The Cost of Knowledge: Evidence from India's 4G Internet Revolution

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December 8, 2025

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Motivation: Why do we care?

- Digital access is becoming central to learning: online lectures, tutorials, doubt-solving, peer communities.

  (Bulman and Fairlie 2016; Muralidharan, Singh and Ganimian 2019)
- In developing countries, cheap internet may especially help poorer students who lack educational resources.

  (World Bank Group 2016)
- Yet evidence is mixed: prior studies on 3G, laptops, or limited broadband show weak or inconsistent effects.

  (Bessone, Dahis and Ho 2023; Fairlie and Robinson 2013; Ponnusamy and Trinh 2025)

Why India? Why Jio?

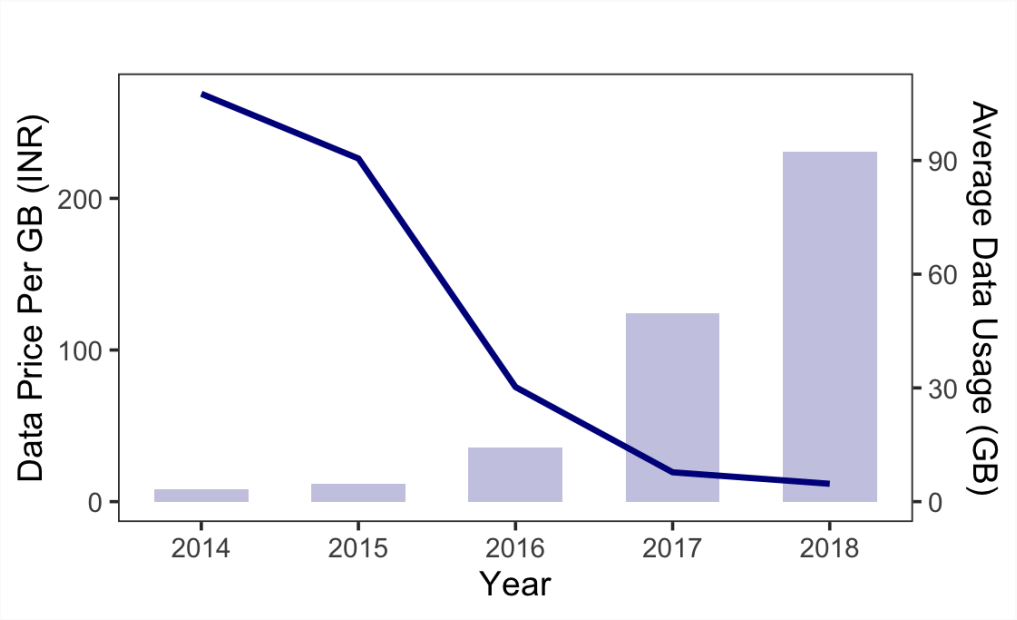


Figure 1: Data Prices and Usage

- India is a mobile-first economy.
- Jio's 2016 launch was sudden and provided months of free 4G.
- Data prices fell $\approx$ 92% and data usage increased $\approx$ 940% between 2015–2017
- Provides a natural experiment to test: **Does affordable 4G internet access improve learning outcomes?**

Data Sources: What makes this testable?

- **Mozilla Location Services (MLS)**: Crowdsourced cell tower data identifying each operator through MCC/MNC codes, which allows mapping Jio's 4G rollout at a tower-level resolution.
- **WorldPop** (1×1 km grid): High-resolution population density estimates; enables calculation of % district population covered by 4G (with 5 km buffers around each tower).
- **ASER** (2010-2018, biennially): Nationally representative, district-level learning outcomes for reading and math: Aggregated to district-year panel, with controls such as class, household size, dropout rate, and mobile ownership.
- **Nightlights (VIIRS)**: Proxy for district-level economic activity changes.

Treatment Identification

- Identify Jio towers at launch.
- Create 5km buffers around each tower.
- Overlay with 1×1 km population density grid.
- Compute share of population under Jio 4G coverage.

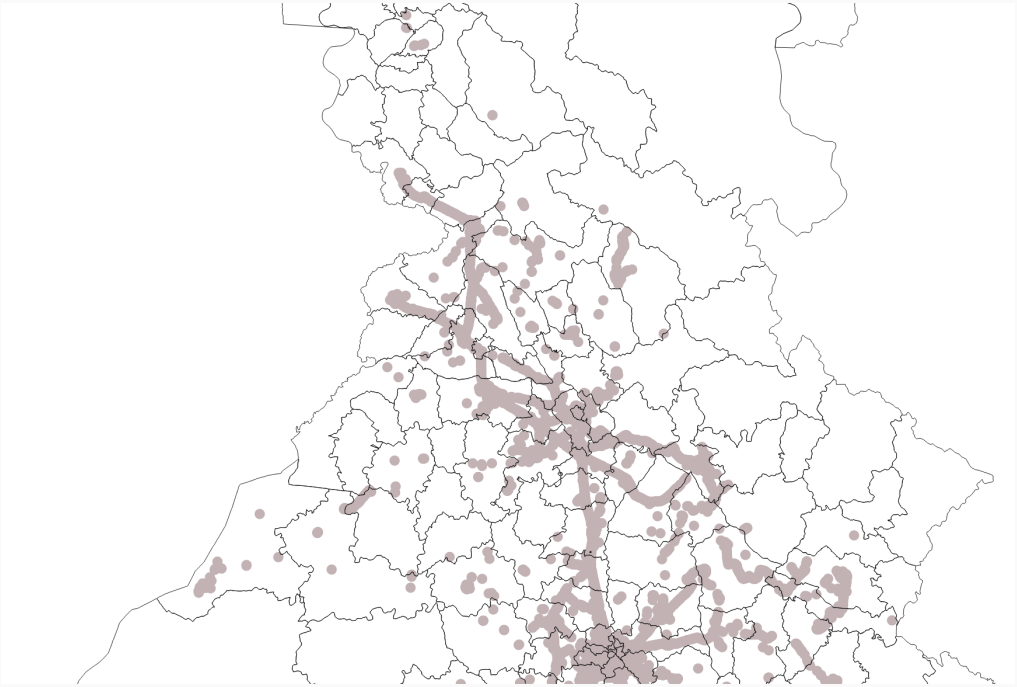


Figure: Jio Network Coverage at Launch

Treatment Identification

Main Classification

$$treat_{ds} = \begin{cases} 1 & \text{if district } d \text{ has } > 50\% \text{ Jio 4G coverage in 2016} \\ 0 & \text{if district } d \text{ has } \leq 50\% \text{ 4G coverage till 2018} \end{cases}$$

Second Classification

$$treat_{ds} = \begin{cases} 1 & \text{if district } d \text{ has } > 50\% \text{ Jio 4G coverage in 2016} \\ 0 & \text{if district } d \text{ has } \leq 50\% \text{ Jio 4G coverage till 2018} \end{cases}$$

Third Classification

$$treat_{ds} = \begin{cases} 1 & \text{if district } d \text{ has } > 50\% \text{ 4G coverage in 2016} \\ 0 & \text{if district } d \text{ has } \leq 50\% \text{ 4G coverage till 2018} \end{cases}$$

Empirical Strategy

Base specification with controls

$$score_{dst} = \beta_0 + \beta_1 treat_{ds} + \beta_2 post_t + \beta_3 (treat_{ds} \times post_t) + \gamma \mathbf{X}_{dst} + u_{dst} \quad (1)$$

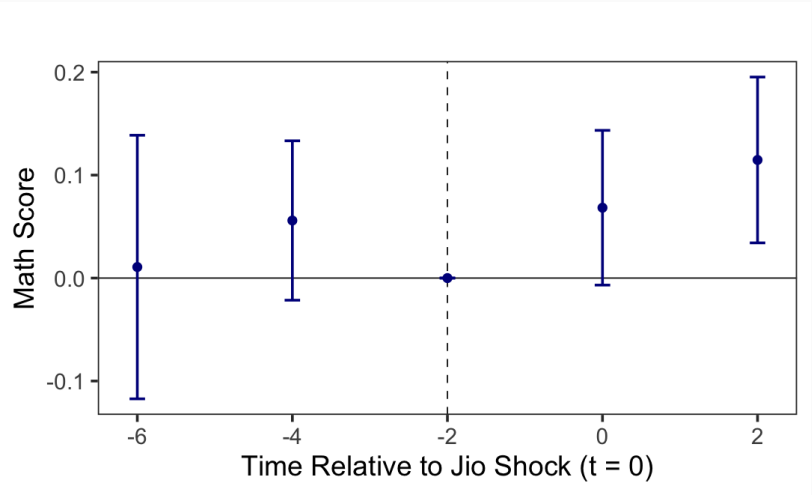
Base specification with controls and year + state fixed effects

$$score_{dst} = \beta_0 + \beta_1 treat_{ds} + \beta_3 (treat_{ds} \times post_t) + \gamma \mathbf{X}_{dst} + \alpha_s + \delta_t + u_{dst} \quad (2)$$

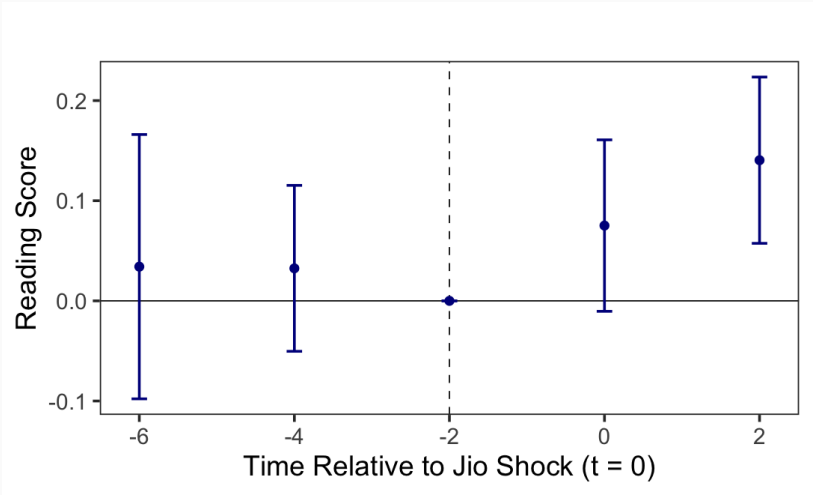
Treatment intensity specification

$$score_{dst} = \beta_0 + \beta_1 \, TreatIntensity_{ds} + \beta_3 \, (TreatIntensity_{ds} \times post_t) + \gamma \mathbf{X}_{dst} + \alpha_s + \delta_t + u_{dst} \quad (3)$$

Parallel Trends



(a) Math Scores



(b) Reading Scores

Figure 2: Event-study Estimates

- Coefficients for pre-treatment leads are statistically insignificant, which supports the parallel trends assumption.
- Post treatment lag is significant, which shows that test scores improved more in treated districts after Jio's 4G rollout relative to control districts over the same period.

Findings

Table 1: Average Treatment Effect of Jio 4G Shock (Main Specification)

	Read Score			Math Score		
	(1)	(2)	(3)	(4)	(5)	(6)
Post	0.0455**	-0.0685***		0.0232	-0.0951***	
	(0.0181)	(0.0213)		(0.0178)	(0.0244)	
Treat	0.304***	0.0708*	0.0717**	0.326***	0.122***	0.0740**
	(0.0446)	(0.0371)	(0.0304)	(0.0429)	(0.0366)	(0.0295)
DiD	**0.0343**	**0.0734****	**0.0700****	**0.0357**	**0.0726****	**0.0584****
	(0.0263)	(0.0266)	(0.0267)	(0.0253)	(0.0275)	(0.0257)
Observations	577	577	577	577	577	577
R^2	0.150	0.676	0.818	0.187	0.598	0.788
Controls	No	Yes	Yes	No	Yes	Yes
FE	No	No	Yes	No	No	Yes

Notes: Standard errors clustered at the district level.

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

- Early access to affordable 4G internet has a significant positive impact on learning outcomes.

Findings

Table 2: Average Treatment Effect of Jio 4G Shock (Main Specification)

	Read Score	Math Score
Treat Intensity	0.101**	0.110**
	(0.0511)	(0.0495)
DiD Intensity	**0.113*****	**0.0893****
	(0.0410)	(0.0398)
Observations	577	577
R^2	0.816	0.787
Controls	Yes	Yes
FE	Yes	Yes

Notes: Standard errors are clustered at the district level.

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

- Districts with higher initial Jio 4G coverage experienced proportionately larger improvements in learning outcomes.

Conclusion

- Empirically, we leverage a unique natural experiment and provide evidence on the educational returns to large-scale, low-cost mobile internet access in a developing-country context.
- Conceptually, we show that digital infrastructure can act as an equalizing input to human capital formation when it reduces barriers to educational content, consistent with theories linking resource access to learning outcomes.