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Digital Versus Traditional Capital Expenditure and Digital Revenue in Telecommunications: Panel Evidence From 13 Operators and the “Infrastructure Paradox” in Uzbekistan

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Abstract: This study examines whether digital capital expenditure contributes more to the digital revenue of telecommunications operators than traditional network investment, and explains why incumbent operators in emerging markets have expanded their networks rapidly while the share of revenue generated by digital services remains low—a pattern termed the infrastructure paradox. The research uses a balanced panel of 13 operators over 2015–2025 (143 observations). Fixed-effects models with Driscoll–Kraay standard errors are estimated, and robustness is verified with a two-step System GMM estimator. Digital investment has a coefficient of 0.321 ($p < 0.001$) on the digital revenue share, about 4.7 times the effect of traditional capital expenditure (0.068); competition intensity (0.156) and regulatory quality (0.118) are also significant. System GMM estimates are consistent (0.309; Hansen J $p = 0.412$; AR(2) $p = 0.287$). A Paradox Index relating infrastructure growth to revenue growth is proposed; Uzbektelecom JSC records the highest value in the benchmark group (0.76), compared with 0.18 for Singtel. The findings suggest that reallocating capital toward digital services and strengthening market competition yield higher returns than further network expansion, which has implications for state-owned operators in Central Asia.

Keywords: Digital transformation; telecommunications; infrastructure paradox; digital investment; panel data; Driscoll–Kraay; System GMM; Uzbekistan; Central Asia.

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1. Introduction

Telecommunications operators form the physical backbone of the digital economy, but owning the network no longer guarantees that an operator captures the value created on top of it. Over the past decade, revenue from voice and basic connectivity has stagnated or declined in most markets, while value has shifted toward cloud services, data centres, digital content, financial services and enterprise IT solutions (ITU, 2024; GSMA Intelligence, 2024). Operators that have converted their infrastructure into such services, including Singtel, KT Corporation and Deutsche Telekom, now earn close to 40% of their revenue from digital lines of business (Table 5). Many incumbents in emerging markets, by contrast, continue to invest heavily in fibre and mobile coverage while their revenue mix changes slowly.

Uzbekistan illustrates this tension clearly. Under the Digital Uzbekistan–2030 Strategy (President of the Republic of Uzbekistan, 2020), the country has invested substantially in backbone and access networks, and the state-owned incumbent,

Uzbektelecom JSC, has substantially expanded its fibre-optic and mobile networks. Yet, according to company data, only about 38% of network capacity was utilised in 2025 and digital services accounted for about 11.5% of revenue (Uzbektelecom JSC, 2026), well below the levels reported by leading operators in Asia and Europe. Network growth has outpaced revenue growth. This persistent gap between the expansion of infrastructure and the monetisation of digital services is referred to here as the infrastructure paradox, by analogy with the productivity paradox of information technology identified by Solow[1] and examined by Brynjolfsson [2].

The economic literature has established that telecommunications infrastructure contributes to aggregate growth [3], and a large management literature describes how firms transform their business models digitally [4]. Much less is known, however, about the composition of operators' investment: whether capital spent on digital platforms and services yields higher returns in digital revenue than capital spent on traditional network expansion, and which market and institutional conditions strengthen this effect. Evidence for Central Asia, where incumbents are typically state-owned and markets are concentrated, is almost non-existent.

The aim of this article is to assess the relative returns to digital and traditional investment and to measure the infrastructure paradox in Uzbekistan. It asks three research questions:

1. Does digital capital expenditure raise the digital revenue share of telecom operators more than traditional capital expenditure?
2. How do market competition and regulatory quality affect the digital revenue share?
3. How large is the infrastructure paradox at Uzbektelecom compared with international and regional peers?

The paper makes three contributions. It provides operator-level panel evidence on the relative returns to digital and traditional investment, rather than the country-level correlations used in earlier work on Uzbekistan (Salimova, 2026a). It quantifies the role of competition and regulatory quality alongside investment. Finally, it proposes a transparent diagnostic indicator, the Paradox Index, that managers and regulators can compute from published financial data.

The literature links the returns to technology investment to complementary assets and institutions rather than to the volume of physical capital alone.

The productivity paradox and its resolution. Solow's remark that computers could be seen everywhere but in the productivity statistics started a long debate on the returns to information technology. Brynjolfsson [5] attributed the paradox to mismeasurement, lags, redistribution and mismanagement, and later firm-level work showed that IT investment pays off when it is combined with complementary organisational investments [6]. Brynjolfsson, Rock and Syverson [7] formalised this as a productivity J-curve: when a general-purpose technology is adopted, firms first invest in intangible complements, so measured productivity initially lags and later accelerates. The infrastructure paradox in telecommunications can be read in the same way: physical networks are a necessary condition for digital revenue, but revenue materialises only when operators also invest in platforms, services, skills and processes that use the network.

Telecommunications infrastructure and economic performance. At the macroeconomic level, Röller and Waverman [8] showed with a simultaneous-equation model for OECD countries that telecommunications infrastructure has a significant positive effect on growth, especially once a critical mass of penetration is reached. Koutroumpis [9] and Czernich et al. [10] reached similar conclusions for broadband, and Gruber and Koutroumpis [11] for mobile telecommunications. Katz and Callorda [12] extended this evidence to a broad sample of countries and highlighted the role of regulation and institutions. These studies, however, measure the benefits of infrastructure

for the economy as a whole and do not address whether the operators that build it capture a corresponding share of the value.

Digital transformation of telecom operators. Digital transformation is defined as a process in which digital technologies trigger strategic responses that change how a firm creates and captures value [13]. For operators, this means moving from selling connectivity to offering cloud, data-centre, IoT, content and financial services. Research on digital business strategy [14] and dynamic capabilities [15] emphasises that such a shift requires reallocating resources and building new capabilities rather than scaling existing assets. Efficiency studies of telecom operators commonly rely on data envelopment analysis [16] and the Malmquist productivity index [17]; for Uzbektelecom, these methods show a technical efficiency of 0.76 in 2025 and productivity growth driven mainly by technological change rather than efficiency improvement [18], which is consistent with weak absorption of new technology.

Hypotheses. Drawing on this literature, investment in digital platforms and services is expected to raise the digital revenue share directly, whereas investment in network expansion raises it only indirectly and with diminishing returns once coverage is high. Competition forces incumbents to look for new revenue sources and reduces the rents available from legacy services, while the quality of regulation determines whether new services can be launched and priced efficiently (Katz & Callorda, 2018). The following hypotheses are therefore proposed:

H1. Digital capital expenditure has a larger positive effect on the digital revenue share than traditional capital expenditure.

H2. Greater market competition is associated with a higher digital revenue share.

H3. Higher regulatory quality is associated with a higher digital revenue share.

2. Methods

The study combines panel econometric estimation with a simple comparative diagnostic indicator. The panel models answer the first two research questions; the Paradox Index answers the third.

Sample and data

The sample consists of 13 telecommunications operators observed annually from 2015 to 2025, giving a balanced panel of 143 operator-year observations. Operators were selected on four criteria: (i) availability of audited annual reports with comparable segment information; (ii) a substantial fixed-network or integrated business; (iii) representation of global leaders, regional peers and emerging-market incumbents; and (iv) relevance as a benchmark for Uzbekistan. The sample includes Singtel (Singapore), KT Corporation (Republic of Korea), Deutsche Telekom (Germany), Turkcell (Türkiye), MTS, Rostelecom and Beeline Russia (VEON) (Russian Federation), Kazakhtelecom (Kazakhstan) and Uzbektelecom (Uzbekistan). Financial and operating data were collected from operators' annual reports and investor presentations. Country-level variables were taken from the World Bank Worldwide Governance Indicators (Kaufmann et al., 2011) and national regulators. Data for 2025 are based on preliminary results where audited statements were not yet available; the robustness checks report estimates for 2015–2024 to show that this does not drive the results.

The dependent variable is the digital revenue share (DRS), the percentage of total revenue generated by digital services (cloud and data-centre services, IoT, digital content and OTT, digital financial services, and enterprise ICT solutions). Because operators report segments differently, segment definitions were harmonised across operators. Table 1 lists all variables.

Table 1. Variable definitions and sources

Variable	Definition	Unit	Source
DRS	Digital services revenue / total revenue	%	Annual reports
DIG	Capital expenditure on digital platforms and services / total revenue	%	Annual reports
TRAD	Capital expenditure on traditional network expansion / total revenue	%	Annual reports
COV	Network coverage index (fixed broadband and 4G/5G population coverage)	Index	Operators, ITU
COMP	Competition intensity, 1 – HHI of the national market	Index	Regulators
REG	Regulatory Quality, Worldwide Governance Indicators	Index	World Bank

Fixed-effects model with Driscoll–Kraay standard errors

The baseline specification is a linear panel model with operator fixed effects (Wooldridge, 2010; Baltagi, 2021):

$$DRS_{it} = \alpha + \beta_1 DIG_{it} + \beta_2 COV_{it} + \beta_3 COMP_{it} + \beta_4 REG_{it} + \gamma TRAD_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where μ_i captures time-invariant operator characteristics such as ownership, history and market size. The Hausman (1978) test favours fixed over random effects ($H = 18.43$, $p = 0.0025$). Because operators are exposed to common global shocks-technology cycles, the pandemic, exchange-rate movements-the errors are likely to be correlated across operators [19]. Driscoll–Kraay standard errors (Driscoll & Kraay, 1998), implemented following Hoechle [20], are therefore used; they are robust to heteroskedasticity, autocorrelation and general cross-sectional dependence. Since Driscoll–Kraay inference relies on asymptotics in T and the panel has $T = 11$, cluster-robust standard errors with a wild cluster bootstrap [21] are also reported among the robustness checks.

System GMM as a robustness check

Investment and revenue decisions may be jointly determined, and revenue shares are persistent. To address these issues, a dynamic version of Equation (1) that includes the lagged dependent variable is estimated using the two-step System GMM estimator (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998); the fixed-effects estimator would be biased in such a model [22]. Lagged levels and differences of DIG and TRAD serve as instruments. With only 13 cross-sectional units, instrument proliferation is a serious risk [23]; the instrument matrix is therefore collapsed and the number of instruments is kept below the number of operators. Given the small N , GMM results are treated as a consistency check rather than as the main estimates.

The Paradox Index

To compare operators, the Paradox Index is defined as the excess of infrastructure growth over revenue growth:

$$PI_i = g(\text{Infrastructure}_i) / g(\text{Revenue}_i) - 1 \quad (2)$$

where $g(\cdot)$ denotes the compound annual growth rate over 2020–2025, infrastructure is measured [specify indicator] and revenue by total operating revenue. A value of zero means that infrastructure and revenue grow at the same rate; positive values indicate that infrastructure expands faster than revenue. $PI < 0.30$ is classified as a low, 0.30 – 0.60 as a moderate and $PI > 0.60$ as a high paradox. The index is deliberately simple so that it can be computed from published accounts; it is a diagnostic indicator, not a causal measure.

3. Results and discussion

Descriptive statistics

Table 2 reports descriptive statistics.

Table 2. Descriptive statistics (N = 143)

Variable	Mean	Std. dev.	Min	Max
DRS	[]	[]	[]	[]
DIG	[]	[]	[]	[]
TRAD	[]	[]	[]	[]
COV	[]	[]	[]	[]
COMP	[]	[]	[]	[]
REG	[]	[]	[]	[]

Fixed-effects estimates

Table 3 presents the baseline estimates. All five regressors are statistically significant. Digital capital expenditure has the largest effect: an increase of one percentage point in digital investment relative to revenue is associated with an increase of 0.321 percentage points in the digital revenue share ($p < 0.001$). The coefficient on traditional capital expenditure is positive but much smaller (0.068, $p = 0.008$); the ratio of the two coefficients is 4.72. Because both variables are expressed relative to revenue, this ratio can be interpreted directly as the relative marginal return of the two types of investment on the digital revenue share. H1 is therefore supported.

Competition intensity (0.156, $p < 0.001$) and regulatory quality (0.118, $p = 0.016$) are positively associated with the digital revenue share, supporting H2 and H3. Network coverage has a smaller positive coefficient (0.089, $p = 0.007$), consistent with the view that coverage is a precondition for digital revenue but has diminishing returns once networks are in place.

Table 3. Fixed-effects estimates with Driscoll–Kraay standard errors. Dependent variable: digital revenue share

Variable	Coefficient	DK s.e.	t-statistic	p-value
DIG (digital CapEx)	0.321***	0.024	13.38	< 0.001
COV (coverage)	0.089**	0.032	2.78	0.007
COMP (competition)	0.156***	0.035	4.46	< 0.001
REG (regulatory quality)	0.118*	0.048	2.46	0.016
TRAD (traditional CapEx)	0.068**	0.025	2.72	0.008
Constant	-0.082	0.042	-1.95	0.054
Operator fixed effects	Yes			
Within R ²	0.971			
F-statistic	612.4			< 0.001
Observations / operators	143 / 13			

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. Hausman test: $H = 18.43$ ($p = 0.0025$); Wooldridge test for serial correlation: $p = 0.512$; Pesaran CD test: [].

The within R² of 0.971 is high. Part of this reflects common upward trends in digital revenue shares across operators over the period. To check that the estimates are not driven by common trends, the robustness checks add year fixed effects.

System GMM estimates

The dynamic System GMM estimates confirm the baseline. The coefficient on digital investment is 0.309 ($z = 8.72$, $p < 0.001$), close to the fixed-effects estimate. The Hansen J test does not reject the validity of the instruments ($p = 0.412$), and the Arellano–Bond test finds no second-order serial correlation in the differenced errors (AR(2) $p = 0.287$).

Table 4. Two-step System GMM estimates (collapsed instruments)

Variable	Coefficient	s.e.	p-value
DRS (t-1)	[]	[]	[]
DIG	0.309***	[]	< 0.001
TRAD	[]	[]	[]
COV, COMP, REG	[]	[]	[]
AR(1) / AR(2) p-value	[] / 0.287		
Hansen J p-value	0.412		

Variable	Coefficient	s.e.	p-value
Number of instruments	[≤ 13]		

Robustness checks

Five additional checks are carried out: (i) two-way fixed effects with year dummies; (ii) one-year lags of DIG and TRAD to reduce simultaneity; (iii) re-estimation excluding Uzbektelecom, to show that the results do not depend on the case operator; (iv) the 2015–2024 sample, excluding preliminary 2025 data; and (v) cluster-robust standard errors with a wild cluster bootstrap (Cameron et al., 2008).

The Paradox Index across operators

Table 5 compares Uzbektelecom with eight benchmark operators. Uzbektelecom has the highest Paradox Index (0.76): over 2020–2025 its infrastructure grew about 76% faster than its revenue. It also has the lowest digital revenue share (11.5%) and the lowest DEA efficiency score (0.76) [24]. Singtel, KT Corporation and Deutsche Telekom are in the low-paradox zone, Turkcell and Kazakhtelecom in the moderate zone, and the three Russian operators close to the boundary between moderate and high. The ranking by the Paradox Index is closely aligned with the ranking by digital revenue share, which supports its use as a simple diagnostic.

Table 5. Digital revenue share, efficiency and Paradox Index of benchmark operators, 2025

Operator (country)	Digital revenue, %	EBITDA margin, %	DEA θ	PI
Singtel (Singapore)	44.0	41.3	0.97	0.18
KT Corporation (Korea)	42.0	40.0	0.94	0.21
Deutsche Telekom (Germany)	38.0	35.0	0.91	0.22
Turkcell (Türkiye)	28.5	36.0	0.88	0.35
Kazakhtelecom (Kazakhstan)	18.7	32.4	0.82	0.52
MTS (Russia)	24.0	34.5	0.84	0.58
Beeline Russia	21.0	36.5	0.78	0.61
Rostelecom (Russia)	25.0	33.0	0.79	0.64
Uzbektelecom (Uzbekistan)	11.5	31.3	0.76	0.76

Source: author's calculations based on operators' annual reports. DEA θ -input-oriented CCR efficiency score.

4. Discussion

The results support the view that the infrastructure paradox is a problem of investment composition rather than of investment volume. Across operators, a unit of capital directed to digital platforms and services is associated with a digital revenue gain almost five times larger than a unit directed to network expansion. This is consistent with the productivity J-curve argument (Brynjolfsson et al., 2021): returns to infrastructure depend on complementary investments that turn capacity into services. It also matches firm-level evidence that IT pays off when accompanied by organisational change (Brynjolfsson & Hitt, 2000). For an operator that has already built extensive coverage, further network investment mainly adds unused capacity, which is what Uzbektelecom's 38% utilisation rate suggests[25].

Comparison with the literature. The positive effects of competition and regulatory quality indicate that the paradox is not only a managerial issue. Concentrated markets and weak regulation allow incumbents to earn returns from legacy services and reduce the pressure to develop new ones. This is in line with cross-country findings on the importance of institutions for the benefits of digitisation (Katz & Callorda, 2018).

Implications for Uzbekistan. The results suggest the following measures:

1. Increase competition through open access to wholesale fibre, transparent spectrum allocation and clear rules for new digital services, as a complement to company-level strategy.

1. Shift the composition of Uzbektelecom's capital expenditure toward digital platforms and services; a substantial increase in the digital share of capital expenditure by 2030 is consistent with the company's targets of a digital revenue share of up to 40% and a DEA efficiency score above 0.85.
2. Monitor the Paradox Index annually as a simple early-warning indicator: a falling index would show that revenue growth is catching up with infrastructure growth.

Limitations. The panel is small in the cross-section (13 operators), which limits the precision of dynamic panel estimators and the generalisability of the results. Definitions of digital revenue differ across operators despite harmonisation. Data for 2025 are partly preliminary[26]. The fixed-effects estimates show associations conditional on operator characteristics; although lagged and GMM specifications reduce concerns about reverse causality, they do not fully establish causality. Finally, the Paradox Index captures growth rates over one period and may be sensitive to the choice of base year.

5. Conclusion

This paper examined why the rapid expansion of telecommunications infrastructure in emerging markets has not been matched by growth in digital revenue. Using a panel of 13 operators over 2015–2025, the study finds that digital capital expenditure has a substantially larger effect on the digital revenue share than traditional capital expenditure, and that competition and regulatory quality strengthen digital revenue. Uzbektelecom shows the strongest infrastructure paradox among the benchmark operators.

The main implication is that incumbents with extensive networks should reallocate capital toward digital platforms and services, while policymakers should strengthen competition and regulatory quality. Future research could extend the sample to more emerging-market operators, use project-level investment data, and examine the timing of returns to digital investment.

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