GSMA Intelligence

Assessing operator scale in the mobile data era in Latin America (technical annex)

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Contents

Econometrics estimation outputs

This annex documents the methodological foundations of the empirical analysis presented in the main report. It sets out the econometric specifications, data sources, sample coverage and estimation strategies in sufficient detail for the reader to follow and assess the findings.

1. Data sources and sample coverage

Countries and time period

The analysis draws on a quarterly operator panel dataset covering 18 Latin American markets from Q1 2010 to Q4 2024. The dataset covers up to 58 operators over the period analysed. As expected, it is an unbalanced panel, reflecting both operator entry and exit events.

Table 1: Countries included in the analysis

Source: GSMA Intelligence

Argentina	Bolivia
Brazil	Chile
Colombia	Costa Rica
Dominican Republic	Ecuador
El Salvador	Guatemala
Honduras	Nicaragua
Mexico	Paraguay
Panama	Uruguay
Peru	Venezuela

Variables and data sources

Table 2 summarises the outcome variables, market structure indicators and controls used across the ordinary least squares (OLS), instrumental variables (IV) and difference-in-differences (DiD) models. Monetary variables are expressed in real US dollars. Speed variables are sourced from Ookla Speedtest Intelligence®.

Table 2: Variable definitions and sources

Source: GSMA Intelligence

Variable	Definition	Source
Capex per connection (log)	Log of operator-level capex divided by total country connections	GSMA Intelligence
Total capex, real USD (log)	Log of total operator capex deflated to real USD	GSMA Intelligence
Weighted download speed (Mbps)	Download speed weighted by mobile technology tests (2G, 3G, 4G, and 5G).	GSMA Intelligence, Ookla
Weighted upload speed (Mbps)	Upload speed weighted by mobile technology tests (2G, 3G, 4G, and 5G).	GSMA Intelligence, Ookla
Latency (ms)	Overall latency measured in milliseconds	GSMA Intelligence, Ookla
4G population coverage (%)	Share of population covered by 4G networks	GSMA Intelligence
5G population coverage (%)	Share of population covered by 5G networks	GSMA Intelligence
ARPU, real USD	Average revenue per user in real US dollars	GSMA Intelligence
ARPU, real USD (log)	Logarithm of real ARPU	GSMA Intelligence
Revenue per MB, real USD (log)	Unit cost of mobile data; removes consumption volume effects	GSMA Intelligence
HHI	Sum of squared operator connection shares × 10,000	GSMA Intelligence
HHI^2	Squared HHI; tests for the inverted-U relationship	GSMA Intelligence
Number of operators	Count of active MNOs in the market	GSMA Intelligence

EBITDA margin (%)	Operator EBITDA as % of revenue; weighted to market level	GSMA Intelligence
EBITDA margin²	Squared EBITDA margin; tests for non-linearity	GSMA Intelligence
C2	Combined connection share of the two largest operators	GSMA Intelligence
GDP per capita (log)	Log of real PPP-adjusted GDP per capita	World Bank, IMF
Rural population (%)	Share of population in rural areas	World Bank
Spectrum holdings (MHz)	Licensed spectrum per operator and country	GSMA Intelligence
Data traffic per subscription	MB of data per subscriber per month	GSMA Intelligence

Measures of market structure and scale

Four complementary measures of operator scale and market concentration are used, each capturing a different dimension of market structure:

- **Herfindahl–Hirschman Index (HHI):** The primary concentration measure, calculated as the sum of squared operator connection shares multiplied by 10,000. Values range from 0 to 10,000.
- **Number of operators:** The count of active MNOs in a market. MNOs are considered once they reach a 5% market share and/or hold national spectrum.
- **EBITDA margin (%):** Operator-level profitability, serving as a proxy for the financial ability to sustain investment, aggregated to the market level as a weighted average.
- **C2:** The combined connection share of the two largest operators.

2. Ordinary least squares and instrumental variables analysis

Baseline specification

The baseline OLS model estimated throughout Chapter 3 of the main report is:

$$ln(CAPEX_{it}) = \alpha + \beta_1 \cdot Scale_{it} + \beta_2 \cdot Scale_{it}^2 + \gamma \cdot X_{it} + \delta_i + \lambda_t + \varepsilon_{it}$$

Where i indexes operators, t indexes quarters and $Scale_{it}$ is alternately HHI, number of operators, EBITDA margin or C2. The control vector X_{it} includes spectrum holdings, GDP per capita (log), rural population share and – in post-2018 specifications – data traffic per subscription. Operator fixed effects δ_i absorb time-invariant heterogeneity; quarter fixed effects λ_t absorb common shocks. Standard errors are clustered at the country level throughout. The same structure applies to quality and price models, with the relevant dependent variable replacing ln(CAPEX). The squared term is retained where the non-linearity test is statistically significant.

Temporal subsamples

OLS models are estimated across three subsamples: (i) the full period (Q1 2010 – Q4 2024); (ii) the pre-2018 voice and SMS era; and (iii) the post-2018 mobile data era. The 2018 cut-off reflects the structural shift in Latin American market economics, with 4G/5G at majority adoption and ARPU in sustained decline.

Summary of OLS results

Table 3 summarises the direction and significance of OLS results across outcomes, scale measures and time periods.

Table 3: Summary of OLS results: direction and significance by outcome

Source: GSMA Intelligence

Outcome	Scale Measure	Full Period	Pre-2018	Post-2018
Capex per connection (log)	HHI	+ (**)	Not sig.	+ (***)
Capex per connection (log)	Number of operators	– (**)	Not sig.	– (***)
Capex per connection (log)	EBITDA margin	+ (***)	+ (**)	+ (***)
Capex per connection (log)	C2	+ (*)	Not sig.	+ (*)
Download speed	HHI	+ (**)	Not sig.	+ (***)
Upload speed	HHI	+ (**)	Not sig.	+ (**)
4G/5G coverage	HHI	n/a	n/a	+ (***)
ARPU (real USD)	HHI	Not sig.	+ (*)	Not sig.
Revenue per MB (log)	HHI	Not sig.	+ (*)	Not sig.
PPP basket prices	HHI	Not sig.	Not sig.	Not sig.

*10%, **5%, ***1%

Note: '+' indicates positive and significant; '–' indicates negative and significant; 'Not sig.' indicates not significant at 10%.Standard errors clustered at country level. For 4G and 5G coverage the pre/post-2018 split is not applied as these technologies only became relevant in the region after 2018.

OLS regressions underlying the main report

OLS: operator scale (HHI) with capex and quality

The regressions underlying the relationship between HHI and capex per connection, download speeds and upload speeds are reported here. These are associated with the plots illustrating the inverted-U relationship between HHI and the outcome variables correspond to the post-2018 estimation period in Chapter 3 of the main report.

Table 4: OLS results: capex per connection (log) and capex, real USD (log)

Source: GSMA Intelligence

	Capex per connection (log)						Capex, real USD (log)					
Variables	**(1) All**	**(2) All sq.**	**(3) Pre**	**(4) Pre sq.**	**(5) Post**	**(6) Post sq.**	**(7) All**	**(8) All sq.**	**(9) Pre**	**(10) Pre sq.**	**(11) Post**	**(12) Post sq.**
HHI	0.0002**	0.0008	0.0000	−0.0000	0.0003**	0.0019**	0.0002**	0.0005	−0.0001	−0.0005	0.0002**	0.0017***
	(0.0001)	(0.0006)	(0.0001)	(0.0006)	(0.0001)	(0.0007)	(0.0001)	(0.0005)	(0.0001)	(0.0006)	(0.0001)	(0.0005)
HHI²	—	−0.0000	—	0.0000	—	−0.0000**	—	−0.0000	—	0.0000	—	−0.0000**
		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Rural share	0.0486	0.0608	0.1946*	0.1942**	0.0900	0.0779	0.0574	0.0642	0.1286	0.1221	0.1031**	0.0927**
	(0.0371)	(0.0425)	(0.0928)	(0.0895)	(0.0531)	(0.0470)	(0.0357)	(0.0396)	(0.1143)	(0.1101)	(0.0445)	(0.0411)
GDP	0.5177	0.9264	1.5121**	1.5032*	0.8940	0.9233	0.8432	1.0694	1.8642*	1.7299*	0.8578	0.8832
	(0.8736)	(0.6345)	(0.7015)	(0.7592)	(1.0036)	(0.8591)	(0.7744)	(0.6357)	(0.8900)	(0.9767)	(0.8477)	(0.7275)
Spectrum	0.0001	0.0001	−0.0011	−0.0011	−0.0000	−0.0003	0.0002	0.0002	−0.0006	−0.0006	0.0001	−0.0002
	(0.0005)	(0.0005)	(0.0008)	(0.0008)	(0.0005)	(0.0003)	(0.0004)	(0.0004)	(0.0009)	(0.0009)	(0.0004)	(0.0003)
Traffic/connection	—	—	—	—	0.0000	0.0000	—	—	—	—	0.0000	0.0000**
					(0.0000)	(0.0000)					(0.0000)	(0.0000)
Constant	−6.9028	−12.1833*	−19.0275**	−18.8823*	−11.7762	−14.8140*	6.5573	3.6351	−3.7458	−1.5493	5.0373	2.4014
	(8.8895)	(6.6850)	(8.5486)	(9.2639)	(9.7449)	(8.1760)	(8.0608)	(6.8161)	(10.8529)	(11.9393)	(8.4004)	(7.1727)
Observations	2,248	2,248	830	830	1,418	1,418	2,248	2,248	830	830	1,418	1,418
R-squared	0.2372	0.2382	0.2351	0.2351	0.2248	0.2281	0.6044	0.6045	0.6365	0.6366	0.5964	0.5977

*p<0.10, **p<0.05, ***p<0.01

Note: Standard errors clustered at the country level in parentheses. Country and quarter fixed effects included in all specifications. Traffic per connection included in post-2018 specifications only.

Table 5: OLS results: download speeds (Mbps) and upload speeds (Mbps)

Source: GSMA Intelligence

	Download speeds (Mbps)						Upload speeds (Mbps)					
Variables	**(1) All**	**(2) All sq.**	**(3) Pre**	**(4) Pre sq.**	**(5) Post**	**(6) Post sq.**	**(7) All**	**(8) All sq.**	**(9) Pre**	**(10) Pre sq.**	**(11) Post**	**(12) Post sq.**
HHI	0.0125*	0.1113**	−0.0003	−0.0019	0.0160	0.2431**	0.0007	0.0070	−0.0009	−0.0036	0.0006	0.0189**
	(0.0068)	(0.0435)	(0.0015)	(0.0073)	(0.0142)	(0.0927)	(0.0006)	(0.0042)	(0.0009)	(0.0048)	(0.0010)	(0.0073)
HHI²	—	−0.0000**	—	0.0000	—	−0.0000**	—	−0.0000	—	0.0000	—	−0.0000**
		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Rural share	0.1203	2.3639	1.2418	1.2159	4.0586	1.9588	0.0086	0.1504	1.3207*	1.2766*	−0.6373	−0.8061

	(2.6897)	(2.9690)	(1.4090)	(1.3908)	(5.3686)	(5.9780)	(0.2660)	(0.2809)	(0.7371)	(0.7221)	(0.6424)	(0.6378)
GDP	6.8295	84.1858*	15.7472	15.1746	60.4917	70.8145	8.2322	13.1201*	18.4666***	17.4923***	11.1958	12.0256
	(43.0192)	(48.1248)	(9.5984)	(9.3923)	(82.6692)	(69.1297)	(6.1960)	(6.1890)	(4.0604)	(4.0841)	(8.6462)	(7.9826)
Spectrum	0.1121**	0.1001***	−0.0022	−0.0020	0.1077**	0.0678*	0.0053	0.0046*	0.0012	0.0016	0.0073**	0.0041
	(0.0407)	(0.0297)	(0.0102)	(0.0097)	(0.0457)	(0.0369)	(0.0032)	(0.0023)	(0.0073)	(0.0072)	(0.0034)	(0.0025)
Traffic/conn.	—	—	—	—	0.0020**	0.0028***	—	—	—	—	0.0000	0.0001
					(0.0009)	(0.0008)					(0.0001)	(0.0001)
Constant	−138.6630	−1,126.6074*	−173.3181	−164.0668	−770.4615	−1,236.1448	−76.3926	−138.8184**	−205.7570***	−190.0169***	−88.5229	−125.9582
	(452.6850)	(560.7582)	(115.3843)	(114.9867)	(874.7587)	(785.2017)	(62.4389)	(64.8837)	(55.0053)	(57.9754)	(88.9620)	(83.6380)
Observations	2,340	2,340	877	877	1,463	1,463	2,340	2,340	877	877	1,463	1,463
R-squared	0.5556	0.5833	0.5196	0.5197	0.5413	0.5823	0.6790	0.6827	0.5479	0.5485	0.4843	0.5023

*p<0.10, **p<0.05, ***p<0.01

Note: Standard errors clustered at the country level in parentheses. Country and quarter fixed effects included. Traffic per connection included in post-2018 specifications only.

OLS: coverage and price outcomes

The regressions below refer to the analysis of 4G and 5G population coverage presented in Chapter 3.1 of the main report. Coverage models are estimated for the post-2018 subsample only, as these technologies only became material in Latin American markets after that point. The positive and significant HHI coefficient in the 5G specification – alongside the significant negative coefficient on the number-of-operators measure – confirms that greater operator scale is associated with faster 5G rollout.

Table 6: OLS results: 4G and 5G population coverage (post-2018 subsample)

Source: GSMA Intelligence

	4G coverage				5G coverage			
Variables	**(1) HHI**	**(2) HHI sq.**	**(3) Number of operators**	**(4) Number of operators**	**(5) HHI**	**(6) HHI sq.**	**(7) Number of operators**	**(8) Number of operators**
Scale	0.0028	0.0158	−6.4735**	−2.9014**	0.0035	0.0903**	−11.2105**	−11.6022**
	(0.0025)	(0.0127)	(2.8327)	(1.3187)	(0.0056)	(0.0325)	(4.0579)	(4.2819)
Scale²	—	−0.0000	—	—	—	−0.0000**	—	—
		(0.0000)				(0.0000)		
Rural share	−1.6413	−1.4234	−2.3223	−5.2588***	−2.6013	−5.2617	−3.8276	−0.0423
	(2.6252)	(2.5462)	(2.4205)	(1.3526)	(5.0523)	(5.0913)	(5.7457)	(8.0397)
GDP	−25.27	−18.12	−33.92	5.74	192.91**	152.95	146.09	164.89
	(36.53)	(33.92)	(38.57)	(18.12)	(76.14)	(104.83)	(113.30)	(137.51)
Spectrum	−0.0216*	−0.0216**	−0.0184*	−0.0021	0.0230*	0.0083	0.0105*	0.0157***
	(0.0104)	(0.0098)	(0.0092)	(0.0062)	(0.0117)	(0.0054)	(0.0051)	(0.0038)
Traffic/connection	—	—	—	−0.0007**	—	—	—	0.0012***
				(0.0003)				(0.0003)
Observations	1,987	1,987	1,987	1,332	259	259	259	259
R-squared	0.6978	0.6983	0.6999	0.4216	0.6278	0.6346	0.6317	0.6388

*p<0.10, **p<0.05, ***p<0.01

Note: Standard errors clustered at the country level in parentheses. Country and quarter fixed effects included in all specifications. Traffic per connection included where data availability permits in the post-2018 period.

The regressions below apply the same baseline OLS specification to consumer prices, including ARPU (real USD) and revenue per MB (real USD, log). These results reinforce Figure 21 of the main report. The key finding is that, in the post-2018 period, the HHI coefficient on ARPU is not statistically significant and the coefficient on revenue per MB is negative or insignificant across specifications. There is therefore no evidence of upward price pressure from increases in operator scale or market concentration during the data era.

Table 7: OLS results: ARPU (real USD) and revenue per MB

Source: GSMA Intelligence

	ARPU (real USD)						Revenue per MB (log)					
Variables	**(1) All**	**(2) All sq.**	**(3) Pre**	**(4) Pre sq.**	**(5) Post**	**(6) Post sq.**	**(7) All**	**(8) All sq.**	**(9) Pre**	**(10) Pre sq.**	**(11) Post**	**(12) Post sq.**
HHI	0.0012**	0.0057**	0.0038***	0.0052	−0.0004*	0.0029	−0.0000**	−0.0000	0.0000**	−0.0000	−0.0000**	0.0000
	(0.0005)	(0.0025)	(0.0010)	(0.0087)	(0.0002)	(0.0021)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
HHI²	—	−0.0000*	—	−0.0000	—	−0.0000	—	0.0000	—	0.0000	—	−0.0000
		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)
Rural share	−0.1021	−0.0014	0.0987	0.1234	0.3456	0.3216	0.0016	0.0016	0.0005	0.0006	0.0017**	0.0017**
	(0.3049)	(0.2778)	(1.3795)	(1.4293)	(0.2297)	(0.2046)	(0.0019)	(0.0019)	(0.0051)	(0.0051)	(0.0007)	(0.0007)
GDP	0.1804	3.5448	13.6328	14.1418	2.1360	2.1944	0.0234	0.0233	−0.0766	−0.0650	0.0120	0.0120*
	(5.1884)	(4.8973)	(16.5946)	(16.8665)	(2.3544)	(2.1703)	(0.0167)	(0.0169)	(0.0581)	(0.0668)	(0.0070)	(0.0068)
Spectrum	−0.0008	−0.0014	0.0050	0.0048	0.0004	−0.0002	0.0000**	0.0000**	0.0000	0.0000	0.0000**	0.0000**
	(0.0013)	(0.0013)	(0.0078)	(0.0083)	(0.0010)	(0.0008)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Traffic/connection	—	—	—	—	−0.0002**	−0.0001**	—	—	—	—	0.0000***	0.0000**
					(0.0000)	(0.0000)					(0.0000)	(0.0000)
Observations	2,248	2,248	830	830	1,418	1,418	1,834	1,834	416	416	1,418	1,418
R-squared	0.4155	0.4173	0.3343	0.3344	0.4776	0.4780	0.7750	0.7750	0.7401	0.7406	0.8071	0.8073

*p<0.10, **p<0.05, ***p<0.01

Note: Standard errors clustered at country level in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Country and quarter fixed effects included.

Consistent with these results, the tariffs baskets analysis, which is conducted at the country level, shows similar patterns. Across all metrics, the post-2018 HHI and C2 coefficients are either not statistically significant or negative. This is aligned with the conclusions in Chapter 3 of the main report: there is no evidence that greater operator scale or market concentration leads to higher consumer prices in the mobile data era.

Table 8: OLS results: PPP-adjusted basket prices (entry-level and high-usage baskets)

Source: GSMA Intelligence

	Entry-level basket						High-usage basket					
Variables	**(1) All (HHI)**	**(2) All (C2)**	**(3) Pre (HHI)**	**(4) Pre (C2)**	**(5) Post (HHI)**	**(6) Post (C2)**	**(7) All (HHI)**	**(8) All (C2)**	**(9) Pre (HHI)**	**(10) Pre (C2)**	**(11) Post (HHI)**	**(12) Post (C2)**
Scale	−0.0011	−0.0730	−0.0011	−0.1477	−0.0009	−0.0844**	−0.0007	−0.0799	−0.0020	−0.2569	0.0006	0.0139
	(0.0011)	(0.0711)	(0.0015)	(0.1092)	(0.0005)	(0.0379)	(0.0016)	(0.1131)	(0.0028)	(0.1984)	(0.0012)	(0.0826)
Rural share	0.075	0.026	1.761	1.386	−1.494**	−1.487**	0.029	−0.010	1.422	0.795	−1.204	−1.159
	(0.734)	(0.751)	(1.481)	(1.427)	(0.594)	(0.598)	(0.623)	(0.617)	(1.706)	(1.832)	(1.165)	(1.138)
GDP	19.60	17.99	10.45	7.48	0.03	1.39	38.01	37.70	13.82	8.79	21.09	22.60

	(13.15)	(12.73)	(21.98)	(21.93)	(7.39)	(7.49)	(33.08)	(31.20)	(33.90)	(33.26)	(14.17)	(13.77)
Spectrum	0.0026	0.0024	−0.0188	−0.0189*	−0.0008	−0.0006	−0.0001	−0.0006	−0.0421**	−0.0422**	0.0038	0.0040
	(0.0036)	(0.0034)	(0.011)	(0.0107)	(0.0023)	(0.0024)	(0.0047)	(0.0051)	(0.0172)	(0.0165)	(0.0039)	(0.0040)
Observations	187	187	68	68	119	119	187	187	68	68	119	119
R-squared	0.709	0.709	0.877	0.880	0.816	0.819	0.555	0.559	0.843	0.851	0.738	0.737

*p<0.10, **p<0.05, ***p<0.01

Note: Standard errors clustered at country level in parentheses. Country and quarter fixed effects included.

IV analysis

OLS estimates may be subject to endogeneity if market concentration is jointly determined with investment outcomes. The IV analysis addresses this using instruments lagged by four years (16 quarters), comprising operator-level spectrum holdings and normalised spectrum costs averaged across other sub-regions (Central America or South America), excluding the own observation. First-stage diagnostics, reported in Table 9, confirm the validity of the instruments across specifications. The second-stage IV results confirm the direction and significance of the OLS findings across all control-variable specifications, with positive and significant HHI coefficients for capex per connection and download speed in the post-2018 period. For ARPU and revenue per MB, the IV coefficients are not statistically significant in most models, consistent with the absence of price effects found in the OLS analysis.

Table 9: IV results: capex per connection, download speeds, ARPU and revenue per MB (post 2018)

Source: GSMA Intelligence

	CAPEX per connection			Download speed (Mbps)			ARPU (real USD)			Revenue per MB		
Variables	**(1) Baseline**	**(2) Interm.**	**(3) Full**	**(5) Baseline**	**(6) Interm.**	**(7) Full**	**(10) Baseline**	**(11) Interm.**	**(12) Full**	**(13) Baseline**	**(14) Interm.**	**(15) Full**
HHI	0.0106***	0.0120***	0.0111***	0.0702***	0.0836***	0.0750***	0.00196	0.00861	0.0116**	2.86e-06	2.35e-06	2.62e-06
	(0.00278)	(0.00304)	(0.00246)	(0.0170)	(0.0186)	(0.0154)	(0.00718)	(0.00591)	(0.00476)	(1.78e-06)	(1.79e-06)	(1.78e-06)
GDP p.c.	−29.02***	−17.61**	−16.57**	−118.1***	−1.462	−11.50	−0.629	−11.35	−16.17*	-0.0155**	-0.00687	-0.00916
	(8.240)	(7.661)	(6.734)	(32.55)	(40.36)	(37.43)	(20.28)	(9.360)	(9.264)	(0.00676)	(0.00776)	(0.00781)
Rural share	—	1.601***	1.338***	—	13.26***	10.49***	—	0.824	1.087	—	0.00154***	0.00104**
		(0.553)	(0.475)		(3.274)	(2.949)		(0.991)	(0.846)		(0.000424)	(0.000465)
Spectrum	—	—	0.00246	—	—	0.0287**	—	—	0.00221	—	—	4.38e-06***
			(0.00231)			(0.0134)			(0.00262)			(9.36e-07)
Observations	1,430	1,430	1,430	1,512	1,512	1,512	1,430	1,430	1,430	947	947	947
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
First-stage validity tests												
Kleibergen-Paap F (weak ID)	2.800	3.607	5.466	4.526	5.349	6.980	2.800	3.607	5.466	31.03	30.67	31.35
Stock-Yogo 10% CV [= 16.38]	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38
Underidentification p-value	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Anderson-Rubin p-value (weak-IV robust)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.081	0.16	0.114
Endogeneity p-value	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.008	0.011	0.007

*p<0.10, **p<0.05, ***p<0.01

Note: Second-stage IV estimates. Instruments are lagged by 16 quarters and comprise operator-level spectrum holdings and normalised spectrum costs observed in other sub-regions. First-stage diagnostics reported in bottom panel: KP-F = Kleibergen-Paap Wald F statistic (heteroskedasticity-robust); AR = Anderson-Rubin weak-instrument-robust test; Stock-Yogo 10% critical value = 16.38. Robust standard errors in parentheses.

3. Difference-in-differences analysis

Framework and identification

Chapter 4 of the main report estimates the causal effect of consolidation and entry events on investment, network quality and consumer prices across Latin America. The DiD strategy compares the evolution of outcomes in markets affected by a structural event (treated markets) against comparable markets that were unaffected (control markets), before and after the event. Country and time fixed effects absorb time-invariant unobservable and common macroeconomic shocks respectively. The parallel trends assumption is tested via pre-treatment lead coefficients in all DiD specifications.

Events included in the analysis

Table 10 lists the consolidation and entry events assessed in Chapter 4 of the main report, covering the period Q1 2010 to Q4 2024. Subsequent events – including Colombia's Tigo–Movistar merger (approved in 2025) – fall outside the sample period and are not included in the empirical estimates.

Table 10: Consolidation and entry events included in the DiD analysis

Source: GSMA Intelligence

Country	Year	Description
Consolidation events		
Honduras	2011	Digicel sells Honduras unit to Claro (America Movil)
Dominican Republic	2014	Altice acquires Orange and Tricom DR; merged under Altice brand
Guatemala	2019	Claro (America Movil) acquires Movistar Guatemala
Brazil	2022	Oi mobile assets divided between TIM, Claro and Vivo
Mexico	2022	Movistar transitions to MVNO; own network and spectrum returned
Panama	2022 / 2024	C&W and Claro Panama merge; Digicel subsequently exits
Entry events		
Costa Rica	2011	Claro and Movistar launch commercially; ICE Kolbi monopoly ends
Peru	2014	Viettel (Bitel) launches as fourth operator
Mexico	2015	AT&T enters via Iusacell and Nextel Mexico acquisitions
Chile	2015	Novator acquires Nextel Chile; relaunches as WOM
Nicaragua	2016	Xinwei (CooTel) launches as third entrant
Colombia	2021	WOM Colombia commences commercial operations

Note: For Panama, the C&W–Claro merger and the Digicel exit are treated as a single consolidation sequence given their proximity and combined market-structure effect.

Estimators

To ensure robustness in settings with heterogeneous treatment effects and staggered adoption, we apply three modern DiD estimators:

- **Sun and Abraham (2021):** This method estimates cohort-specific treatment effects using interaction-weighted estimators. It assigns non-negative weights based on the share of each cohort in the sample and the relevant post-treatment periods. The approach is robust to heterogeneous treatment effects and allows for dynamic event-study analysis, capturing how impacts evolve over time after an event.
- **Borusyak, Jaravel, and Spiess (2024):** This estimator uses a two-step imputation procedure. In the first step, untreated observations are used to estimate unit and time fixed effects. These are then used to impute counterfactual untreated outcomes for treated units, allowing for the estimation of treatment effects without relying on potentially biased TWFE comparisons. The method is particularly useful when treatment timing varies and when pre-treatment trends differ across units.
- **de Chaisemartin and D'Haultfoeuille (2020):** This estimator calculates group-time average treatment effects using only comparisons between treated and untreated units at each time point. It ensures that all weights are positive and is valid under heterogeneous treatment effects. The method is well suited for policy evaluations where treatment effects may differ by cohort or evolve over time. For the purposes of this study, periods are evaluated quarterly. The analysis assesses six periods following the implementation of the event experiment.

These estimators allow us to estimate both average and dynamic treatment effects and to differentiate impacts by type of event. The three estimators applied are summarised in Table 11.

Table 11: DiD estimators used in this study

Source: GSMA Intelligence

Estimator	Description	Role
de Chaisemartin and D'Haultfoeuille (2020) — DYN	Dynamic DiD estimator based on clean treated–control comparisons with positive weights. Estimates effects period by period.	Primary estimator for consolidation and entry event-study dynamic effects simulations
Sun and Abraham (2021)	Cohort-based DiD estimator that accounts for different treatment timings and heterogeneous effects	Robustness check for event-study dynamic effects
Borusyak, Jaravel and Spiess (2024) – BJS	Imputation-based estimator that constructs counterfactual outcomes using untreated observations	Brazil case study: effect on capex per connection

Results are assessed for consistency across all three estimators. DiD models are estimated in four control-variable variants: (1) no controls; (2) all controls – GDP per capita (log), rural population share, spectrum holdings; (3) GDP per capita only; (4) GDP per capita plus rural population. Standard errors are clustered at the country level throughout. The dynamic analysis covers six post-treatment quarters.

The simulations and event-study charts shown in the main report are mainly based on the dynamic DiD estimator developed by de Chaisemartin and D'Haultfoeuille (2020). This estimator is selected as the primary reporting specification because it enables the estimation of period-by-period treatment effects, allowing us to explore how impacts materialise quarter by quarter following consolidation or entry events. The approach relies exclusively on clean treated–control comparisons with non-negative weights and is therefore robust to heterogeneous treatment effects and staggered adoption.

Sun and Abraham (2021) and Borusyak, Jaravel and Spiess (2024) are also estimated as complementary specifications to assess robustness. Across outcomes, the sign and statistical significance of effects are generally consistent across methodologies, supporting the overall conclusions.

Consolidation events

The simulations and event-study charts shown in Figures 22 and 23 of the main report are derived from the regression results reported below. The period-by-period effects (Effect_1 through to Effect_6) trace the estimated causal impact on each outcome variable in each of the six quarters following a consolidation event, relative to the counterfactual trajectory of the control group. The average treatment effects (Av_tot_eff) correspond to the summary estimates reported in the body of the main report.

In the preferred all-controls variant (Model 2), the estimated average treatment effect on capex per connection is +0.177 log points – equivalent to approximately 19–20% in levels – and statistically significant at the 5% level. The effect builds progressively: by quarter 3 it reaches +0.249 log points (approximately +28%). For weighted download speeds, the average treatment effect under Model 2 is +2.13 Mbps, significant at the 10% level, with individual period effects exceeding +2 Mbps from quarter 2 onwards. Pre-treatment lead coefficients (Placebo_1 and Placebo_2) are not statistically significant across any control variant in the capex specification, supporting the parallel trends assumption.

For ARPU (Figure 23 of the main report), the estimated average treatment effect is −$0.08 (Model 3), which is not statistically significant, confirming that consolidation events did not result in higher consumer prices in all the specifications.

Table 12: DiD results: consolidation events (capex per connection, download speed, ARPU)

Source: GSMA Intelligence

	Capex per connection (ln)				Weighted download speed (Mbps)				ARPU (real USD)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Effect_1	0.093	0.131*	0.076	0.027	0.437**	0.669**	0.461**	0.460**	0.044	−0.043	−0.032	−0.059
	(0.065)	(0.061)	(0.067)	(0.069)	(0.168)	(0.243)	(0.168)	(0.170)	(0.090)	(0.069)	(0.060)	(0.061)
Effect_2	0.065	0.094	0.045	−0.016	1.006**	1.446**	1.020**	1.018**	−0.002	−0.120	−0.170	−0.204*
	(0.070)	(0.061)	(0.072)	(0.075)	(0.332)	(0.483)	(0.334)	(0.336)	(0.138)	(0.118)	(0.101)	(0.101)
Effect_3	0.234**	0.249***	0.202**	0.134	1.456*	2.107*	1.421*	1.419*	0.309	0.004	0.175	0.137
	(0.075)	(0.070)	(0.076)	(0.080)	(0.640)	(0.962)	(0.645)	(0.645)	(0.190)	(0.237)	(0.168)	(0.171)
Effect_4	0.114	0.205*	0.096	0.035	1.431	2.116	1.333	1.331	−0.028	−0.103	−0.115	−0.149
	(0.068)	(0.085)	(0.068)	(0.076)	(0.882)	(1.324)	(0.890)	(0.889)	(0.238)	(0.306)	(0.224)	(0.226)
Effect_5	0.134*	0.208**	0.081	−0.030	1.950	3.046	1.890	1.887	0.131	−0.105	−0.061	−0.122
	(0.059)	(0.066)	(0.060)	(0.075)	(1.203)	(1.802)	(1.211)	(1.210)	(0.281)	(0.335)	(0.252)	(0.257)
Effect_6	0.147*	0.185*	0.086	−0.039	2.360	3.637	2.259	2.256	0.257	0.158	−0.275	−0.345
	(0.070)	(0.073)	(0.066)	(0.080)	(1.343)	(2.010)	(1.351)	(1.349)	(0.350)	(0.163)	(0.185)	(0.192)
Placebo_1	0.025	0.064	0.051	0.041	−0.162	−0.316	−0.202	−0.202	−0.357	−0.052	−0.072	−0.078
	(0.033)	(0.046)	(0.036)	(0.036)	(0.239)	(0.343)	(0.238)	(0.238)	(0.298)	(0.170)	(0.122)	(0.122)
Placebo_2	0.057	0.103	0.099	0.091	0.075	−0.009	0.026	0.026	−0.290	0.001	−0.058	−0.063
	(0.047)	(0.063)	(0.052)	(0.052)	(0.328)	(0.467)	(0.327)	(0.327)	(0.320)	(0.321)	(0.230)	(0.230)
Av_tot_eff	**0.130***	**0.177****	**0.097**	**0.018**	**1.424***	**2.134***	**1.383**	**1.381**	**0.116**	**−0.036**	**−0.080**	**−0.124**

	(0.055)	(0.060)	(0.056)	(0.063)	(0.717)	(1.062)	(0.721)	(0.720)	(0.184)	(0.183)	(0.144)	(0.147)

*p<0.10, **p<0.05, ***p<0.01

Note: de Chaisemartin and D'Haultfoeuille (2020) DYN estimator. Models: (1) no controls; (2) all controls – GDP per capita (log), rural population, spectrum; (3) GDP per capita only; (4) GDP per capita + rural population. Standard errors clustered at country level. Placebo_1 and Placebo_2 are pre-treatment lead coefficients; Av_tot_eff is the average treatment effect over all post-treatment periods.

Brazil case study

Brazil provides a specific point illustration of the region-wide consolidation findings. The Oi mobile asset divestiture started in 2020 (in which Oi's mobile operations were divided among TIM, Claro and Vivo) is assessed using the Borusyak, Jaravel and Spiess (2024) imputation estimator and a South American control group to improve comparability. Given that this analysis relates to a single consolidation event occurring at a common point in time (i.e. no staggered adoption), this approach provides an appropriate framework to estimate aggregate post-treatment effects. The specification controls for 5G adoption rates, isolating the merger effect from the concurrent 5G rollout.

Table 13 (Models 1–4) reports BJS estimates for capex per connection. The estimated average treatment effect ranges from +0.479 log points (Model 1, significant at 5%) to +0.594 log points (Model 2, significant at 1%), equivalent to approximately +61–81% in levels. Pre-treatment lead coefficients (pre1 and pre2) are not statistically significant across any model. Similarly, for weighted download speed and ARPU (Models 5–7), specifications for which the parallel trends assumption is satisfied are included and present the same direction and statistical significance as those reported in the main results.

Table 13: DiD results (BJS) – Brazil: capex per connection, weighted download speed and ARPU

Source: GSMA Intelligence

	Capex per connection (ln)				Weighted download		ARPU (real USD)
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
τ (average treatment effect)	0.479**	0.594***	0.506***	0.516**	29.517***	27.671***	1.142
	(0.173)	(0.143)	(0.149)	(0.163)	(3.646)	(3.617)	(0.672)
pre1	0.243	0.220	0.266	0.276	6.519	5.400	1.057
	(0.179)	(0.210)	(0.152)	(0.182)	(3.363)	(3.309)	(0.683)
pre2	0.193	0.224	0.242	0.254	5.934	3.454	0.982
	(0.158)	(0.138)	(0.152)	(0.134)	(3.101)	(3.003)	(0.516)
Rural population	—	0.185	—	0.021	—	—	-1.841
		(0.205)		(0.185)			(1.035)
GDP per capita	—	1.315	0.498	0.551			3.753
		(1.602)	(1.675)	(1.289)			(5.170)
Spectrum	—	−0.001	—	—	—	-28.864*	—
		(0.001)				(12.250)	
5G adoption	—	2.797	—	—	—	—	—
		(2.165)					
N	1,750	1,234	1,666	1,666	1853	1686	1666

*** p<0.01, ** p<0.05, * p<0.10.

Note: Borusyak, Jaravel and Spiess (2024) imputation estimator. South American control group. Standard errors in parentheses.

Also, using the de Chaisemartin and D'Haultfoeuille (2020) framework, period-by-period estimates are used to examine short-term post-treatment dynamics following the consolidation for weighted download speed and ARPU. The estimated average treatment effect on download speed ranges from +2.44 to +2.64 Mbps across specifications and is statistically significant at the 1% level. For ARPU, the estimated average effect ranges from −$0.25 to −$0.28 and is not statistically significant in any specification.

Entry events

The regressions below underlie the results of Chapter 4 of the main report, applying the same DiD framework to entry events across Latin America. For capex per connection, the average treatment effect is not statistically significant in any control variant. Individual period effects are predominantly not significant and show no consistent post-entry improvement pattern. For weighted download speed, a marginal positive effect appears in later periods under some specifications but is not consistent across control variants and average effect is not different from zero. For ARPU, no statistically significant effect is found in either direction across all models. Pre-treatment lead coefficients are not statistically significant, supporting the parallel trends assumption.

Table 14: DiD results: entry events (capex per connection, download speed, ARPU)

Source: GSMA Intelligence

	Capex per connection (ln)				Weighted download speed (Mbps)				ARPU (real USD)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Effect_1	0.105*	0.064	0.075	0.019	−0.030	−0.012	−0.032	0.002	−2.635	−3.219	−2.775	−2.825
	(0.051)	(0.049)	(0.044)	(0.046)	(0.217)	(0.260)	(0.219)	(0.218)	(2.814)	(3.309)	(2.814)	(2.813)
Effect_2	0.048	0.048	0.034	−0.004	−0.019	−0.016	−0.029	−0.004	−2.295	−2.875	−2.540	−2.574
	(0.086)	(0.096)	(0.086)	(0.087)	(0.457)	(0.550)	(0.460)	(0.460)	(2.856)	(3.356)	(2.854)	(2.854)
Effect_3	0.172	0.186	0.131	0.118	0.243	0.280	0.219	0.233	−2.299	−2.827	−2.579	−2.590
	(0.120)	(0.126)	(0.119)	(0.120)	(0.536)	(0.652)	(0.542)	(0.541)	(2.879)	(3.381)	(2.877)	(2.877)
Effect_4	0.164	0.275*	0.098	0.127	0.329	0.295	0.288	0.278	−3.452	−4.226	−3.818	−3.791
	(0.112)	(0.128)	(0.109)	(0.116)	(0.598)	(0.722)	(0.603)	(0.600)	(2.989)	(3.502)	(2.985)	(2.984)
Effect_5	0.270*	0.234	0.208	0.183	0.412	0.367	0.355	0.380	−3.187	−4.343	−3.937	−3.960
	(0.136)	(0.129)	(0.133)	(0.135)	(0.669)	(0.808)	(0.675)	(0.671)	(2.996)	(3.481)	(2.975)	(2.973)
Effect_6	0.097	0.141	0.008	0.008	0.231	0.097	0.149	0.162	−3.823	−5.199	−4.656	−4.656
	(0.151)	(0.176)	(0.145)	(0.150)	(0.738)	(0.899)	(0.746)	(0.742)	(3.416)	(3.980)	(3.396)	(3.394)
Placebo_1	−0.064	−0.093	−0.035	−0.089	0.157	0.229	0.178	0.205	−0.779	−0.569	−0.453	−0.503
	(0.180)	(0.190)	(0.180)	(0.179)	(0.161)	(0.181)	(0.164)	(0.165)	(0.477)	(0.453)	(0.427)	(0.423)
Placebo_2	-0.121	-0.149	-0.058	-0.136	0.263	0.352	0.28	0.319	-0.040	0.218	0.299	0.228
	(0.184)	(0.189)	(0.181)	(0.179)	(0.226)	(0.251)	(0.228)	(0.229)	(0.446)	(0.412)	(0.399)	(0.389)
Av_tot_eff	**0.143**	**0.165**	**0.092**	**0.075**	**0.194**	**0.168**	**0.158**	**0.175**	**−2.949**	**−3.782**	**−3.384**	**−3.399**
	(0.095)	(0.104)	(0.092)	(0.094)	(0.504)	(0.609)	(0.508)	(0.506)	(2.957)	(3.465)	(2.952)	(2.951)

*p<0.10, **p<0.05, ***p<0.01

Note: de Chaisemartin and D'Haultfoeuille (2020) DYN estimator. Models: (1) no controls; (2) all controls – GDP per capita (log), rural population, spectrum; (3) GDP per capita only; (4) GDP per capita + rural population. Standard errors clustered at country level. Placebo_1 is the pre-treatment lead coefficient.

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