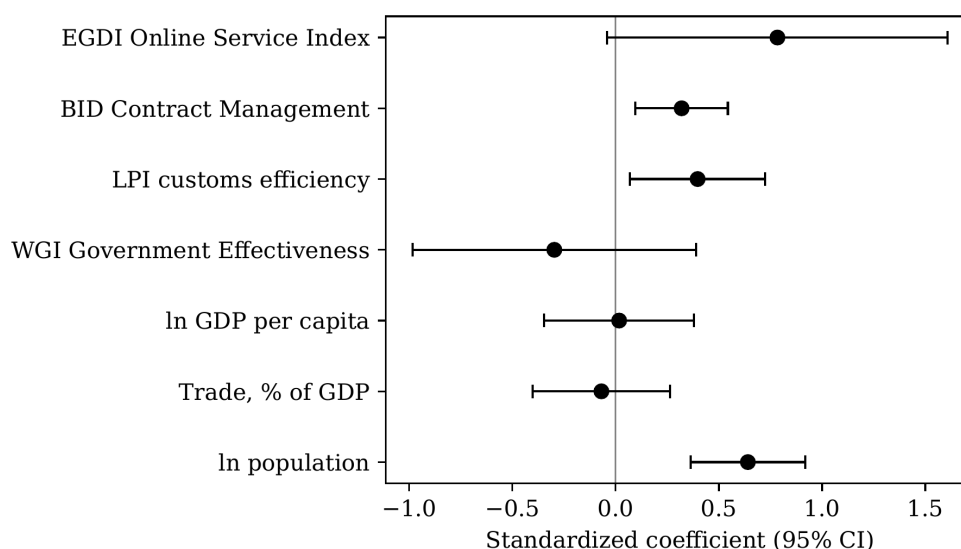


Figure 1. Standardized coefficients from the preferred count model (Poisson, year fixed effects; $\pm 95\%$ confidence intervals)

timation, yet it falls to 0.024 with the full set of governance controls and to 0.226 (n.s.) when the other LPI components enter jointly, and 2018 clearance efficiency does not predict later closures. The perceived-performance measure therefore behaves as one facet of trade-logistics performance rather than as a customs-specific channel, and the evidence on digital customs administration rests

on the two measures that vary within economies (Sections 3.3 and 3.4).

3.3. Legal commitments to digital customs procedures, 2015–2024

Table 3 reports the within-economy estimates for the six Trade Facilitation Agreement measures on

Table 3. Legal commitments under the Trade Facilitation Agreement and PPP project count, 2015–2024

Measure	(1) Poisson	(2) Two-stage ATT	Cohorts / not yet / throughout
Single window (Art. 10.4)	-0.115 (0.222)	-0.109 (0.150)	36 / 57 / 17
Electronic payment (Art. 7.2)	0.287 (0.203)	-0.109 (0.153)	38 / 25 / 47
Post-clearance audit (Art. 7.5)	-0.097 (0.165)	-0.184 (0.159)	36 / 20 / 54
Risk management (Art. 7.4)	-0.103 (0.216)	-0.150 (0.183)	31 / 40 / 39
Information via the internet (Art. 1.2)	0.013 (0.205)	-0.091 (0.117)	41 / 30 / 39
Pre-arrival processing (Art. 7.1), comparison	-0.123 (0.136)	-0.017 (0.126)	34 / 26 / 50
Fixed effects	economy, year	economy, year	
Sample	all members	categories B and C	
Observations (economies)	803 (81)	460-760 (46-76)	

Note: Column 1 reports the coefficient on the implementation indicator from equation (3), one regression per measure, with economy and year fixed effects; controls are Government Effectiveness, ln GDP per capita, and trade openness; standard errors clustered by economy in parentheses. Column 2 reports the average treatment effect on the treated from the two-stage estimator of Gardner (2022) on the inverse hyperbolic sine of the count, on members with category B and C commitments. The last column gives the number of members with definitive dates in 2016–2024, with dates after 2024 or to be determined, and with category A commitments. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

all WTO members in the PPI universe with complete controls, category A commitments being treated as implemented throughout. None of the indicators is associated with the number of financial closures, and the pre-arrival comparison measure behaves the same way.

Sensitivity analyses give the same answer. Restricting the sample to members with category B or C commitments drops the always-implemented group and leaves every coefficient insignificant, as does replacing year effects with region-by-year effects (not tabulated). The two-stage estimator agrees (column 2), and the local-projections estimator shows no pre-treatment trends and no post-treatment effects. Legal commitment to digital customs procedures is therefore not associated with PPP deal flow at any horizon the data allow.

3.4. Realized implementation of digital customs procedures and tax e-services

Table 4 turns from commitments to the level at which digital procedures operate, with the UN implementation scores entering as intensities. One measure stands out. A one-level increase in the implementation of electronic payment of customs

duties is associated with 0.380 log points more financial closures ($p < 0.01$; column 1). When the score two years ahead is added, the lead is insignificant (0.149, $SE = 0.201$; column 2), so the future score is not associated with current closures in this specification. Because the scores are survey-wave levels carried forward between waves, this is a falsification check rather than an event-study test of anticipatory behavior. The estimate survives region-by-year effects and joint inclusion of the other four scores (column 4), where electronic submission of declarations is positive as well. It is sensitive to the largest markets, however, falling to 0.235 ($p = 0.14$) without China, India and Brazil (column 3), and it is absent for investment volumes. The single-window, post-clearance-audit, and automated-system scores are not associated with deal flow in any specification.

Tax e-services show no comparable pattern, since the ISORA rates are near their ceiling and the GTMI tax sub-index is insignificant throughout. The three customs measures therefore do not point in one direction. They separate perceived trade-logistics performance, which is not distinguishable from logistics and governance quality, formal legal commitment, which carries no association, and realized transactional implementation, which

Table 4. Realized implementation of digital customs procedures (UN survey scores) and PPP project count, 2015–2024

Variable	(1)	(2)	(3)	(4)
E-payment of duties, score 0-3	0.380** (0.127)	0.568*** (0.163)	0.235 (0.159)	0.565** (0.192)
E-payment score, lead t+2		0.149 (0.201)		0.267 (0.233)
E-submission of declarations				0.373*** (0.095)
Electronic single window				-0.110 (0.181)
Post-clearance audit				-0.013 (0.148)
Automated customs system				-0.167 (0.241)
Fixed effects	economy, year	economy, year	economy, year	economy, year
Sample	all	all	excl. CHN, IND, BRA	all
Observations (economies)	755 (88)	516 (78)	725 (85)	501 (75)

Note: Poisson estimates of equation (3) with the UN implementation scores as intensities and the project count as the dependent variable; scores are carried forward for at most two years between survey waves; controls are Government Effectiveness, In GDP per capita, and trade openness; standard errors clustered by economy in parentheses. The lagged score entered alone gives -0.103 (0.247), region-by-year effects give 0.329 (0.145), and the PPML investment model gives 0.161 (0.224); single-window, post-clearance-audit, and automated-system scores entered alone give -0.026 (0.145), 0.254 (0.205), and 0.148 (0.227). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

is associated with deal flow for the procedures that change how duties are paid and declarations are filed. H1 thus receives evidence confined to realized implementation and sensitive to the inclusion of the largest markets, and H2 is not supported.

3.5. Oversight of PPP contracts and accounting for their obligations

Table 5 replaces the aggregate contract-management score with the question-level indices of the BID survey. The oversight index gives 0.032 per

point ($p = 0.069$) and the audit and fiscal-liability index 0.005 (n.s.). Entered separately (column 4), two items carry the association. Economies whose framework requires accounting for PPP liabilities record 0.956 log points more closures, and those with an economic or technical regulator 0.800 more (both $p < 0.01$), whereas online disclosure is negative and post-project audit is insignificant, so the fiscal-treatment items do not act as one block. Assigning the survey waves to years by survey date rather than by edition leaves the estimates unchanged, and none of the indices or items survives economy fixed effects (column 5).

Table 5. Question-level oversight and audit items of the BID survey and PPP outcomes, 2020–2024

Variable	(1)	(2)	(3)	(4)	(5)
BID Contract Management (0-100)	0.023** (0.008)				
Oversight index (0-100)		0.032 (0.018)			-0.050 (0.046)
Audit and fiscal-liability index (0-100)			0.005 (0.004)		-0.000 (0.015)
Post-project audit by PPP unit				-0.354 (0.351)	
Reporting of PPP liabilities				0.268 (0.271)	
Accounting for PPP liabilities				0.956** (0.291)	
Online disclosure of PPP liabilities				-0.822* (0.381)	
Monitoring after construction				0.424 (0.408)	
Economic or technical regulator				0.800** (0.282)	
Regulation of modification				-0.113 (0.389)	
Regulation of termination				0.070 (0.353)	
EGDI Online Service Index	3.712 (1.994)	2.992* (1.300)	3.573 (1.904)	0.396 (0.919)	-0.452 (1.623)
LPI customs efficiency	1.083* (0.456)	1.244** (0.406)	0.933* (0.442)	1.274*** (0.332)	1.243*** (0.375)
ln population	0.414*** (0.091)	0.453*** (0.076)	0.471*** (0.089)	0.556*** (0.095)	
Fixed effects	year	year	year	year	economy, year
Observations (economies)	359 (83)	359 (83)	359 (83)	359 (83)	291 (65)

Note: Poisson estimates with the project count as the dependent variable; Government Effectiveness, ln GDP per capita, and trade openness included in all columns; standard errors clustered by economy in parentheses. Column 1 reproduces Table 2, column 2. Items are indicators equal to one where the regulatory framework provides for the practice; the oversight index averages five items and the audit and fiscal-liability index four items (Section 2.1). Column 5 omits ln population. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

A direct measure of audit oversight is available for the 61 economies covered by the Open Budget Survey. Adding its sub-score for oversight by the supreme audit institution to the preferred specification gives 0.010 ($p = 0.33$) for the score itself and reduces contract management from 0.024 on that subsample to 0.017 ($p = 0.18$); the two measures overlap and cannot be separated on 61 economies (not tabulated), so audit capacity as scored by the survey is not associated with deal flow at the available precision. The evidence on H3 is therefore twofold. The regulatory framework for contract oversight, and within it the accounting for PPP liabilities and the presence of a regulator, is associated with deal flow. The audit and fiscal-liability composite, post-project audit, and the audit institution as such are not, so the evidence concerns contract oversight and fiscal-accounting arrangements rather than audit activity itself.

3.6. Kazakhstan as an institutional case

The national PPP registry lists 1,324 projects as of 1 April 2026, 1,258 of them with an identifiable signing year (Figure 2). Contracting was negligible before 2015, peaked at 301 signings in 2018, and fell to between 40 and 56 a year in 2022–2024. The portfolio is almost entirely subnational, with a local-government partner

in about 98% of projects, and concentrated in social infrastructure, with education alone accounting for 748 projects.

The registry and the PPI database describe different universes, so the case complements rather than tests the cross-country estimates. Only 237 registry projects fall in sectors that PPI covers, and PPI records between zero and seven Kazakh closures a year over 2017–2024 against 4 to 53 registry signings in those sectors, because it captures larger, project-financed transactions. The case is therefore an institutional illustration of how the digitalization and oversight environment relates to the composition and durability of a national portfolio.

The three cross-national sources on Kazakhstan's digitalization agree. The customs information system Astana-1 went live on 1 January 2018, and mandatory electronic invoicing followed in 2019; between the 2017 and 2019 UN survey waves, the scores for the automated system, electronic declarations, and electronic payment of duties rose to full implementation. Kazakhstan holds TFA category A commitments for pre-arrival processing, electronic payment, risk management and post-clearance audit, whereas the single window, notified under category B with a definitive date of 31 October 2022, is still recorded as partially implemented. The question-level BID answers are iden-

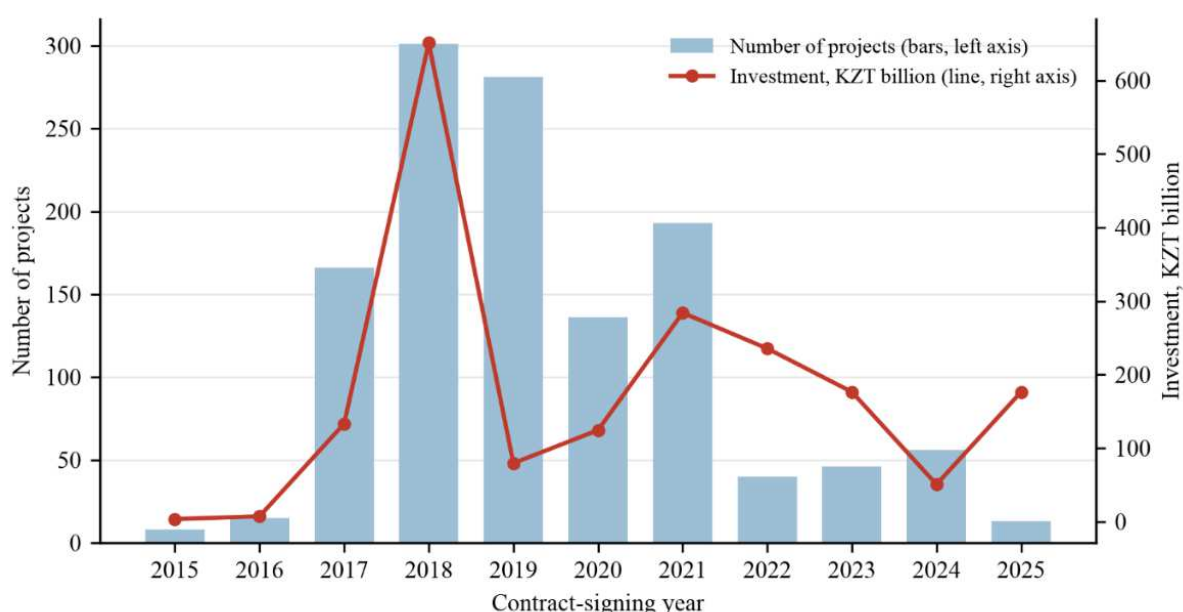


Figure 2. Kazakhstan PPP projects and investment by contract-signing year, 2015–2025

tical in all three waves, providing for accounting and reporting of PPP liabilities and for monitoring, but not for online disclosure, an economic regulator, or post-project audit.

The institutional sequence is documented in official sources. The Law “On Public-Private Partnership” of 31 October 2015 created a unified framework for republican and local projects (Republic of Kazakhstan, 2015a). In July 2019, the President stated that state obligations exceeded 90% of the value of PPP projects and instructed the Government to control the burden on local budgets and to monitor contract performance (President of the Republic of Kazakhstan, 2019). On 21 November 2019, the Accounts Committee found no long-term PPP strategy and 2.1 tenge of state obligations per tenge of attracted investment, and recommended capping state obligations at 30% of project value (Supreme Audit Chamber of the Republic of Kazakhstan, 2024). The Law of 2 January 2021 No. 399-VI then spread investment-cost compensation over at least five years without acceleration and limited full cost recovery to facilities that cannot pay back through service revenue. It also set a five-year minimum contract term, made contract changes subject to budget-commission approval, and introduced a minimum share of own funds for private initiatives, sev-

eral provisions following the recommendations of the Accounts Committee (Government of the Republic of Kazakhstan, 2021). The Supreme Audit Chamber replaced the Accounts Committee in November 2022, and the rules on special-purpose audit of quasi-public entities, which govern the audit of their use of budget funds under Article 18-3 of the Law on Auditing Activity, were re-issued in February 2023 (Supreme Audit Chamber of the Republic of Kazakhstan, 2023).

The registry records the change in the portfolio. Signings fall from 748 in 2017–2019 to 329 in 2020–2021 and 155 in 2022–2025, and in 2021 prices, the median project cost declines from KZT 0.10 billion to KZT 0.01 billion while the mean rises to KZT 5.18 billion. The decline is concentrated in the contract types with the shortest terms, on which the five-year minimum of 2021 bears directly: service contracts fell from 408 signings in 2017–2020 to 71 in 2021–2024, and trust management of state property fell from 149 to 36.

The regional dimension shows how oversight operates below the national level. Almaty region signed 34 contracts in 2021, or 17.6% of the national total, against 0.6% to 5.9% in every year from 2017 to 2020 (Figure 3). After the regional prosecutor’s representation on violations of the law of 23

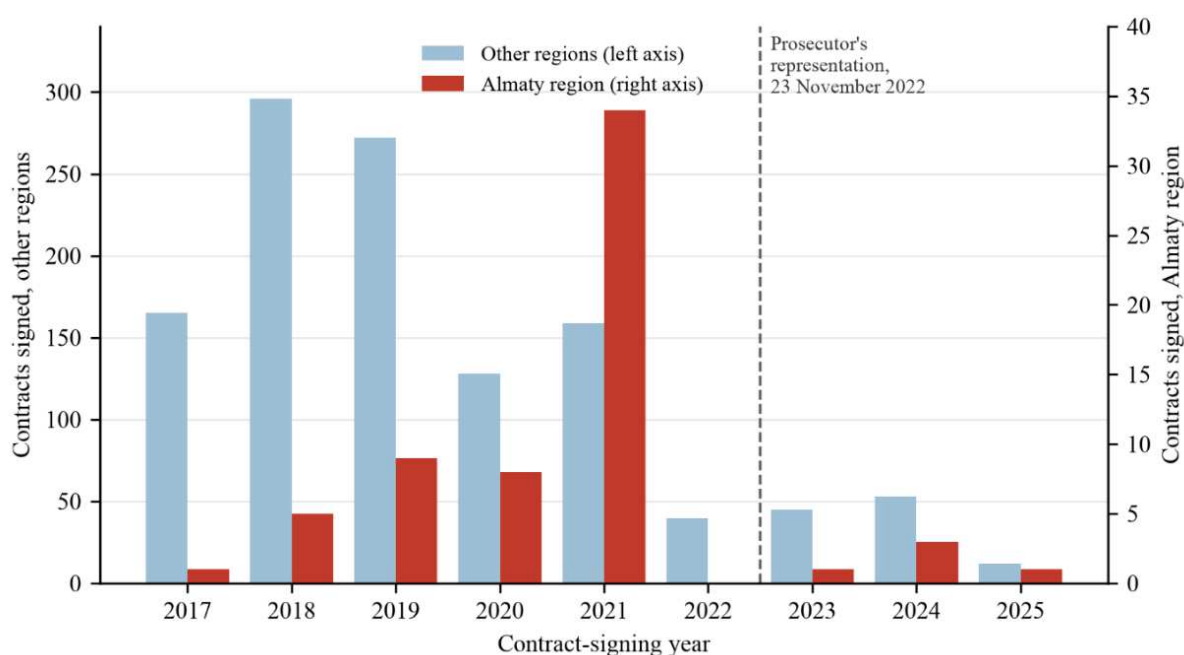


Figure 3. Kazakhstan PPP registry. Contracts signed by year in Almaty region and in the other regions (registry as of 1 April 2026)

November 2022, 18 of them were terminated, and the region signed no contracts in 2022 and one in 2023. The regional revision commission's audit of the 2018–2022 projects found violations of KZT 4.17 billion, compensation paid before facilities were commissioned and expenses not booked as PPP obligations (Revision Commission of Almaty Region, 2023). A difference-in-differences comparison with the other regions is reported only as an illustration, since one treated region does not support inference.

Project durability cannot be read from raw status shares, since cohorts and regions have had different times at risk, and expiry at the end of the term is treated as the end of exposure rather than as failure. Under a constant hazard, cohorts signed from 2020 onward have a termination-rate ratio of 0.78 relative to earlier cohorts (95% CI 0.54 to 1.11), and a joint test of cohort differences does not reject equality ($p = 0.35$; Table D2, Figure D1). Regional differences are far larger (Table D1), from 11.8 per 100 project-years in Pavlodar region and 8.6 in Almaty region to one termination in 194 projects in Turkestan region and none in Atyrau and West Kazakhstan. Cohort indicators are insignificant once region is held constant, so the region rather than the timing of signature explains durability. The registry does not record the reason for termination, so the differences are described rather than explained.

Kazakhstan's institutional indicators move slowly over the same period (Figure 4), with the contract-management score registering the 2021 amendments only in the 2025 wave. Customs digitalization was completed early and uniformly, and PPP deal flow in the PPI database remained between zero and seven closures a year. The tightening of payment schedules, contract-change control, and minimum equity coincided with a smaller and more selective deal flow, and regional oversight, where documented, coincided with terminations and a halt in signings rather than with new closures. This is consistent with, but does not establish, a role of contract-management rules and of the audit of obligations in which partnerships reach signature and survive, since the registry cannot separate these coincidences from budget constraints, the pandemic and other concurrent changes.

4. DISCUSSION

The three customs measures separate three different things. Perceived clearance efficiency is associated with deal flow across economies, but not separately from logistics performance and governance quality, so it is read as trade-logistics performance. Formal legal commitment carries no association, and realized transactional implementation mat-

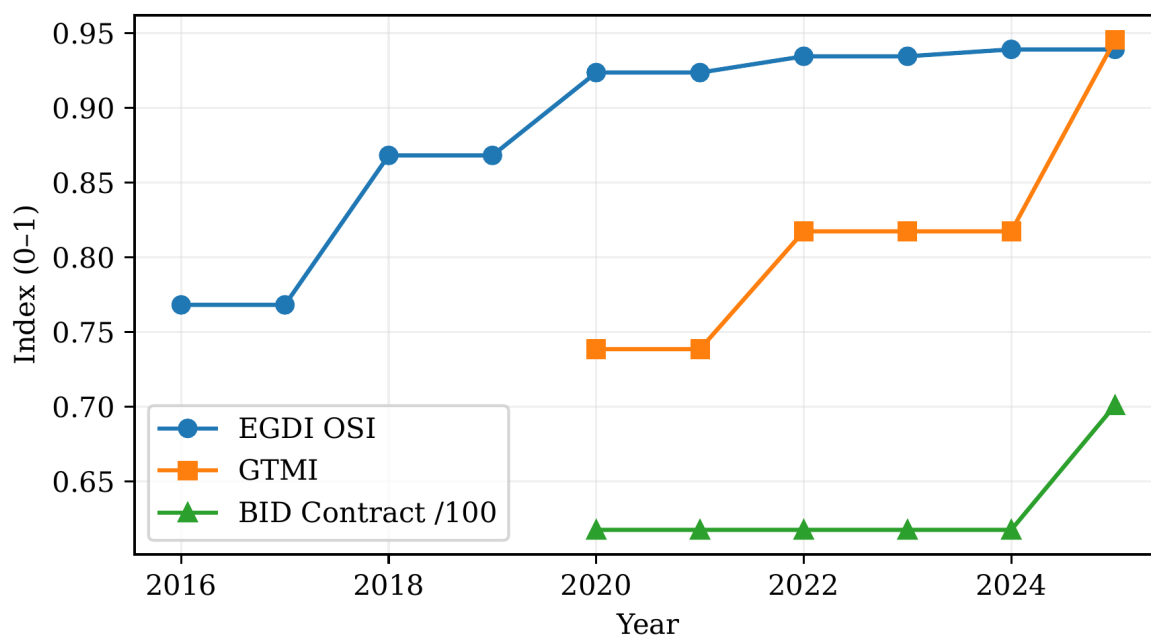


Figure 4. Kazakhstan. Digital-government and PPP-oversight trajectories, 2016–2025

ters only for the procedures that change how firms pay duties and file declarations, with an estimate that depends on the three largest markets. This ordering fits the trade-facilitation literature, in which soft infrastructure works through transaction costs rather than formal adoption (Portugal-Perez & Wilson, 2012).

The null for tax administration rests on direct measures and maturity indices alike. It agrees with evidence that digitalization raises revenue only alongside governmental responsiveness (Lee, 2025) and that e-government indices matter only with institutional safeguards (Yarovenko et al., 2025). Electronic filing reduces compliance costs (Bellon et al., 2022), but for infrastructure sponsors the tax interface is a small part of a decision shaped at the contract stage (Casady et al., 2024).

On the oversight side, contract-management regulatory quality remains the most consistent regularity, though only across regions, and the question-level items locate it in accounting for PPP liabilities and in the existence of a regulator (Hammami et al., 2006). Contract management is where fiscal commitments materialize, since availability payments

and guarantees are claims on future budgets (Engel et al., 2014). The audit and fiscal-liability composite, post-project audit, and supreme-audit oversight show no association, so what the data single out is the accounting for the obligations that audit is meant to verify rather than audit activity itself.

The Kazakh institutional documents describe the reach of the audit instruments rather than their comparative effectiveness, which this study does not estimate. Special-purpose audit reaches PPP obligations only where the state partner is a quasi-public entity, whereas the state audit of budget execution reaches PPP contracts directly. The national audit of 2019 preceded the 2021 amendments, and the Almaty audit found compensation paid before commissioning and obligations not booked. Three boundaries remain. The complete-case sample over-represents larger, more digitalized, and more PPP-active economies, and market size dominates within it. Contract-management quality describes where deal flow concentrates, not what a change of the framework would deliver. The oversight measures capture formal maturity rather than audit activity, and the registry records neither termination reasons nor preceding audits (Kuzior et al., 2026).

CONCLUSION

This study asked whether tax and customs digitalization and the oversight of PPP contracts, including the accounting and audit of the resulting obligations, are associated with the flow of public-private partnerships. Customs digitalization was measured as legal commitment and realized implementation, with perceived clearance efficiency as trade-logistics performance, tax digitalization by electronic filing and payment, and oversight by the contract-management framework and supreme-audit scores. The evidence covers 359 observations across 83 economies over 2020–2024, larger and more PPP-active than the 50 excluded for missing data, 803 observations across 81 WTO members over 2015–2024, and Kazakhstan's registry of 1,324 projects.

Legal commitments to digital customs procedures show no association with financial closures within economies, and neither do electronic tax filing and payment. Realized implementation of electronic payment of duties is associated with about 0.4 log points more closures per level; the two-year lead of the score is insignificant, and the estimate loses significance without the three largest markets. Contract-management regulatory quality ($\beta = 0.023$, $p < 0.01$) is associated with closures across economies, after accounting for PPP liabilities and the existence of a regulator, whereas post-project audit and supreme-audit oversight are not. All estimates are associations. In Kazakhstan, customs digitalization was complete by 2019, the 2021 amendments followed the national audit of PPP obligations, and termination rates differ across regions rather than cohorts.

Three implications follow. The contract stage deserves the attention that platform adoption has received, and accounting for the resulting budget obligations is the element that both bodies of evidence single

out. An assessment of tax and customs digitalization should distinguish commitments from implementation and implementation from its use by firms. For a portfolio with local-government partners in 98% of projects, the audit instrument that reaches PPP obligations is the state audit of local budget execution. Future research needs measures of audit activity by region, project-level PPI data, and registries with termination dates and reasons.

DATA AVAILABILITY

The study relies exclusively on publicly accessible sources. PPI project counts and investment come from the World Bank Private Participation in Infrastructure database (World Bank, 2025a); digital-government indicators from the United Nations E-Government Survey (United Nations, 2024); GovTech maturity and its tax- and customs-system sub-indices from the World Bank GovTech Maturity Index (World Bank, 2022); electronic filing and payment rates from the International Survey on Revenue Administration (Asian Development Bank et al., 2025); PPP regulatory-quality scores and question-level answers from the Benchmarking Infrastructure Development project (World Bank Group, 2020; World Bank, 2020, 2023, 2025b); implementation commitments under the Trade Facilitation Agreement from the WTO TFA Database (World Trade Organization, 2026); implementation scores for digital trade-facilitation measures from the UN Global Survey on Digital and Sustainable Trade Facilitation (United Nations, 2025); governance indicators from the Worldwide Governance Indicators (Kaufmann & Kraay, 2025); supreme-audit oversight scores from the Open Budget Survey (International Budget Partnership, 2025); and customs efficiency, its logistics counterparts, population and macroeconomic controls from the World Development Indicators (World Bank, 2026). Kazakhstan-level evidence draws on the national PPP project database as of 1 April 2026 (Kazakhstan Center for Public-Private Partnership, 2026), on published audit conclusions of the Supreme Audit Chamber and the regional revision commissions, and on the official legal and policy documents cited in the text.

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Writing – review & editing: Alma Bekbolsynova, Bayansulu Tassymbay, Zhyldyz Omurova, Elmira Syzdykova, Alnur Valiev, Elmira Muratova, Maira Valieva.

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APPENDIX A

Table A1. Economies in the estimation sample (preferred specification, 2020–2024)

Economy	Years	N	Economy	Years	N	Economy	Years	N
AFG	2020–2023	4	GIN	2020–2024	5	PAK	2020–2021	2
AGO	2020–2024	5	GTM	2020–2024	5	PER	2020–2024	5
ALB	2020–2024	5	HND	2020–2024	5	PHL	2020–2024	5
ARG	2020–2024	5	HTI	2020–2024	5	PRY	2020–2024	5
ARM	2020–2024	5	IDN	2020–2024	5	RUS	2020–2024	5
BEN	2020–2024	5	IND	2020–2024	5	RWA	2020–2024	5
BFA	2020–2024	5	IRN	2020–2024	5	SDN	2020–2024	5
BGD	2020–2024	5	IRQ	2020–2024	5	SEN	2020–2021	2
BGR	2020–2024	5	JOR	2020–2021	2	SLB	2020–2024	5
BIH	2020–2024	5	KAZ	2020–2024	5	SLE	2020–2021	2
BLR	2020–2024	5	KEN	2020–2021	2	SLV	2020–2024	5
BRA	2020–2024	5	KGZ	2020–2024	5	SOM	2020–2024	5
BWA	2022–2024	3	KHM	2020–2024	5	SRB	2020–2024	5
CHN	2020–2024	5	LBN	2020–2021	2	TCD	2020–2021	2
CIV	2020–2021	2	LKA	2020–2024	5	TGO	2020–2022	3
CMR	2020–2024	5	MAR	2020–2021	2	THA	2020–2024	5
COD	2020–2024	5	MDA	2020–2024	5	TJK	2020–2023	4
COG	2020–2024	5	MDG	2020–2024	5	TUN	2020–2021	2
COL	2020–2024	5	MEX	2020–2024	5	TUR	2020–2024	5
CRI	2020–2024	5	MKD	2020–2024	5	UGA	2020–2021	2
DJI	2020–2024	5	MLI	2020–2024	5	UKR	2020–2024	5
DOM	2020–2024	5	MNE	2020–2024	5	URY	2020–2024	5
DZA	2020–2024	5	MNG	2020–2024	5	UZB	2020–2024	5
ECU	2020–2021	2	MWI	2020–2021	2	VNM	2020–2024	5
EGY	2020–2024	5	MYS	2020–2024	5	ZAF	2020–2024	5
GAB	2020–2024	5	NER	2020–2021	2	ZMB	2020–2021	2
GEO	2020–2024	5	NIC	2022–2024	3	ZWE	2020–2024	5
GHA	2020–2024	5	NPL	2020–2021	2			

Note: ISO3 country codes. The estimation sample for the preferred specification comprises 359 country-year observations across 83 economies (2020–2024); the table reports each economy's year coverage and number of observations.

Table A2. Economies in the preferred sample and economies of the PPI universe excluded by missing data, 2020–2024 means

Variable	Included (83)	Excluded (50)	p-value of difference	Excluded economies with the variable missing, %
PPP projects per year	3.14	0.26	0.003	0
PPP investment per year, USD mn	898.3	38.0	0.017	0
EGDI Online Service Index	0.563	0.344	< 0.001	4
WGI Government Effectiveness	−0.422	−0.553	0.280	0
ln GDP per capita	9.094	8.902	0.252	10
Trade, % of GDP	73.1	81.5	0.283	38
ln population	16.80	14.55	< 0.001	0
BID Contract Management	66.96	51.26	< 0.001	70
LPI customs efficiency	2.453	2.250	0.003	46

Note: Economy-level means for 2020–2024; the excluded group consists of the 50 economies of the PPI universe without complete data for the preferred specification. Means for the excluded group use the economies for which the variable is observed (15 for contract management, 27 for customs efficiency, 31 for trade, 45 for GDP per capita, 48 for the Online Service Index). p-values are from Welch t-tests. Exclusion is most frequent in East Asia and Pacific (11 of 20 economies) and Sub-Saharan Africa (19 of 46); all but two economies of Europe and Central Asia are included.

APPENDIX B

Table B1. Descriptive statistics, 133 low- and middle-income economies, 2020–2024

Variable	N	Mean	SD	Min	Median	Max
PPP projects (count)	665	2.06	7.15	0	0	69
PPP investment, USD million	665	574.9	2,953.0	0	0	40,843.0
EGDI Online Service Index	655	0.483	0.218	0	0.470	0.985
GovTech Maturity Index	655	0.477	0.233	0.019	0.446	0.975
GTMI tax system (I-7, 0-2)	655	1.768	0.612	0	2.000	2.000
GTMI customs system (I-8, 0-2)	655	1.918	0.382	0	2.000	2.000
Tax e-filing rate, %	428	79.92	33.10	0.01	99.88	100.0
Tax e-payment rate, %	522	69.70	33.16	0.08	84.28	100.0
LPI customs efficiency (1-5)	473	2.413	0.363	1.500	2.400	3.300
BID Preparation	490	42.38	17.30	6.14	43.86	82.75
BID Procurement	490	59.46	14.78	8.13	61.38	90.24
BID Contract Management	490	64.55	14.09	20.83	65.62	94.82
WGI Government Effectiveness	665	−0.471	0.649	−2.243	−0.416	0.915
ln GDP per capita (PPP)	633	9.028	0.899	6.938	9.179	11.164
Trade, % of GDP	555	75.47	39.53	2.00	68.55	302.29
Population, million	665	50.67	176.10	0.02	11.23	1,450.94

Note: Universe of 133 economies with at least one PPI project, 2020–2024; coverage differs across indicators. The estimation sample for the preferred specification comprises 359 country-year observations (83 economies). Sources: World Bank PPI; UN EGD; World Bank GovTech Maturity Index; ISORA; World Bank LPI; World Bank Benchmarking Infrastructure Development (BID); World Bank WGI and WDI.

Table B2. Correlation matrix of analysis variables (2020–2024)

Variable	PPI_N	PPI_INV	OSI	GTMI	I7	I8	PREP	PROC	CONTR	LPI	EFILE	EPAY	GE	lnGDP	TRADE	lnPOP
PPI_N	1.00	0.79	0.37	0.33	0.10	0.05	0.23	0.20	0.29	0.39	0.16	0.17	0.23	0.17	−0.14	0.39
PPI_INV	0.79	1.00	0.28	0.23	0.07	0.04	0.16	0.15	0.21	0.33	0.14	0.13	0.20	0.14	−0.12	0.33
OSI	0.37	0.28	1.00	0.85	0.44	0.27	0.55	0.29	0.31	0.56	0.45	0.41	0.63	0.56	−0.02	0.33
GTMI	0.33	0.23	0.85	1.00	0.45	0.30	0.51	0.26	0.34	0.51	0.45	0.37	0.57	0.47	−0.07	0.42
I7	0.10	0.07	0.44	0.45	1.00	0.58	0.34	0.18	0.18	0.23	0.09	0.13	0.41	0.15	−0.01	0.08
I8	0.05	0.04	0.27	0.30	0.58	1.00	0.13	0.01	0.07	0.21	−0.02	0.01	0.27	0.01	0.00	0.05
PREP	0.23	0.16	0.55	0.51	0.34	0.13	1.00	0.46	0.61	0.34	0.37	0.27	0.42	0.27	0.03	0.19
PROC	0.20	0.15	0.29	0.26	0.18	0.01	0.46	1.00	0.34	0.12	0.19	0.35	0.20	0.22	−0.02	0.01
CONTR	0.29	0.21	0.31	0.34	0.18	0.07	0.61	0.34	1.00	0.21	0.42	0.21	0.22	0.16	0.01	0.37
LPI	0.39	0.33	0.56	0.51	0.23	0.21	0.34	0.12	0.21	1.00	0.24	0.19	0.61	0.47	0.15	0.17
EFILE	0.16	0.14	0.45	0.45	0.09	−0.02	0.37	0.19	0.42	0.24	1.00	0.66	0.01	0.05	−0.10	0.49
EPAY	0.17	0.13	0.41	0.37	0.13	0.01	0.27	0.35	0.21	0.19	0.66	1.00	0.00	0.06	0.01	0.43
GE	0.23	0.20	0.63	0.57	0.41	0.27	0.42	0.20	0.22	0.61	0.01	0.00	1.00	0.66	0.18	−0.19
lnGDP	0.17	0.14	0.56	0.47	0.15	0.01	0.27	0.22	0.16	0.47	0.05	0.06	0.66	1.00	0.25	−0.13
TRADE	−0.14	−0.12	−0.02	−0.07	−0.01	0.00	0.03	−0.02	0.01	0.15	−0.10	0.01	0.18	0.25	1.00	−0.44
lnPOP	0.39	0.33	0.33	0.42	0.08	0.05	0.19	0.01	0.37	0.17	0.49	0.43	−0.19	−0.13	−0.44	1.00

Note: Pairwise Pearson correlations over the PPI universe of 133 economies, 2020–2024, each computed on the country-years with both variables available (from 246 for the ISORA rates to 665 for the PPI outcomes). PPI_N, PPI project count; PPI_INV, PPI investment (USD mn); OSI, EGD Online Service Index; GTMI, GovTech Maturity Index; I7/I8, GTMI tax/customs sub-indices; PREP/PROC/CONTR, BID preparation/procurement/contract-management scores; LPI, LPI customs efficiency; EFILE/EPAY, ISORA e-filing/e-payment rates; GE, WGI Government Effectiveness; lnGDP, ln GDP per capita (PPP); TRADE, trade (% of GDP); lnPOP, ln population.

APPENDIX C

Appendix C reports the identification and sample checks for the preferred count specification that Section 3.2 summarizes. Region-by-year effects, the category B and C subsample, and the heterogeneity-robust estimators for the staggered design are reported in Table 3 and Section 3.3.

Table C1. Identification and sample checks for the preferred count specification (dependent variable: PPP project count)

Variable	(1) WGI and credit controls	(2) LPI components	(3) First-wave values, 2022–2024	(4) Inverse-probability weighted	(5) Eligible population	(6) Extensive margin, logit	(7) Intensive margin, truncated Poisson
EGDI Online Service Index	2.491 (1.288)	3.059* (1.292)	5.346* (2.375)	2.636 (1.879)	3.722 (1.983)	1.960 (1.538)	3.639 (2.168)
BID Contract Management	0.032** (0.010)	0.022* (0.010)	0.021* (0.009)	0.026*** (0.007)	0.023** (0.008)	0.023 (0.012)	0.020* (0.009)
LPI customs efficiency	0.024 (0.715)	0.226 (0.628)	−0.308 (0.879)	1.110* (0.435)	1.091* (0.459)	0.602 (0.607)	0.976* (0.494)
In population	0.664*** (0.135)	0.378*** (0.103)	0.384*** (0.109)	0.401*** (0.079)	0.417*** (0.091)	0.616*** (0.152)	0.391*** (0.116)
Controls, year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	321	355	237	359	364	364	197
Economies (clusters)	78	83	81	83	84	84	65

Note: Poisson estimates unless stated; Government Effectiveness, In GDP per capita, and trade openness included; standard errors clustered by economy in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Column 1 adds WGI Rule of Law (0.490, SE 0.654), Regulatory Quality (0.370, 0.391), Control of Corruption (0.642, 0.378), and domestic credit to the private sector, % of GDP (0.005, 0.004). Column 2 adds the LPI components infrastructure (0.156, 0.345), logistics services (1.797, 1.003), timeliness (0.247, 0.450), tracking and tracing (0.036, 0.733), and shipment pricing (−1.361, 0.782); replacing the customs rating with the overall LPI index gives 1.229 (0.488). Column 3 regresses 2022–2024 outcomes on first-wave values (2018 for the customs rating, 2020 for the other indices). Column 4 weights observations by the inverse of an inclusion probability from a probit on the Online Service Index, Government Effectiveness, In GDP per capita, and In population. Column 5 uses the broader eligible population, which adds Mauritius, the only never-PPP economy with complete regressors, with zero projects; four of the other five lack BID scores, and Eritrea lacks GDP per capita. Columns 6 and 7 are the two-part model over that population: a logit for hosting at least one project in the year and a zero-truncated Poisson on country-years with at least one project; a zero-truncated negative binomial ($\alpha = 0.77$) gives 0.024 (0.007) for contract management and 1.285 (0.450) for the customs rating.

APPENDIX D

Table D1. Kazakhstan PPP registry. Exposure-adjusted termination rates by region under a constant-hazard assumption

Region	Projects	Terminated	Project-years	Rate per 100 project-years	95% CI
Pavlodar	39	17	183	11.79	7.29–19.06
Almaty region	62	20	281	8.63	5.55–13.42
Kostanay	49	14	255	6.01	3.55–10.15
Aktobe	22	6	124	5.32	2.39–11.87
Zhetysu	38	9	200	5.29	2.75–10.21
Astana (city)	27	6	137	4.90	2.20–10.93
Almaty (city)	65	10	289	3.83	2.06–7.12
Karaganda	56	10	289	3.71	1.99–6.90
North Kazakhstan	47	8	261	3.17	1.59–6.35
Shymkent (city)	65	8	275	3.04	1.52–6.08
Akmola	77	10	469	2.31	1.24–4.30

Table D1 (cont.). Kazakhstan PPP registry. Exposure-adjusted termination rates by region under a constant-hazard assumption

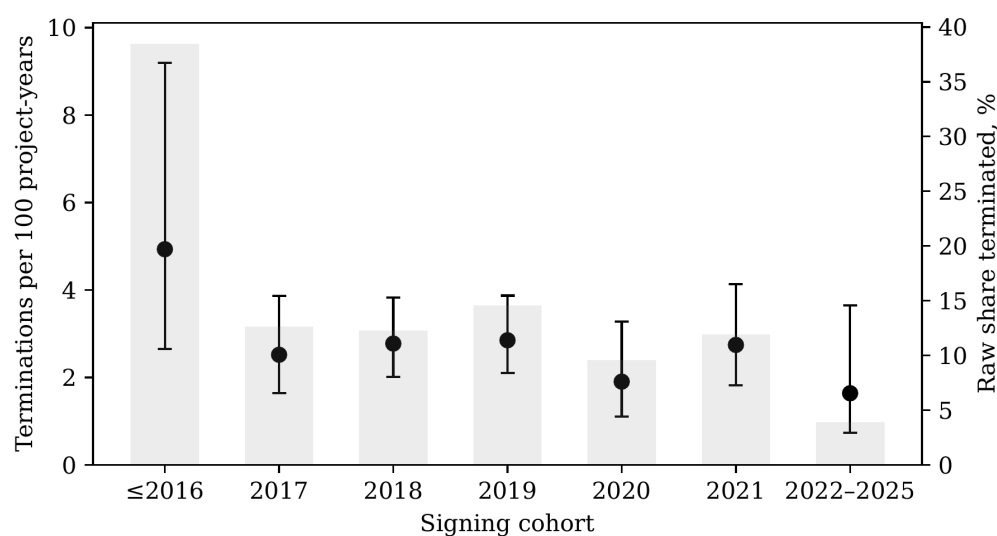
Region	Projects	Terminated	Project-years	Rate per 100 project-years	95% CI
East Kazakhstan	122	12	585	2.16	1.23–3.81
Abai	83	5	282	1.81	0.75–4.35
Kyzylorda	71	6	339	1.79	0.80–3.98
Zhambyl	72	4	316	1.31	0.49–3.50
Mangystau	33	1	181	0.57	0.08–4.02
Turkestan	194	1	1,037	0.10	0.01–0.69
Atyrau	96	0	300	0	≤1.0
West Kazakhstan	22	0	108	0	≤2.8

Note: Projects with a signing date and a final status; exposure as defined in Section 2.2. Regions with fewer than twenty projects (Ulytau) and the national-level projects are omitted. Rates and confidence intervals are maximum-likelihood estimates under a constant hazard. For regions without terminations, the upper bound is the rule-of-three limit of 3/E per 100 project-years, where E is the total exposure. Cohort indicators are jointly insignificant in a model with region effects.

Table D2. Kazakhstan PPP registry: termination rates by signing cohort, adjusted for exposure under a constant-hazard assumption

Signing cohort	Projects	Terminated	Expired	Operating or under construction	Mean age, years	Terminated, % (raw)	Terminations per 100 project-years [95% CI]
≤ 2016	26	10	9	7	10.9	38.5	4.93 [2.65; 9.19]
2017	166	21	107	38	8.6	12.7	2.52 [1.64; 3.87]
2018	301	37	202	62	7.6	12.3	2.78 [2.01; 3.83]
2019	281	41	92	148	6.6	14.6	2.85 [2.10; 3.87]
2020	136	13	30	93	5.7	9.6	1.90 [1.11; 3.28]
2021	193	23	9	161	4.7	11.9	2.74 [1.82; 4.13]
2022–2025	154	6	0	148	2.4	3.9	1.64 [0.74; 3.65]

Note: Exposure is the planned contract duration for expired projects, the age at 1 April 2026 for operating projects, and the smaller of the two for terminated projects. Termination rates and 95% confidence intervals are maximum-likelihood estimates under a constant hazard from the status indicator and the exposure window; duration dependence is not identifiable from a single registry snapshot.

**Figure D1.** Kazakhstan PPP registry: terminations per 100 project-years by signing cohort (points, 95% confidence intervals) and raw share terminated (bars)