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Bricks Over Machines: Capital Technological Composition, Reconstruction Versus Greenfield Expansion, and Regional Industrial Growth in Uzbekistan with Subnational Benchmarks from Kazakhstan

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Abstract

Equipment-embodied growth theory predicts that reallocating fixed-capital formation from civil structures toward machinery and plant modernization accelerates industrial output, yet high-investment transition regions routinely channel over half of capital outlays into construction-installation works. Assembling regional fixed-capital simplex panels across all 14 regions of Uzbekistan (2000–2025 for technological shares, N = 364; 2007–2025 for reproduction modes, N = 266; 2016–2025 for constant-price industrial value-added growth, N = 140) alongside boundary-harmonized regional benchmarks from Kazakhstan (2003–2026Q3), we evaluate compositional reallocation hypotheses using full-simplex two-way fixed-effects regressions and 9,999 null-imposed wild cluster bootstrap replications. Across all six primary specifications conditioning on real investment scale, real investment growth, employment growth, and residual simplex shares, shifting 10 percentage points from construction-installation works into machinery and equipment yields statistically unresolved contemporaneous (+0.74 percentage points; bootstrap p = 0.7025; 95% bootstrap interval [-1.66, 3.66]) and lagged (+0.56; bootstrap p = 0.3828) industrial growth associations that remain null under predetermined scale controls (+0.63; bootstrap p = 0.3710); a one-year-ahead dynamic association (+1.52; bootstrap p = 0.0319) does not survive six-horizon Holm correction (p = 0.1914), and omitting either Karakalpakstan's 10 region-years (-0.60; bootstrap p = 0.0812) or its single 2016 observation (-0.35; bootstrap p = 0.4017) reverses contemporaneous point estimates negative. On the capital-input margin, reallocating 10 percentage points from greenfield expansion to reconstruction and modernization is associated with a 4.35 percentage-point higher regional machinery share (bootstrap p = 0.0003; 5.75 percentage points with real-scale controls, bootstrap p = 0.0003), while Uzbek-Kazakh subnational comparisons show persistent civil-works dominance whose cross-sectional financing gradients depend on regional consolidation and own-funds scope.

Keywords: fixed-capital composition; machinery and equipment investment; reconstruction and modernization; regional industrial growth; Uzbekistan; Kazakhstan

1. Introduction

A foundational proposition in growth and development macroeconomics holds that the technological composition of fixed-capital formation shapes how investment translates into industrial expansion.

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Equipment-embodied technical change models predict that machinery, plant tooling, and transport equipment carry frontier productivity innovations into manufacturing production, generating higher output elasticities than civil structures and non-tradable construction works (De Long & Summers, 1991; Barro, 1991; Greenwood et al., 1997; Eaton & Kortum, 2001; Caselli & Wilson, 2004). Conversely, studies of public investment surges and capital misallocation demonstrate that accounting capital outlays in developing and transition economies frequently flow into non-industrial civil works, residential real estate, or state-directed greenfield facilities whose commissioning lags, cost overruns, and allocative distortions attenuate measurable industrial value-added gains (Aschauer, 1989; Pritchett, 2000; Warner, 2014; Hsieh & Klenow, 2009; Restuccia & Rogerson, 2017). Evaluating whether regional shifts away from civil construction toward machinery and plant modernization are associated with faster industrial growth requires subnational panels that observe complete capital expenditure simplices alongside constant-price industrial output and explicit financing structures.

Post-2016 Uzbekistan and neighboring Kazakhstan provide an instructive institutional setting to examine compositional capital hypotheses across subnational economies. Following foreign-exchange unification and capital-goods import liberalization in September 2017, Uzbekistan recorded rapid fixed-capital expansion accompanied by rising foreign investment and credit inflows (Hasanov & Cherif, 2019; Cherif et al., 2024; Borgersen & King, 2016). Despite real investment growth averaging 19.42 percent across regions during 2016–2025, construction and installation works absorbed an average of 50.46 percent of regional fixed-capital outlays, while new greenfield construction and expansion accounted for 59.25 percent of reproduction expenditures (National Statistics Committee of the Republic of Uzbekistan, 2026). Across the border, Kazakhstan's regional economies display a wider structures-over-machinery gap—averaging 37.10 and 35.08 percentage points in consolidated regional annual accounts for 2024 and 2025—amid substantial on-budget public co-financing and residential construction activity (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026a; Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026b). Policy discussions across Central Asia commonly attribute uneven regional industrialization to this civil-works tilt, presuming both that plant modernization shifts capital composition toward equipment and that higher regional machinery shares translate into higher near-term industrial growth (Cherif & Hasanov, 2024; Cherif et al., 2026).

We assemble subnational capital-composition, financing, and industrial growth panels through 13 November 2026 to evaluate both links in this chain. For Uzbekistan, we construct a 26-year balanced panel of the three-part technological simplex (construction-installation works, machinery and equipment, and other capital outlays summing to 100 percent across all 14 administrative regions over 2000–2025; $N = 364$), a 19-year panel of the three-part reproduction simplex (new greenfield construction and expansion, reconstruction and modernization, and other reproduction outlays over 2007–2025 after setting structural zeros in 2005–2006 to missing; $N = 266$), and a 10-year primary growth panel matching constant-price industrial value-added growth to chained real fixed-capital investment, foreign financing shares, and employment growth over 2016–2025 ($N = 140$) (National Statistics Committee of the Republic of Uzbekistan, 2024; Interstate Statistical Committee of the Commonwealth of Independent States, 2021; National Statistics Committee of the Republic of Uzbekistan, 2026). For Kazakhstan, we harmonize regional technological, financing, manufacturing, and housing investment accounts across both the 20 current administrative regions ($N = 60$) and 16 boundary-consistent parent regions ($N = 48$) for 2024 annual, 2025 annual, and cumulative January–September 2026 releases, complemented by a 23-year regional housing-investment and industrial production panel over 2003–2025 ($N = 368$ investment observations; $N = 364$ matched growth observations) (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026a; Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026b). Panel models pair finite-sample cluster-

robust standard errors across 12 to 16 regional clusters with 9,999 null-imposed Rademacher wild cluster bootstrap replications and test-inverted 95 percent confidence sets (Cameron et al., 2008; Roodman et al., 2019; MacKinnon et al., 2023), while single-period regional cross-sections use heteroskedasticity-robust studentized wild bootstrap inference.

Three empirical findings emerge. First, on the capital-input margin, plant modernization exhibits a strong conditional association with equipment intensity: holding residual reproduction shares, foreign financing shares, and region and year fixed effects constant, a 10-percentage-point reallocation from greenfield expansion to reconstruction and modernization is associated with a 4.35-percentage-point higher regional machinery and equipment share over 2007–2025 ($p_{\mathrm{WCB}} = 0.0003$, 95 percent bootstrap confidence interval $[2.14, 6.81]$) and a 5.75-percentage-point higher share when conditioning on log real investment scale over 2010–2025 ($p_{\mathrm{WCB}} = 0.0003$, $[2.95, 8.59]$). Second, on the industrial-output margin, none of the six primary simplex regressions over 2016–2025 detects a statistically significant positive association with constant-price industrial value-added growth. Reallocating 10 percentage points from construction-installation works to machinery yields +0.74 percentage points contemporaneously ($p_{\mathrm{WCB}} = 0.7025$, $[-1.66, 3.66]$), +0.56 percentage points at a one-year lag ($p_{\mathrm{WCB}} = 0.3828$), and +0.58 percentage points for the prior two-year average ($p_{\mathrm{WCB}} = 0.4751$), and remains statistically unresolved (+0.63 and +0.49 percentage points) when omitting contemporaneous post-decision factor-growth controls; reallocating 10 percentage points from greenfield expansion to reconstruction yields +1.04 percentage points contemporaneously ($p_{\mathrm{WCB}} = 0.4929$) alongside negative lagged estimates (−1.29 percentage points at one lag, $p_{\mathrm{WCB}} = 0.1590$; −1.84 percentage points for the two-year mean, $p_{\mathrm{WCB}} = 0.0773$), with all six Holm-adjusted bootstrap p-values at or above 0.4638 (Holm, 1979). An exploratory one-year-ahead local-projection estimate (+1.52 percentage points, $p_{\mathrm{WCB}} = 0.0319$) does not survive six-horizon multiplicity correction ($p_{\mathrm{Holm}} = 0.1914$), and deletion diagnostics show that omitting either all ten region-years of the Republic of Karakalpakstan (−0.60 percentage points, $p_{\mathrm{WCB}} = 0.0812$) or solely Karakalpakstan's 2016 observation (−0.35 percentage points, $p_{\mathrm{WCB}} = 0.4017$) reverses contemporaneous machinery and reconstruction coefficients negative. Third, cross-national benchmarks confirm persistent structures-over-machinery dominance in both economies while showing that cross-sectional budget-financing gradients depend on territorial consolidation, Uzbekistan's off-budget investment system, and whether household developers enter own-funds denominators.

2. Conceptual Framework and Compositional Hypotheses

2.1. Equipment Embodiment, Simplex Accounting, and Relative Valuation

In multi-sector investment models, capital goods differ in embodied technological content and gestation horizons (Greenwood et al., 1997; Kogan et al., 2017). Machinery purchases install tradable equipment onto factory floors, whereas construction-installation outlays combine industrial plant shells with non-industrial civil infrastructure, commercial buildings, and residential structures (Leduc & Wilson, 2013; Ramey, 2020; Duranton & Puga, 2020). Financial frictions, public budget earmarks, and state-guaranteed credit further influence whether regional capital flows into greenfield complexes or brownfield retooling of existing plants (Buera et al., 2011; Claessens et al., 2014; Gopinath et al., 2017). At the regional aggregate level, three mechanisms can attenuate the reduced-form association between annual expenditure shares and industrial value-added growth: commissioning lags and temporary retooling downtime during plant modernization (Pritchett, 2000; Bils et al., 2021), compositional dilution when economy-wide fixed-capital shares pool manufacturing equipment with municipal and residential civil works, and relative-price shifts between imported tradable equipment and non-tradable domestic construction after major exchange-rate adjustments such as Uzbekistan's September 2017 currency unification. Because official technological shares (M_{it}, C_{it}, O_{it}) are recorded in current soums whereas total regional investment

I_{it}^{real} is deflated by a composite capital price index, a sharp nominal depreciation mechanically elevates current-price imported machinery shares relative to physical equipment quantities.

Because technological shares (M_{it}, C_{it}, O_{it})—representing machinery and equipment, construction-installation works, and other capital expenditures—sum identically to 100 percent within every region-year cell (i, t), linear regressions cannot vary one share in isolation without specifying which counterpart share adjusts (Aitchison, 1982). Omitting construction-installation share C_{it} while retaining scaled residual share $o_{it} \equiv O_{it}/10$ defines the coefficient on scaled machinery share $m_{it} \equiv M_{it}/10$ as the conditional association of a 10-percentage-point reallocation from civil structures into machinery. Analogously, within the reproduction simplex (R_{it}, N_{it}, U_{it})—representing reconstruction and modernization, new greenfield construction and expansion, and other reproduction outlays summing to 100 percent—omitting greenfield share N_{it} while retaining $u_{it} \equiv U_{it}/10$ defines the conditional association of a 10-percentage-point shift from greenfield expansion into plant modernization.

2.2. Falsifiable Empirical Hypotheses

This simplex accounting motivates three falsifiable hypotheses:

1. **Hypothesis 1 (Technological Reallocation and Regional Industrial Growth)**: Conditional on regional and annual fixed effects, real fixed-capital scale, factor growth controls, and residual capital shares, a 10-percentage-point reallocation from construction-installation works into machinery and equipment is positively associated with regional constant-price industrial value-added growth contemporaneously or over one- to two-year lags.
2. **Hypothesis 2 (Modernization Channel and Equipment Intensity)**: A 10-percentage-point reallocation from greenfield expansion into reconstruction and modernization is positively associated with regional machinery and equipment shares (**Hypothesis 2a**) and exhibits positive conditional associations—or positive slope complementarity with machinery shares—in regional industrial value-added growth regressions (**Hypothesis 2b**).
3. **Hypothesis 3 (Cross-National Civil-Works Skew and Financing Structure)**: Subnational fixed-capital formation in both Uzbekistan and Kazakhstan exhibits persistent civil-works dominance ($C_{it} > M_{it}$), with regional structures-over-machinery skew positively associated with government budget financing shares and residential housing shares across comparable administrative boundaries.

3. Data Harmonization, Comparability Boundaries, and Econometric Design

3.1. Primary Statistical Sources and Missing-Data Rules

Uzbekistan regional series are compiled from official releases of the National Statistics Committee of the Republic of Uzbekistan through 13 November 2026, governed by Methodological Order No. 55 of 25 April 2024 and Commonwealth of Independent States methodological provisions (National Statistics Committee of the Republic of Uzbekistan, 2024; Interstate Statistical Committee of the Commonwealth of Independent States, 2021; National Statistics Committee of the Republic of Uzbekistan, 2026). Articles 31–34 of Order No. 55 stipulate that real fixed-capital volume indices are evaluated at comparable prices using composite investment deflators. Every regional series is merged by four-digit territorial classification codes across the 14 first-level regions (the Republic of Karakalpakstan, 12 provinces, and Tashkent City), excluding national totals and district sub-rows.

Three structural reporting anomalies in official Uzbek tables are isolated transparently without altering valid observations. First, all three reproduction-composition series report exact zeros across every region in 2005 and 2006 (84 regional cells); setting those cells to structural missingness anchors the valid reproduction panel at 2007–2025 ($N = 266$). Second, the quarterly industrial value-added index table contains an irregular fifth-quarter column for 2025 across 14 regions; excluding that column without relabel-

ing quarters, annual constant-price industrial value-added net growth (g_{it}) is defined strictly as the official fourth-quarter full-year cumulative index minus 100 over 2016–2025 ($N = 140$). Tail realizations—including +64.50 percent in Karakalpakstan and −27.10 percent in Andijan in 2016—trace directly to official full-year indices and are retained un-winsorized, with leverage evaluated via both whole-region and single-observation deletion checks. Third, trailing unnamed columns in the non-financial assets auxiliary table are excluded, and foreign investment and credit shares over 2010–2025 are computed as foreign investment and foreign loans divided by exact fixed-capital investment levels in billion Uzbek soums (spliced with published official foreign shares for 2000–2009 background regressions, where 2010–2025 overlap differences do not exceed 0.067 percentage points). Real regional fixed-capital investment (I_{it}^{real}) is chained forward from 2010 current-price regional levels via $\ln I_{it}^{\text{real}} = \ln I_{i,2010}^{\text{real}} + \sum_{\tau=2011}^{t} \ln(1 + \Delta I_{i\tau}^{\text{real}}/100)$, and regional employment growth (ΔL_{it}) sums public and non-state employment.

Kazakhstan subnational benchmarks draw on bilingual Russian- and Kazakh-language statistical workbooks published by the Bureau of National Statistics through October 2026 (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026a; Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026b), yielding verified 2024 annual, 2025 annual, and January–September 2026 cumulative cross-sections across technological structure, financing sources, institutional own funds excluding individual residential developers, manufacturing investment, external inflows, and housing construction. To eliminate mechanical breaks from Kazakhstan's 2018 Shymkent split and 2022 creation of Abai, Zhetysu, and Ulytau regions, we construct additive tenge aggregates for 16 time-consistent parent regions ($N = 48$) alongside the 20 administrative regions ($N = 60$). Two cross-national statistical differences govern comparison: Kazakhstan's regional industrial series measures real gross industrial production volume indices as distinct from System of National Accounts industrial value-added growth, and Kazakh technological investment accounts include capital repairs whereas Uzbek Order No. 55 tracks fixed-capital formation excluding routine capital repairs. In the 2003–2025 Kazakhstan panel ($N = 368$), industrial growth in split parent regions weights constituent real production indices by prior-year nominal industrial output ($N = 364$), paired with a 347-observation check restricted to directly published official indices. Because Uzbekistan does not publish regional housing-investment outlays in soums, Uzbek housing shares remain missing without proxy imputation.

3.2. Full-Simplex Specifications, Financing Simplex, and Few-Cluster Inference

For the 2016–2025 Uzbekistan primary growth panel ($N = 140$, $G = 14$), the six primary specifications take the full-simplex two-way fixed-effects form:

$$g_{it} = \alpha_i + \lambda_t + \beta_M m_{it}^{(k)} + \beta_O o_{it}^{(k)} + \gamma_1 \ln I_{it}^{\text{real}} + \gamma_2 \Delta I_{it}^{\text{real}} + \gamma_3 \Delta L_{it} + \varepsilon_{it} \tag{1}$$

and for reproduction modes:

$$g_{it} = \alpha_i + \lambda_t + \beta_R r_{it}^{(k)} + \beta_U u_{it}^{(k)} + \delta_1 \ln I_{it}^{\text{real}} + \delta_2 \Delta I_{it}^{\text{real}} + \delta_3 \Delta L_{it} + \nu_{it} \tag{2}$$

where $k \in \{0, 1, 2a\}$ denotes contemporaneous shares (t), one-year lagged shares ($t - 1$), and prior two-year averages ($(x_{i,t-1} + x_{i,t-2})/2$) constructed on the pre-2016 long panel so that all six models retain $N = 140$. Because ($\ln I_{it}^{\text{real}}, \Delta I_{it}^{\text{real}}, \Delta L_{it}$) in lagged models ($k \in \{1, 2a\}$) are realized after the capital-composition decision and could act as post-treatment colliders if plant retooling induces subsequent investment or hiring, Section 6.1 re-estimates all four lagged models conditioning solely on predetermined scale ($\ln I_{i,t-1}^{\text{real}}$) alongside residual simplex shares and two-way fixed effects.

Dynamic horizon associations follow local projections (Jordà, 2005) of $g_{i,t+h}$ on period-t simplex shares and period-t controls for $h \in \{-2, -1, 0, +1, +2, +3\}$. Modernization intensity regressions relate

machinery share M_{it} to scaled reconstruction share r_{it}, residual reproduction share u_{it}, foreign financing share $f_{it} \equiv F_{it}/10$, and region and year fixed effects over 2007–2025 ($N = 266$), adding $\ln I_{it}^{\text{real}}$ over 2010–2025 ($N = 224$). Single-period cross-sectional benchmark regressions ($N \in \{14, 16, 20\}$) estimate $C_i - M_i = a + \delta_B(B_i/10) + \delta_A(A_i/10) + e_i$. Because regional financing shares—government budget B_i, narrow enterprise or institutional own funds A_i^{narrow}, household and individual developer funds H_i^{own}, foreign inflows F_i, and bank or other credit D_i—sum to 100 percent, δ_B under narrow own funds ($A_i = A_i^{\text{narrow}}$) measures a 10-percentage-point shift into on-budget financing out of the composite residual ($F_i + D_i + H_i^{\text{own}}$), whereas switching to broad own funds ($A_i^{\text{broad}} = A_i^{\text{narrow}} + H_i^{\text{own}}$) removes household residential funds from the omitted financing baseline ($F_i + D_i$).

Panel regressions use full-rank ordinary least squares with finite-sample CR1 cluster-robust standard errors evaluated against $t(G - 1)$ ($G \in \{12, 13, 14, 16, 20\}$) and 9,999 null-imposed Rademacher wild cluster bootstrap replications studentized by CR1 t-statistics and inverted to form 95 percent bootstrap confidence sets (Cameron et al., 2008; Roodman et al., 2019; MacKinnon et al., 2023). In single-period cross-sections where each region contributes one observation ($N_g = 1$), the finite-sample adjustment $(N/(N-1))((N-1)/(N-K)) = N/(N-K)$ reduces algebraically to heteroskedasticity-robust HC1 covariance paired with 9,999 Rademacher wild bootstrap draws. Sequential Holm adjustments are applied across the six primary models and across the six dynamic horizons (Holm, 1979); other mechanism and diagnostic p-values are reported unadjusted for multiplicity.

4. Empirical Results

4.1. Simplex Trajectories, Two-Way Variance Structure, and Summary Distributions

Figure 1 documents the long-run evolution and two-way sum-of-squares decomposition of Uzbekistan's regional capital simplices, while Table 1 summarizes the 2016–2025 primary estimation sample ($N = 140$). Across 2000–2025 (Figure 1a), unweighted regional mean construction-installation shares declined from 63.18 percent in 2000 to a trough of 42.29 percent in 2019 as nominal machinery shares peaked at 50.06 percent after the September 2017 exchange-rate devaluation raised the domestic-currency valuation of imported equipment alongside physical import volumes, before rebounding to 55.39 percent construction versus 34.96 percent machinery in 2025. Across 2007–2025 (Figure 1b), greenfield construction and expansion consistently dominated regional capital reproduction, averaging 59.25 percent during 2016–2025 compared with 23.98 percent for reconstruction and modernization and 16.77 percent for other reproduction outlays.

Because all panel regressions include both region fixed effects α_i and year fixed effects λ_t, Figure 1c partitions the 2016–2025 sum of squares ($N = 140$) across all six simplex shares into orthogonal between-region variation absorbed by α_i, common nationwide year variation absorbed by λ_t, and residual region-by-year (i, t) variation that identifies β_M and β_R. Common annual waves account for 14.12 to 30.70 percent of total technological variance and 11.02 to 22.34 percent of reproduction variance, yet residual two-way (i, t) variation still represents 49.52 percent of total variance in construction-installation shares, 45.14 percent in machinery shares, 54.98 percent in other capital outlays, 50.80 percent in greenfield expansion, 65.55 percent in reconstruction and modernization, and 38.64 percent in other reproduction outlays (40.84 to 66.74 percent over the full 2000–2025 and 2007–2025 historical windows).

Table 1. Summary statistics for the Uzbekistan primary regional estimation sample (14 regions, 2016–2025, $N = 140$)

Variable (unit)	Mean	SD	P25	Median	P75	Min	Max
Industrial value-added growth (constant prices, %)	7.45	8.00	4.73	7.05	9.10	-27.10	64.50

(continued)

Table 1 (continued)

Variable (unit)	Mean	SD	P25	Median	P75	Min	Max
Construction and installation share (%)	50.46	11.85	39.65	49.40	59.53	28.70	82.70
Machinery and equipment share (%)	40.27	13.09	30.15	41.75	50.13	6.90	69.70
Other capital expenditure share (%)	9.27	5.24	5.45	8.00	12.23	1.60	26.10
Greenfield construction and expansion share (%)	59.25	11.44	50.68	59.95	68.65	35.50	81.10
Reconstruction and modernization share (%)	23.98	8.68	17.88	24.05	29.65	6.60	52.40
Other reproduction investment share (%)	16.77	7.92	10.80	15.70	21.08	3.90	38.50
Foreign investment and credit share (%)	39.18	22.07	22.97	39.13	56.90	1.30	81.82
Chained real fixed-capital investment (billion soums)	4,306.80	3,151.27	2,228.04	3,361.34	5,193.24	663.89	18,917.96
Real fixed-capital investment growth (%)	19.42	26.07	5.38	16.10	35.15	-37.90	135.50
Total regional employment (thousand persons)	980.89	379.42	710.33	1,029.90	1,285.28	332.20	1,611.70
Regional employment growth (%)	1.45	2.88	0.14	1.50	3.00	-5.11	10.19

Notes. Unweighted region-year summary statistics across all 14 first-level administrative regions of Uzbekistan from 2016 through 2025 ($N = 140$). Technological shares sum to 100 percent within every region-year cell, as do reproduction shares. Chained real fixed-capital investment levels (billion constant 2010 soums) are chained forward from 2010 regional current-price outlays using official comparable-price investment volume indices.

4.2. Primary Full-Simplex Industrial Growth Regressions

Table 2 reports all six primary simplex regressions testing Hypothesis 1 and Hypothesis 2b. Conditioning on region and year fixed effects, log chained real investment, real investment growth, employment growth, and other capital expenditure shares, a 10-percentage-point reallocation from construction-installation works into machinery and equipment yields a contemporaneous conditional association of +0.739 percentage points of constant-price industrial value-added growth (SE = 1.131, $p_{\mathrm{WCB}} = 0.7025$, 95 percent bootstrap interval $[-1.663, 3.663]$). Replacing contemporaneous shares with one-year lagged machinery share (+0.558 percentage points, SE = 0.625, $p_{\mathrm{WCB}} = 0.3828$, $[-0.796, 1.719]$) or the prior two-year moving average (+0.579 percentage points, SE = 0.896, $p_{\mathrm{WCB}} = 0.4751$, $[-1.284, 2.449]$) narrows the confidence bands while remaining statistically indistinguishable from zero.

Table 2. Full-simplex two-way fixed-effects regressions of constant-price industrial value-added growth in Uzbekistan (2016–2025)

Simplex timing & 10 pp reallocation (omitted base)	Coeff. (SE)	Conv. p	WCB p	95% CI	Holm p	Within R^2
Technological (t): Machinery vs. construction-installation	0.739 (1.131)	0.5247	0.7025	[-1.663, 3.663]	1.0000	0.1246
Technological ($t - 1$): Machinery vs. construction-installation	0.558 (0.625)	0.3887	0.3828	[-0.796, 1.719]	1.0000	0.1107
Technological (prior 2-yr mean): Machinery vs. construction	0.579 (0.896)	0.5293	0.4751	[-1.284, 2.449]	1.0000	0.1117

(continued)

Table 2 (continued)

Simplex timing & 10 pp reallocation (omitted base)	Coeff. (SE)	Conv. p	WCB p	95% CI	Holm p	Within R^2
Reproduction (t): Reconstruction vs. greenfield expansion	1.037 (1.198)	0.4024	0.4929	[-1.267, 4.177]	1.0000	0.1251
Reproduction ($t-1$): Reconstruction vs. greenfield expansion	-1.286 (0.849)	0.1537	0.1590	[-3.129, 0.511]	0.7950	0.1271
Reproduction (prior 2-yr mean): Reconstruction vs. greenfield	-1.836 (0.955)	0.0769	0.0773	[-3.805, 0.181]	0.4638	0.1323

Notes. All six models are estimated on the balanced panel of 14 regions over 2016–2025 ($N = 140$, $G = 14$ clusters; lags constructed on the long panel prior to windowing). Every specification includes region fixed effects, year fixed effects, log real fixed-capital investment, real fixed-capital investment net growth, regional employment net growth, and the corresponding residual simplex share. Parentheses report CR1 cluster-robust standard errors; conventional two-sided p-values use $t(13)$; WCB p-values and test-inverted 95 percent confidence intervals (95% CI) use 9,999 null-imposed Rademacher wild cluster bootstrap draws. Exact two-sided 80 percent minimum detectable effects under noncentral $t(13)$ are 3.43, 1.90, and 2.71 percentage points for rows 1–3 and 3.63, 2.57, and 2.90 percentage points for rows 4–6. Holm p-values adjust WCB p across all six primary focal tests.

In the reproduction simplex (Table 2, rows 4–6), a 10-percentage-point shift from new greenfield construction and expansion into reconstruction and modernization yields +1.037 percentage points contemporaneously (SE = 1.198, $p_{\mathrm{WCB}} = 0.4929$, $[-1.267, 4.177]$), −1.286 percentage points at a one-year lag (SE = 0.849, $p_{\mathrm{WCB}} = 0.1590$, $[-3.129, 0.511]$), and −1.836 percentage points for the prior two-year average (SE = 0.955, $p_{\mathrm{WCB}} = 0.0773$, $[-3.805, 0.181]$). Negative one- to two-year lagged modernization coefficients are consistent with temporary plant retooling downtime and brownfield overhaul disruptions at legacy industrial enterprises, though sequential Holm adjustment across the six primary tests yields adjusted bootstrap p-values between 0.4638 and 1.0000. Consequently, neither Hypothesis 1 nor Hypothesis 2b receives confirmatory support in annual regional industrial value-added growth.

5. Mechanisms, Dynamic Horizons, and Subnational Benchmarks

5.1. Modernization-to-Machinery Intensity Versus Output Translation

Table 3 and Figure 2 separate input-side capital composition relationships from output-side dynamic horizons and Uzbek-Kazakh subnational benchmarks. On the capital-input margin, Hypothesis 2a is strongly supported (Table 3, Panel A): holding residual reproduction shares, foreign financing shares, and region and year fixed effects constant, a 10-percentage-point reallocation from greenfield expansion to reconstruction and modernization is associated with a 4.349-percentage-point higher regional machinery and equipment share over 2007–2025 ($SE = 0.991$, $p_{\mathrm{WCB}} = 0.0003$, 95 percent bootstrap interval $[2.138, 6.814]$, $N = 266$) and a 5.747-percentage-point higher share over 2010–2025 when controlling for log real fixed-capital scale ($SE = 1.257$, $p_{\mathrm{WCB}} = 0.0003$, $[2.954, 8.594]$, $N = 224$). Regional reconstruction outlays are thus closely aligned with higher equipment intensity relative to greenfield expansion, even though aggregate regional industrial growth does not co-move tightly with contemporaneous or lagged equipment shares.

Long-run foreign financing regressions (Table 3, Panel A) clarify why rising foreign inflows after 2017 did not lock in permanent machinery dominance. Across 2000–2025 ($N = 364$), a 10-percentage-point higher foreign investment and credit share exhibits no statistically significant positive association with machinery share (+2.293 percentage points, $p_{\mathrm{WCB}} = 0.2452$; +1.642 percentage points scale-adjusted over 2010–2025, $p_{\mathrm{WCB}} = 0.4970$). Pre-2017 foreign share is negatively associated with construction share (−3.054 percentage points, $p_{\mathrm{WCB}} = 0.0129$), whereas post-2017 slope changes are unresolved under bootstrap inference (+1.392 percentage points for construction, $p_{\mathrm{WCB}} = 0.2072$; +2.420 percentage points

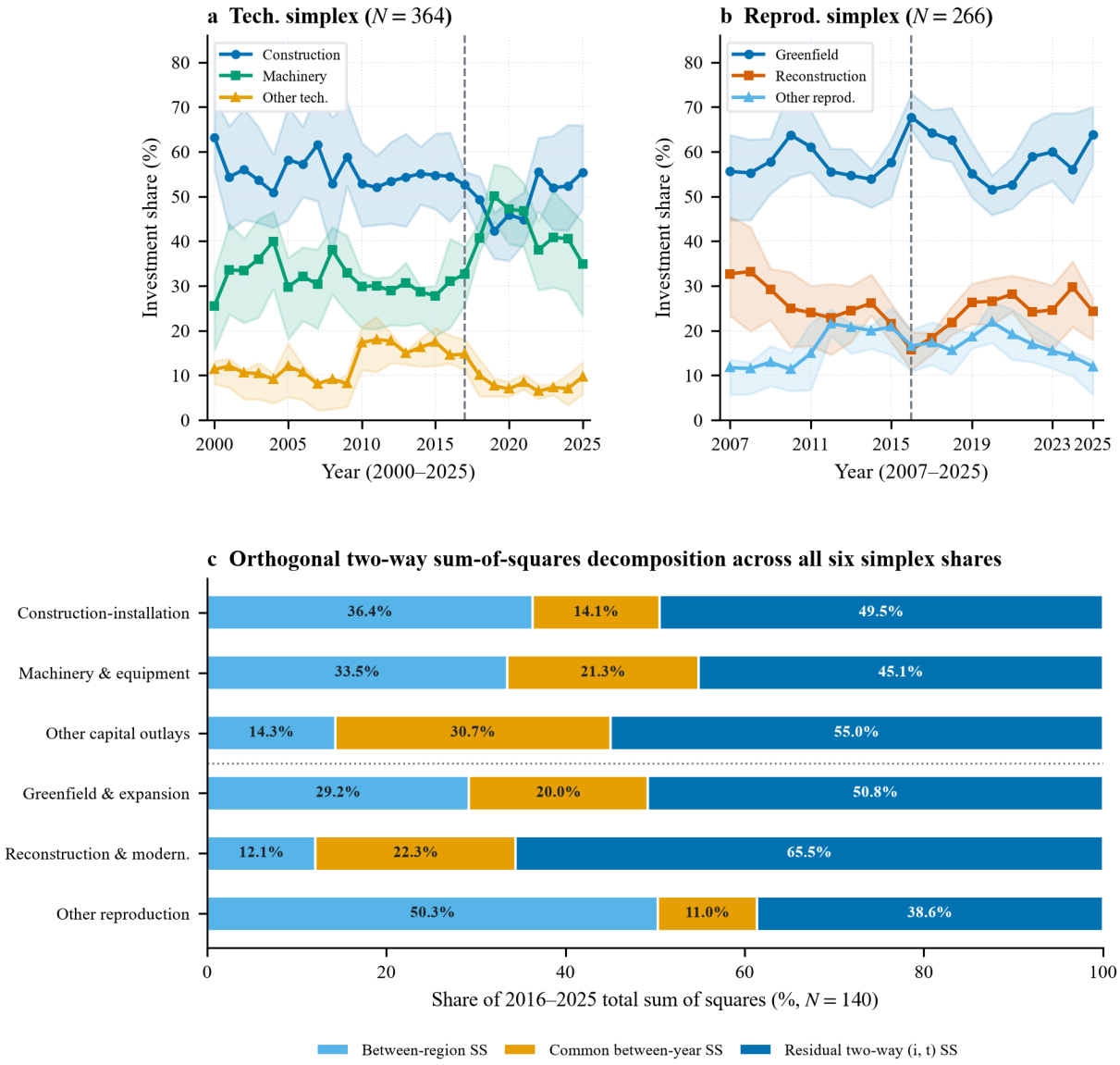


Figure 1. Evolution and orthogonal two-way sum-of-squares decomposition of fixed-capital technological and reproduction simplices across 14 regions of Uzbekistan.

Notes. Panel a plots annual unweighted regional means (solid lines with markers) and interquartile ranges (shaded bands) of the three current-price technological investment shares summing to 100 percent across all 14 regions over 2000–2025 (N = 364), marking the September 2017 foreign-exchange unification and import reform. Panel b plots the three reproduction investment shares over the 2007–2025 valid window (N = 266; structural zeros in 2005–2006 set to missing), marking the 2016–2025 primary industrial growth window. Panel c decomposes the 2016–2025 sum of squares (N = 140) across all six simplex components into between-region variation, common between-year variation, and residual two-way (i, t) identifying variation.

for reconstruction despite conventional $p = 0.0474$, $p_{\text{WCB}} = 0.2152$). In industrial growth equations, multiplicative slope-change interactions—measuring how the 10-percentage-point machinery slope shifts per 10-percentage-point increase in reconstruction (-0.461, $SE = 0.724$, $p_{\text{WCB}} = 0.5200$, $[-2.092, 1.011]$) or foreign share (-0.161, $SE = 0.346$, $p_{\text{WCB}} = 0.7889$, $[-1.056, 0.488]$)—are likewise indistinguishable from zero.

Local-projection horizon estimates (Figure 2a and Table 3, Panel B) do not detect statistically significant pre-investment associations at $h = -2$ ($+0.305$, $p_{\text{WCB}} = 0.6591$, $[-1.051, 1.795]$) or $h = -1$ ($+0.467$, $p_{\text{WCB}} = 0.6634$, $[-1.756, 2.970]$), show an unresolved contemporaneous estimate at $h = 0$

(+0.739, p_{WCB} = 0.7025), yield a positive unadjusted one-year-ahead association at h = +1 (+1.521 percentage points, SE = 0.694, p_{WCB} = 0.0319, [0.132, 3.105], N_1 = 126), and attenuate at h = +2 (+0.749, p_{WCB} = 0.2074) and h = +3 (+0.281, p_{WCB} = 0.5704). Evaluated jointly across all six exploratory horizons, the h = +1 estimate carries a Holm-adjusted bootstrap p-value of 0.1914 and remains suggestive. Because local projections condition on base-year (t) investment scale and drop 2025 when evaluating t + 1, h = +1 (N = 126) differs algebraically from the Table 2 lag-one specification (N = 140), which conditions on realization-year (t) scale and retains 2016 via pre-2016 capital lags.

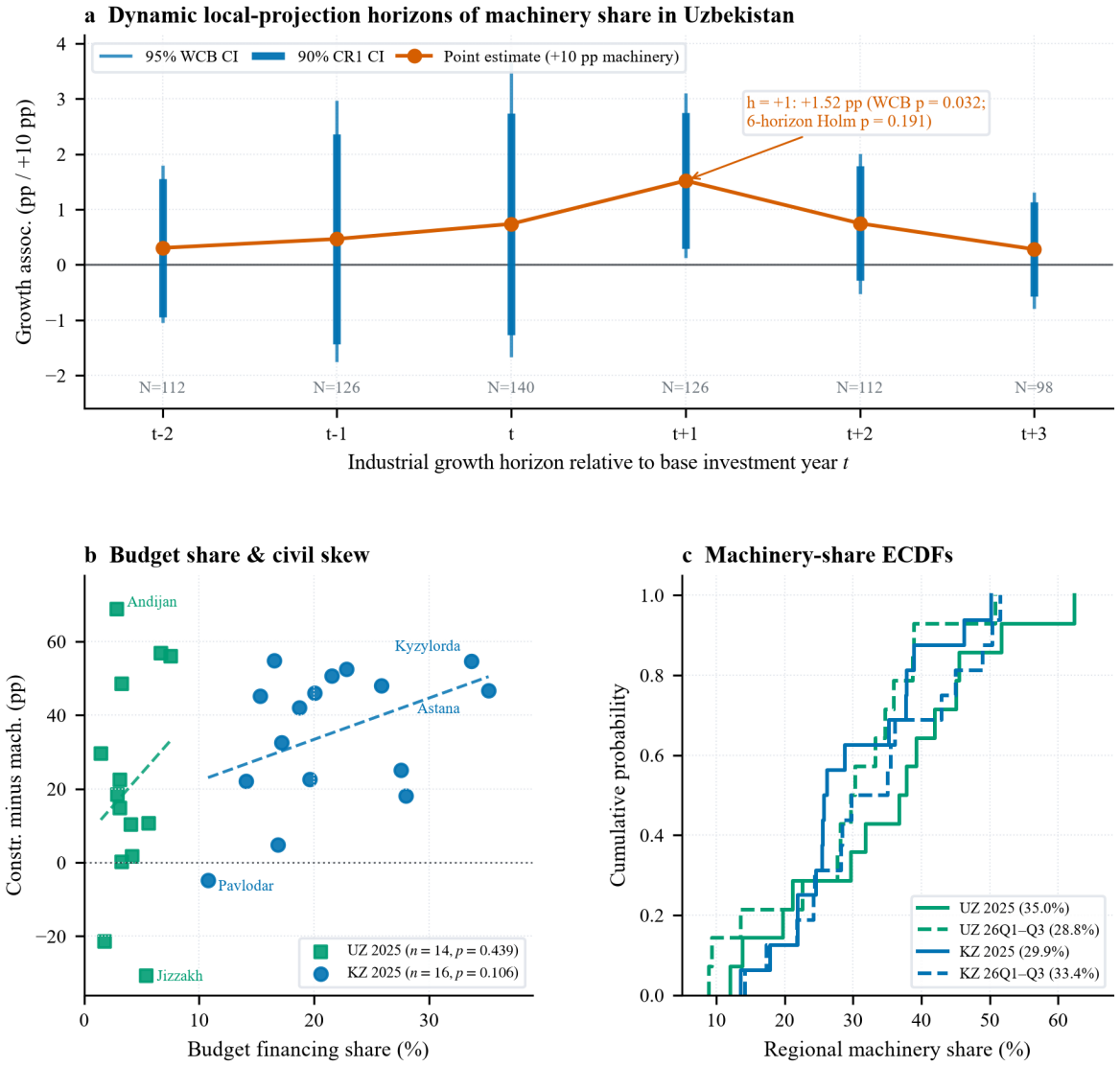


Figure 2. Dynamic local-projection horizons in Uzbekistan and subnational financing and machinery-share benchmarks across Uzbekistan and Kazakhstan.

Notes. Panel a plots local-projection coefficients (h = −2 to +3) of constant-price industrial value-added growth ($g_{i,t+h}$) on base-year t machinery share (+10 percentage points vs. construction-installation), showing CR1 90 percent intervals (thick bars), 95 percent wild cluster bootstrap intervals (thin bars), exact sample sizes N_h, and six-horizon Holm-adjusted inference. Panel b plots 2025 annual regional structures-over-machinery skew ($C_i - M_i$, percentage points) against on-budget government financing shares across Uzbekistan's 14 regions and Kazakhstan's 16 consolidated parent regions with unadjusted bivariate OLS reference lines and multivariate Table 3 WCB p-values. Panel c plots empirical cumulative distribution functions of regional machinery shares comparing 2025 full-year and January–September 2026 cumulative accounts.

Table 3. Modernization-intensity mechanisms, dynamic horizons, and Uzbek-Kazakh subnational benchmarks

Sample, dependent variable & focal regressor (+10 pp)	*N*	Coeff. (SE)	Conv. *p*	WCB *p*	95% CI
Panel A: Uzbekistan capital-input & interaction models					
Machinery share (%, 2007–2025): Reconstruction vs. greenfield	266	4.349 (0.991)	0.0007	0.0003	[2.138, 6.814]
Machinery share (%, scale-adj. 2010–2025): Reconstruction vs. greenfield	224	5.747 (1.257)	0.0005	0.0003	[2.954, 8.594]
Machinery share (%, 2000–2025): Foreign investment & credit	364	2.293 (1.755)	0.2141	0.2452	[-1.312, 6.472]
Construction share (%, 2000–2025): Pre-2017 foreign share	364	-3.054 (1.422)	0.0512	0.0129	[-6.832, -0.396]
Construction share (%, 2000–2025): Post-2017 foreign slope change	364	1.392 (1.154)	0.2491	0.2072	[-1.553, 4.910]
Industrial growth (%, 2016–2025): Machinery × reconstruction	140	-0.461 (0.724)	0.5358	0.5200	[-2.092, 1.011]
Industrial growth (%, 2016–2025): Machinery × foreign share	140	-0.161 (0.346)	0.6493	0.7889	[-1.056, 0.488]
Panel B: Uzbekistan dynamic local-projection horizons					
Lead $h = -2$ industrial growth (%): Machinery vs. construction (t)	112	0.305 (0.707)	0.6730	0.6591	[-1.051, 1.795]
Lead $h = -1$ industrial growth (%): Machinery vs. construction (t)	126	0.467 (1.071)	0.6696	0.6634	[-1.756, 2.970]
Horizon $h = +1$ industrial growth (%): Machinery vs. construction (t)	126	1.521 (0.694)	0.0472	0.0319	[0.132, 3.105]
Horizon $h = +2$ industrial growth (%): Machinery vs. construction (t)	112	0.749 (0.585)	0.2232	0.2074	[-0.525, 2.003]
Horizon $h = +3$ industrial growth (%): Machinery vs. construction (t)	98	0.281 (0.480)	0.5679	0.5704	[-0.795, 1.307]
Panel C: Kazakhstan & Uzbekistan civil-works skew & housing					
Kazakhstan 16 parent $C - M$ (2025): Budget share (narrow own ctrl.)	16	12.169 (5.779)	0.0525	0.1058	[-6.276, 40.945]
Kazakhstan 20 admin. $C - M$ (2025): Budget share (narrow own ctrl.)	20	13.130 (5.644)	0.0312	0.0412	[1.073, 32.445]
Uzbekistan 14 regions $C - M$ (2025): Budget share (enterprise own ctrl.)	14	41.207 (47.068)	0.3972	0.4394	[-261.014, 126.660]
Uzbekistan 14 regions $C - M$ (2026 Q1–Q3): Budget share (ent. own ctrl.)	14	27.491 (12.715)	0.0498	0.5993	[-108.445, 92.298]
Kazakhstan 16 parent ind. growth (03–25): Contemporaneous housing share	364	-0.586 (0.771)	0.4593	0.4602	[-2.534, 1.118]
Kazakhstan 16 parent official ind. indices (03–25): Housing share	347	-0.514 (0.795)	0.5272	0.5187	[-2.282, 1.217]

Notes. Panel A controls for region and year fixed effects (plus residual reproduction and foreign shares in machinery-intensity models; interaction rows measure changes in the +10 pp machinery slope when reconstruction or foreign share rises by +10 pp). Panel B six-horizon Holm-adjusted WCB $p = 0.1914$ at $h = +1$ and 1.0000 elsewhere; all other individual p-values are unadjusted. Panel C single-period cross-sections ($N = 14, 16, 20$) use HC1 heteroskedasticity-robust standard errors and studentized wild bootstrap controlling for narrow institutional/enterprise own-funds shares (leaving foreign, credit, and household developer funds in the omitted base); Kazakhstan 2003–2025 panel models measure real gross industrial production volume growth (including capital repairs in investment accounts) with 16 parent-region and year fixed effects.

5.2. Cross-National Civil-Works Skew, Off-Budget Channels, and Financing Gradients

Subnational comparisons across Kazakhstan and Uzbekistan (Figure 2b–c and Table 3, Panel C) qualify Hypothesis 3. In full-year 2024 and 2025 data, Kazakhstan's 16 consolidated parent regions exhibit steeper civil-works dominance—mean construction shares of 66.37 and 64.98 percent versus machinery shares of 29.28 and 29.90 percent (structures-minus-machinery gaps of +37.10 and +35.08 percentage points)—than Uzbekistan's 14 regions, where construction averaged 52.34 and 55.39 percent and machinery averaged 40.61 and 34.96 percent (gaps of +11.73 and +20.44 percentage points). In cumulative January–September 2026 releases (Figure 2c), however, the cross-national machinery ranking reverses: Uzbekistan's regional machinery mean falls to 28.78 percent (gap +31.18 percentage points) while consolidated Kazakhstan rises to 33.39 percent (gap +28.51 percentage points), showing that intra-year cumulative investment structures diverge substantially from full-year settlements.

Cross-sectional regressions of structures-minus-machinery skew on on-budget government financing shares (+10 percentage points, controlling for narrow institutional own funds) yield positive point estimates across Kazakhstan windows (Figure 2b), reaching $p_{\mathrm{WCB}} = 0.0412$ (+13.130 percentage points, $[1.073, 32.445]$) across the 20 administrative regions in 2025. Consolidating split territories into 16 parent regions widens the interval to $[-6.276, 40.945]$ ($p_{\mathrm{WCB}} = 0.1058$, +12.169 percentage points); adding regional housing shares shifts the 20-region budget p_{WCB} to 0.0685 while the 20-region housing-share bootstrap confidence set splits into two disconnected intervals ($[-13.684, 12.512] \cup [12.530, 12.539]$) due to finite-sample leverage. By contrast, Uzbekistan's 14-region on-budget coefficients carry extreme dispersion (SE = 47.068 and $[-261.014, 126.660]$ in 2025; conventional $p = 0.0498$ vs. $p_{\mathrm{WCB}} = 0.5993$ and $[-108.445, 92.298]$ in 2026 Q1–Q3). This contrast reflects an institutional asymmetry in public-investment financing: direct on-budget state appropriations averaged only 3.94 percent of regional fixed investment across Uzbekistan in 2025 (compressed within 1.45 to 7.52 percent in Figure 2b, versus 21.48 percent in consolidated Kazakhstan) because major state-directed industrial and infrastructure projects in Uzbekistan are financed off-budget through the Fund for Reconstruction and Development of Uzbekistan, state-owned enterprise capital accounts, and state-guaranteed foreign credit lines (39.18 percent mean foreign share). Across Kazakhstan's 2003–2025 regional panel ($N = 364$), a 10-percentage-point higher housing share yields −0.586 percentage points of industrial production growth ($p_{\mathrm{WCB}} = 0.4602$; −0.514 on directly published indices, $N = 347$, $p_{\mathrm{WCB}} = 0.5187$).

6. Robustness, Influential Regions, and Scope Sensitivity

6.1. Predetermined Controls, Karakalpakstan Deletion, and Financing Scope

Figure 3 and Table 4 subject our primary specifications to predetermined-control, region- and observation-deletion, subperiod, future-lead, and financing-scope checks. First, to verify that null lagged growth estimates in Table 2 are not induced by conditioning on post-decision contemporaneous investment and employment growth, rows 1–2 of Table 4 re-estimate lagged technological and reproduction equations controlling solely for predetermined scale ($\ln I^{\mathrm{real}}_{i,t-1}$), residual simplex shares, and region and year fixed effects ($N = 140$, $G = 14$). Lag-one machinery remains statistically unresolved (+0.631, SE = 0.702, $p_{\mathrm{WCB}} = 0.3710$, $[-1.009, 1.939]$; +0.485, $p_{\mathrm{WCB}} = 0.5789$ for the prior two-year mean), while two-year mean reconstruction remains borderline negative (−1.670, SE = 0.819, $p_{\mathrm{WCB}} = 0.0541$, $[-3.266, 0.051]$; −1.130, $p_{\mathrm{WCB}} = 0.1600$ at one lag).

Second, omitting Uzbekistan's capital metropolis (Tashkent City; +0.765, $p_{\mathrm{WCB}} = 0.7294$), mining-metallurgical hub (Navoi; +0.798, $p_{\mathrm{WCB}} = 0.6905$), or both simultaneously (+0.858, $p_{\mathrm{WCB}} = 0.7147$, $N = 120$, $G = 12$) leaves contemporaneous machinery estimates positive and unresolved. Leave-one-region-out estimation across all 14 regions (Figure 3a), however, shows that omitting all ten region-years of the Republic of Karakalpakstan ($N = 130$, $G = 13$) reverses the contemporaneous machinery co-

efficient from +0.739 to −0.601 percentage points (SE = 0.341, $p_{\mathrm{WCB}} = 0.0812$, $[-1.316, 0.081]$) and reverses the contemporaneous reconstruction coefficient from +1.037 to −0.150 percentage points (SE = 0.522, $p_{\mathrm{WCB}} = 0.7564$, $[-1.148, 0.910]$), whereas all other 13 single-region omissions remain positive ($[0.348, 1.174]$ for machinery, $p_{\mathrm{WCB}} \geq 0.6198$). Isolating Karakalpakstan's single +64.50 percent industrial-growth observation in 2016 while retaining its 2017–2025 observations ($N = 139$, $G = 14$; Table 4, rows 8–9) already reverses both contemporaneous coefficients negative (−0.349, SE = 0.427, $p_{\mathrm{WCB}} = 0.4017$ for machinery; −0.181, SE = 0.523, $p_{\mathrm{WCB}} = 0.7097$ for reconstruction).

Table 4. Predetermined-control, regional and single-cell deletion, subperiod, future-lead, and own-funds scope checks

Diagnostic specification & focal regressor (+10 pp)	*N*	Clusters	Coeff. (SE)	WCB *p*	95% CI
Predetermined controls only ($t-1$): Lag-1 machinery vs. construction	140	14	0.631 (0.702)	0.3710	[-1.009, 1.939]
Predetermined controls only (2-yr): Mean reconstruction vs. greenfield	140	14	-1.670 (0.819)	0.0541	[-3.266, 0.051]
Exclude Tashkent City: Machinery vs. construction (t)	130	13	0.765 (1.208)	0.7294	[-1.729, 3.825]
Exclude Navoi Region: Machinery vs. construction (t)	130	13	0.798 (1.208)	0.6905	[-1.872, 3.887]
Exclude Tashkent City & Navoi: Machinery vs. construction (t)	120	12	0.858 (1.327)	0.7147	[-2.021, 4.162]
Exclude Karakalpakstan (all years): Machinery vs. construction (t)	130	13	-0.601 (0.341)	0.0812	[-1.316, 0.081]
Exclude Karakalpakstan (all years): Reconstruction vs. greenfield (t)	130	13	-0.150 (0.522)	0.7564	[-1.148, 0.910]
Omit Karakalpakstan 2016 cell only: Machinery vs. construction (t)	139	14	-0.349 (0.427)	0.4017	[-1.240, 0.569]
Omit Karakalpakstan 2016 cell only: Reconstruction vs. greenfield (t)	139	14	-0.181 (0.523)	0.7097	[-1.197, 0.901]
Other 13 single-region omissions: Min-to-max machinery range	130	13	[0.348, 1.174]	≥ 0.6198	0/13 sig.
Subperiod 2016–2019: Machinery vs. construction (t)	56	14	1.645 (3.132)	0.7498	[-3.647, 8.783]
Subperiod 2020–2025: Machinery vs. construction (t)	84	14	-0.122 (0.607)	0.8589	[-1.460, 1.195]
Future lead ($t+1$): Lead machinery share vs. construction	126	14	0.776 (1.208)	0.5657	[-2.001, 3.623]
Future lead ($t+2$): Lead machinery share vs. construction	112	14	-0.031 (1.172)	0.9804	[-2.213, 2.698]
Kazakhstan 16 parent (broad own funds): Budget share on $C-M$ (2025)	16	HC1	17.534 (7.445)	0.0673	[-4.628, 41.688]
Kazakhstan 16 parent (broad own funds): Budget share on $C-M$ (2026 Q1–Q3)	16	HC1	16.577 (7.011)	0.0367	[1.341, 39.520]
Uzbekistan 14 regions (broad own funds): Budget share on $C-M$ (2025)	14	HC1	-1.269 (55.829)	0.9842	[-163.43, 117.12]

Notes. Predetermined-control models include region and year fixed effects, lagged log real investment ($\ln I^{\mathrm{real}}_{i,t-1}$), and residual simplex shares, omitting contemporaneous factor-growth controls. Other Uzbekistan panel models include baseline controls from Equation (1) clustered across $G \in \{12, 13, 14\}$ regions (0 of 13 non-Karakalpakstan single-region deletions reject zero at 5%). Bottom three rows are single-period regional cross-sections ($N_g = 1$) estimated with HC1 standard errors and studentized wild bootstrap, where broad own funds combine enterprise/institutional funds with household developer funds (shifting the omitted financing base strictly to foreign inflows plus bank/other credit). Individual *p*-values are unadjusted for multiplicity.

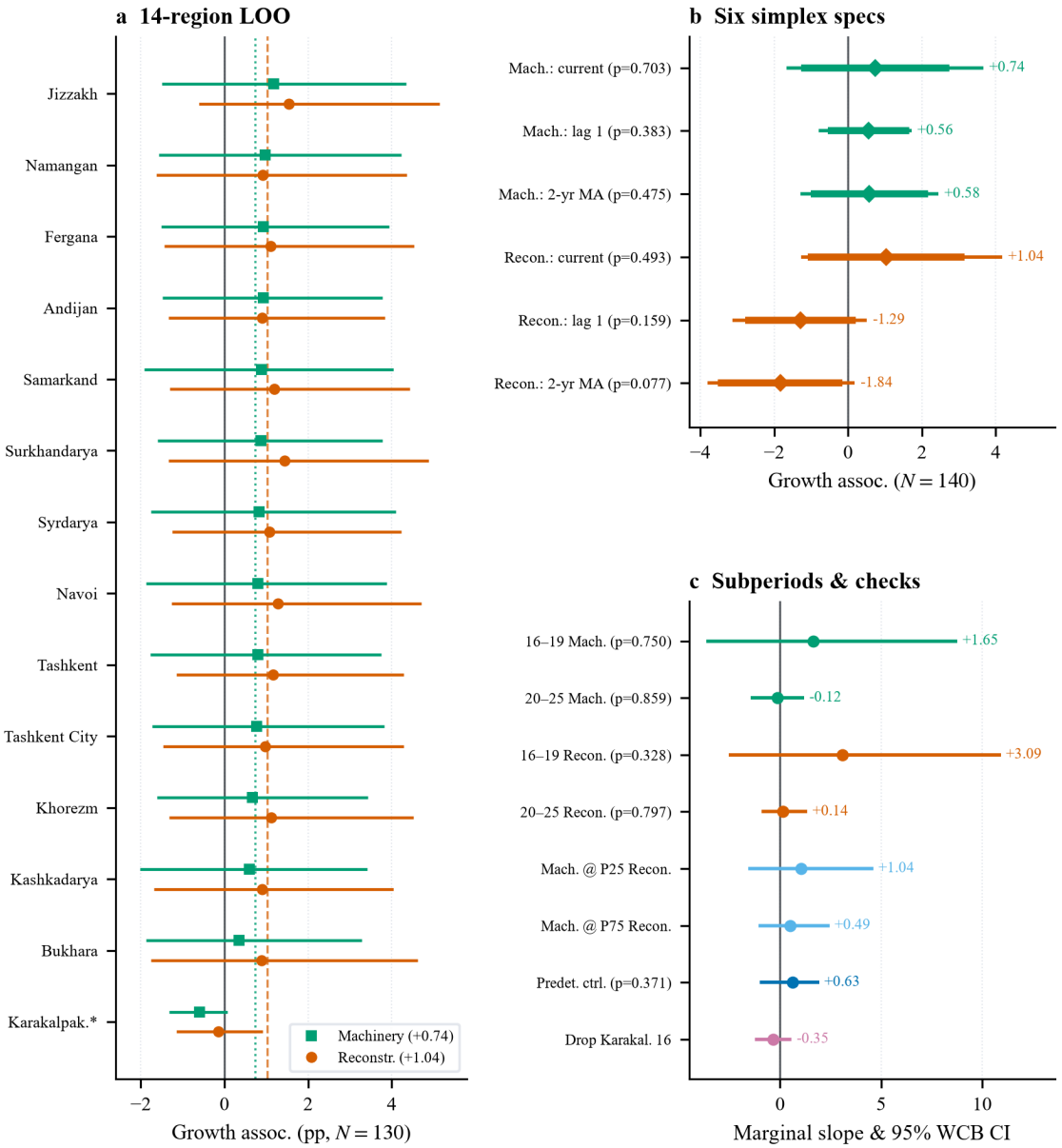


Figure 3. Leave-one-region-out sensitivity, primary simplex specifications, and subperiod, quantile-slope, and specification diagnostics for Uzbekistan.

Notes. Panel a plots 28 leave-one-region-out regressions ($N = 130$, $G = 13$ each) omitting one Uzbek region at a time for contemporaneous machinery (+10 percentage points vs. construction) and reconstruction (+10 percentage points vs. greenfield expansion) with 95 percent wild cluster bootstrap intervals; vertical lines mark full-sample estimates, and the asterisk denotes Karakalpakstan. Panel b displays the six primary specifications ($N = 140$) with 90 percent CR1 and 95 percent WCB intervals. Panel c plots 2016–2019 versus 2020–2025 subperiod slopes, marginal machinery slopes at the 25th (17.88 percent) and 75th (29.65 percent) reconstruction percentiles, predetermined-control lag-1 machinery ($N = 140$), and single-observation deletion of Karakalpakstan 2016 ($N = 139$) in commensurate units (pp per +10 pp), reporting the multiplicative interaction slope change separately.

Splitting the panel into 2016–2019 (+1.645, $p_{\mathrm{WCB}} = 0.7498$; +3.085, $p_{\mathrm{WCB}} = 0.3282$ for reconstruction) and 2020–2025 (−0.122, $p_{\mathrm{WCB}} = 0.8589$; +0.144, $p_{\mathrm{WCB}} = 0.7972$ for reconstruction) windows confirms the absence of a stable positive equipment-growth slope. Future composition leads at $t + 1$ (+0.776, $p_{\mathrm{WCB}} = 0.5657$, $[-2.001, 3.623]$) and $t + 2$ (−0.031, $p_{\mathrm{WCB}} = 0.9804$, $[-2.213, 2.698]$) do not detect statistically significant reverse-timing associations, while their wide intervals reflect finite 14-region precision and do not establish exact zero equivalence. Switching from narrow institutional own funds to broad own funds including household developers (Table 4, bottom rows) raises consolidated Kazakhstan's 2025 and 2026 Q1–Q3 budget coefficients to +17.534 (SE = 7.445, $p_{\mathrm{WCB}} = 0.0673$) and +16.577 (SE = 7.011, $p_{\mathrm{WCB}} = 0.0367$) while shifting Uzbekistan's 2025 budget estimate to −1.269 (SE = 55.829, $p_{\mathrm{WCB}} = 0.9842$), demonstrating how altering the omitted financing simplex base reshapes cross-sectional slopes.

6.2. Scope Limitations

Four methodological boundaries govern interpretation. First, regional capital-composition shares measure current-price, economy-wide fixed-capital outlays (aggregating manufacturing equipment with infrastructure, utilities, and real estate), so both non-industrial civil works and post-2017 tradable/non-tradable relative investment prices dilute physical industrial equipment signals. Second, our design estimates conditional compositional associations without exogenous treatment assignment, and official series lack regional industrial capital stocks or total factor productivity accounts. Third, under exact two-sided noncentral $t(13)$ power at 5 percent size, 80 percent minimum detectable effects across the six primary models equal 3.43, 1.90, and 2.71 percentage points of annual industrial growth per +10 percentage-point machinery reallocation (contemporaneous, one-year lag, and prior two-year mean) and 3.63, 2.57, and 2.90 percentage points per +10 percentage-point reconstruction reallocation; 14-cluster regional panels therefore rule out large equipment elasticities exceeding roughly 19 to 36 percentage points per full unit share while leaving smaller positive returns inside the bootstrap intervals admissible. Fourth, unavailable Uzbek regional housing-investment totals and differences between Uzbek industrial value-added indices and Kazakh gross industrial production volume indices bound direct cross-national regressions.

7. Conclusion and Policy Implications

Subnational capital-simplex panels across Uzbekistan (2000–2025) and boundary-harmonized regional benchmarks from Kazakhstan (2003–2026Q3) distinguish two empirical margins often conflated in Central Asian industrial policy. First, on the capital-input margin, reallocating 10 percentage points from greenfield expansion to plant reconstruction and modernization in Uzbekistan is associated with a 4.35 to 5.75 percentage-point higher regional machinery and equipment share ($p_{\mathrm{WCB}} = 0.0003$). Second, on the regional output margin, aggregate machinery and reconstruction shares exhibit no statistically resolved positive association with annual constant-price industrial value-added growth across all six primary simplex specifications ($p_{\mathrm{Holm}} \geq 0.4638$) or predetermined-control checks, with positive contemporaneous point estimates reversing negative when either Karakalpakstan's 10 region-years or its single 2016 observation is omitted, and lagged reconstruction slopes turning modestly negative consistent with retooling gestation.

These measurement and empirical findings inform two institutional priorities for statistical and economic ministries in Tashkent and Astana. First, statistical committees can substantially improve subnational capital accounting by publishing regional technological and reproduction matrices cross-tabulated by industry—separating manufacturing equipment installation from residential, municipal, and transport civil works—alongside deflated asset-class investment price indices and harmonized Uzbek regional housing-investment accounts. Second, because economy-wide regional machinery shares and on-budget financing ratios pool industrial modernization with non-industrial construction and omit off-budget quasi-

fiscal credit channels, aggregate regional equipment-share ratios are unreliable standalone performance indicators; complementing regional capital reporting with project-level tracking of commissioning lags, retooling downtime, and post-modernization industrial value-added would provide a firmer evidentiary basis for evaluating industrial credit programs.

Statements

Data availability. Subnational fixed-capital composition tables, financing breakdowns, constant-price industrial output series, and methodological standards used in this article are sourced from public releases of the National Statistics Committee of the Republic of Uzbekistan, the Interstate Statistical Committee of the Commonwealth of Independent States, and the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. All frozen source tables, harmonized Uzbek and Kazakh regional panels, and replication scripts are openly archived on Zenodo (https://doi.org/10.5281/zenodo.24199992).

AI declaration. Use of OpenAI Codex in this study was restricted to assisting with the translation and proofreading of Russian-, Uzbek-, and Kazakh-language primary materials, cleaning statistical series, and conducting implementation-level checks of the replication code. All authors independently verified the assisted outputs; every remaining stage of the research and writing was completed by the authors, who hold full responsibility for the article.

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