The Ecological Footprint of Transportation Infrastructure Or "Losing the Forest for the ~~Trees~~ Freeways"

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November 27, 2017
GGKP Conference on Sustainable Infrastructure

Agenda: local economic impacts of transport infrastructure

- Series of papers on road construction in India
- Rural roads
  - Paper 1: facilitate exit from agriculture through access to nearby labor markets but not much firm growth or increases in welfare
  - Paper 2: increase schooling, evidence for labor market channel
- Paper 3: environmental impacts of rural roads and highways

Motivation

- Does human economic progress have an unavoidable environmental cost?
  - Arrow et al., 1995; Grossman & Krueger, 1995; Foster and Rosenzweig, 2003; Dasgupta, 2007
- Transportation infrastructure key to economic progress
  - Bryan et al., 2014; Atkin et al., 2015; Ghani et al., 2015; Storeygard, 2016
- Key empirical challenge: endogenous roads/causal identification
  - Data on localized environmental outcomes and road placement
  - We focus on forest cover as a measure of environmental quality

Main results

- Result #1: "Last-mile" rural roads have no effect on forest cover (precise zeros)
  - Also true in areas where we are most likely to see effects - high baseline forest cover
- Result #2: Highways have large negative effects on forest cover (17% loss)
  - Mechanism: expansion of forest intensive industries
  - Rule out: changes in fuel wood use, agricultural extensification and expansion of land for settlement and industry.

Previous work

- Large literature on roads and forests - very few using quasi-experimental techniques
  - Chomitz & Gray, 1996; Pfaff, 1999; Cropper et al., 2001; Deng et al., 2011
- Mixed evidence - dominant finding is that roads lead to deforestation
- A broad range of proposed mechanisms
  - (-/+) Changes in relative returns to agriculture
  - (-) Lower transportation costs for timber
  - (-/+) Demand for forest-intensive industries
  - (-/+) Changes in fuel use
  - (-) More clearing for industry, settlements etc.

Our Contribution

- Causal estimates of roads on forests, and at a large national scale:
  - RD, Difference-in-Differences design
- Identify the critical role of differentiating construction period from post-completion period
- Distinguish between types of transportation infrastructure:
  - Different modalities of transportation generate different environmental externalities
- Identify mechanisms of impact

Data

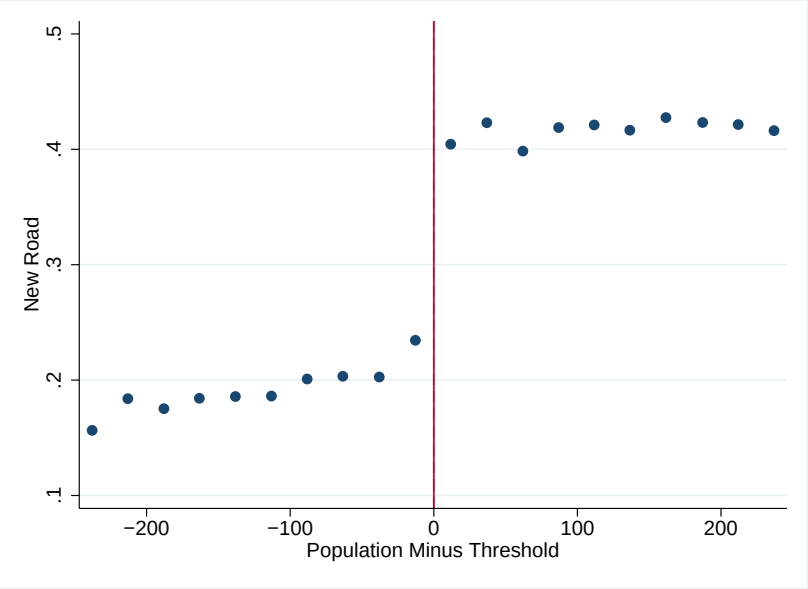
- Forest Cover: Vegetative Forest Cover | 250x250 | Continuous | Alternative: Global Forest Change
- Rural Roads: Administrative Data | 113,000+ roads built between 2001 and 2014
- Highways: Construction dates | Spatial data | Ghani, Goswami and Kerr (2016)
- Other: Population Census of 1991, 2001, 2011| Economic Census of 1990, 1998, 2005 and 2013

Rural Roads: PMGSY Program

- Launched in 2000 to connect all villages to road network
- Paved all weath roads, average length 4 km
- By 2015:
  - 113,000 roads constructed (400,000 km)
  - 107,000 previously unconnected villages
  - $>$ \$37 billion disbursed
- Funded centrally, construction administered by states
- Transparent, systematic electronic record keeping: details of every habitation and road built
- Objective eligibility rules: prioritization to villages over 1000, 500 population
- Two empirical strategies: regression discontinuity and difference-in-differences

Research Design

21% increase in road treatment at threshold



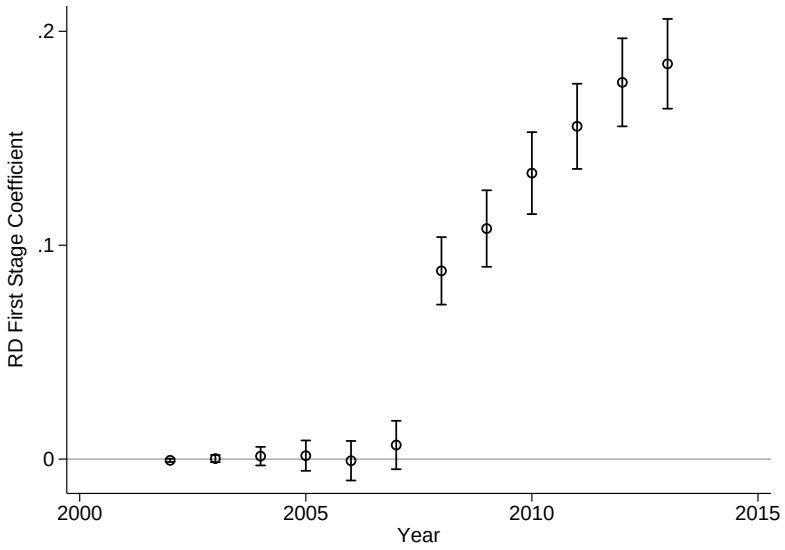


Figure: First Stage Regression Discontinuity Estimates

Results: Rural Roads - RD

First stage, reduced form, IV

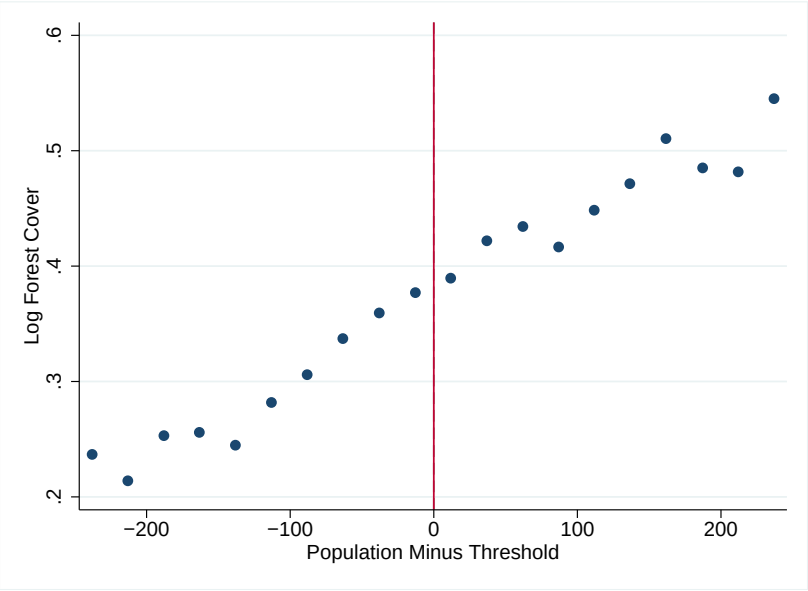
Table: Rural Roads and Deforestation: RD Estimates

	First Stage	Reduced Form					IV	
	Any Road	Log Forest	Avg Forest	High Baseline	High ST	Low Assets	Log Forest	Avg Forest
Above Population Threshold	0.163***	0.003	0.042	-0.006	0.007	0.017		
	(0.010)	(0.011)	(0.060)	(0.013)	(0.014)	(0.017)		
New Road							0.016	-0.062
							(0.065)	(0.539)
N	89476	89476	89476	44880	44388	35520	89476	89476
r2	0.25	0.80	0.56	0.69	0.83	0.78	0.80	0.36

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Results: Rural Roads - RD

No discontinuity at the threshold



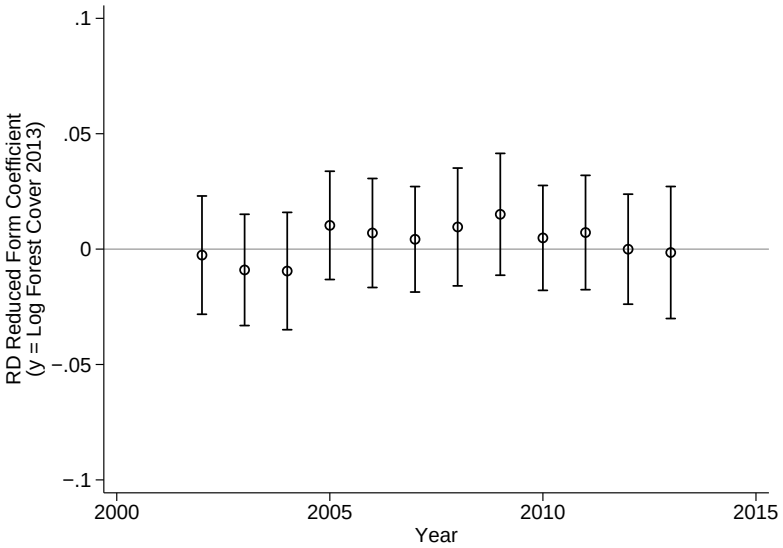


Figure: Reduced Form Regression Discontinuity Estimates

Results: Rural Roads - DD

Important to separate award period and completion period

Table: Rural Roads and Deforestation: Diff-in-Diff Estimates

	Log Forest		Average Forest	
	(1)	(2)	(3)	(4)
Award Period	-0.005***		-0.035***	
	(0.002)		(0.013)	
Completion Period	0.002	0.005***	0.009	0.014
	(0.002)	(0.002)	(0.015)	(0.012)
District-Year F.E.	Yes	Yes	Yes	Yes
Village F.E.	Yes	Yes	Yes	Yes
N	689745	689745	689745	689745
r2	0.94	0.94	0.92	0.92

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Highways: Golden Quadrilateral and North-South, East-West Corridors

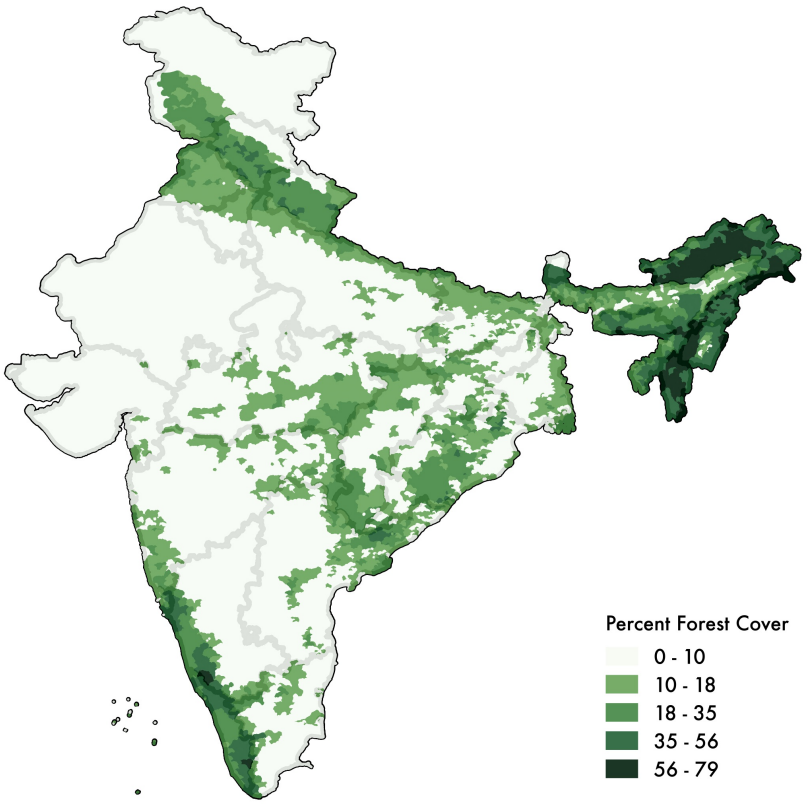
- In 1999-2000 the government announced two major highway programs with a realized cost > \$18 billion.
- Golden Quadrilateral (GQ):
  - Connecting New Delhi, Mumbai, Chennai and Kolkatta
  - Rapid progress: 80% (95%) completed by 2004 (2006)
- North-South and East-West Corridors (NSEW):
  - Connecting farthest ends of the mainland - Srinagar to Kanyakumari and Porbandar to Silchar.
  - Delayed onset: 4% (10%) completed by 2004 (2006)

Research Design

Highways: Golden Quadrilateral and North-South, East-West Corridors

Panel A: Highway Construction (2001-2014)

Panel B: Forest Cover (2001)



Research Design

Highways: Difference-in-Differences Specification

$$Forest_{vst} = \beta_0 + \beta_1 CLOSE_{vs} + \beta_2 POST_t + \beta_3 CLOSE_{vs} * POST_t + \varepsilon_{vst} \quad (1)$$

$$Forest_{vst} = \sum_{d=1}^{D} \sum_{t=2000}^{2014} \beta_{d,t} 1(DIST \in (d^-, d^+), YEAR = t) + \gamma_{st} + \boldsymbol{X}_v \cdot \nu_t + \eta_{vst} \quad (2)$$

- $Forest_{vst}$: forest cover in village v and state s in year t
- $CLOSE_{vs} = 1$: village v is "close" to highway
- $POST_t = 1$: after the completion of the highway
- Drop within 200km of nodal cities
- Standard errors clustered at village level

Results: Highways

Full Specification

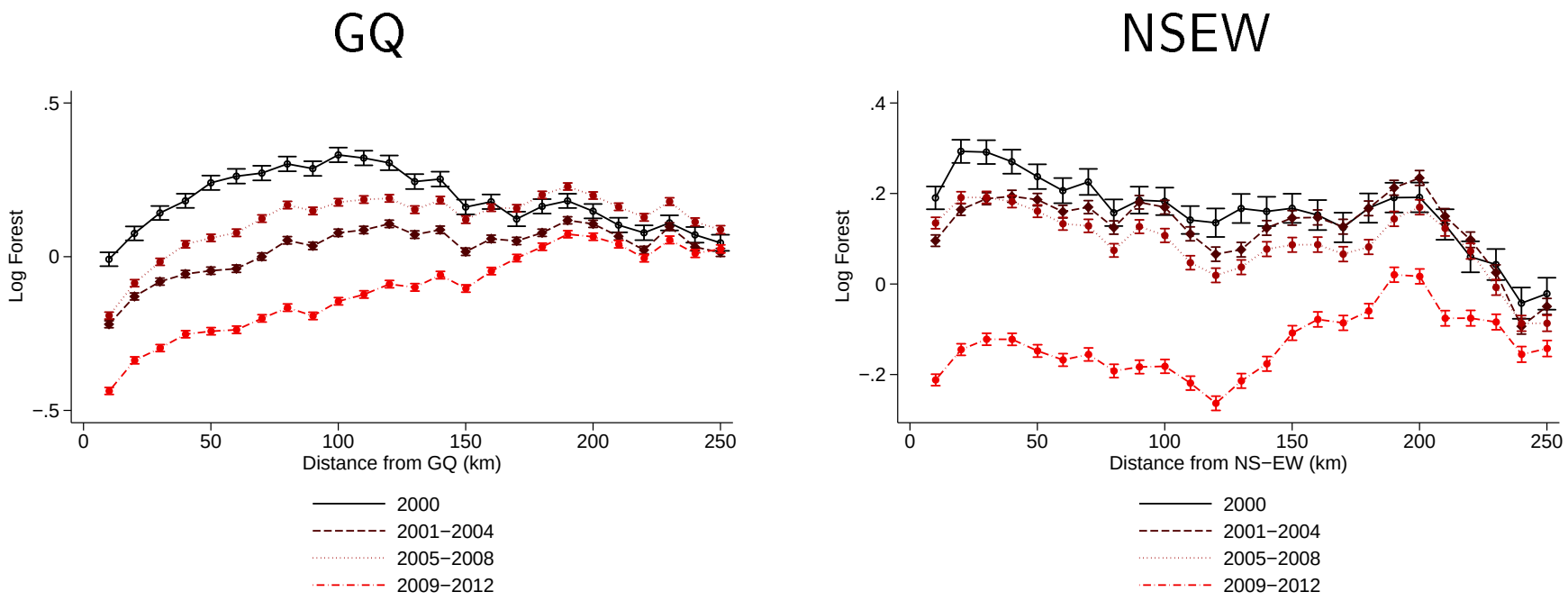
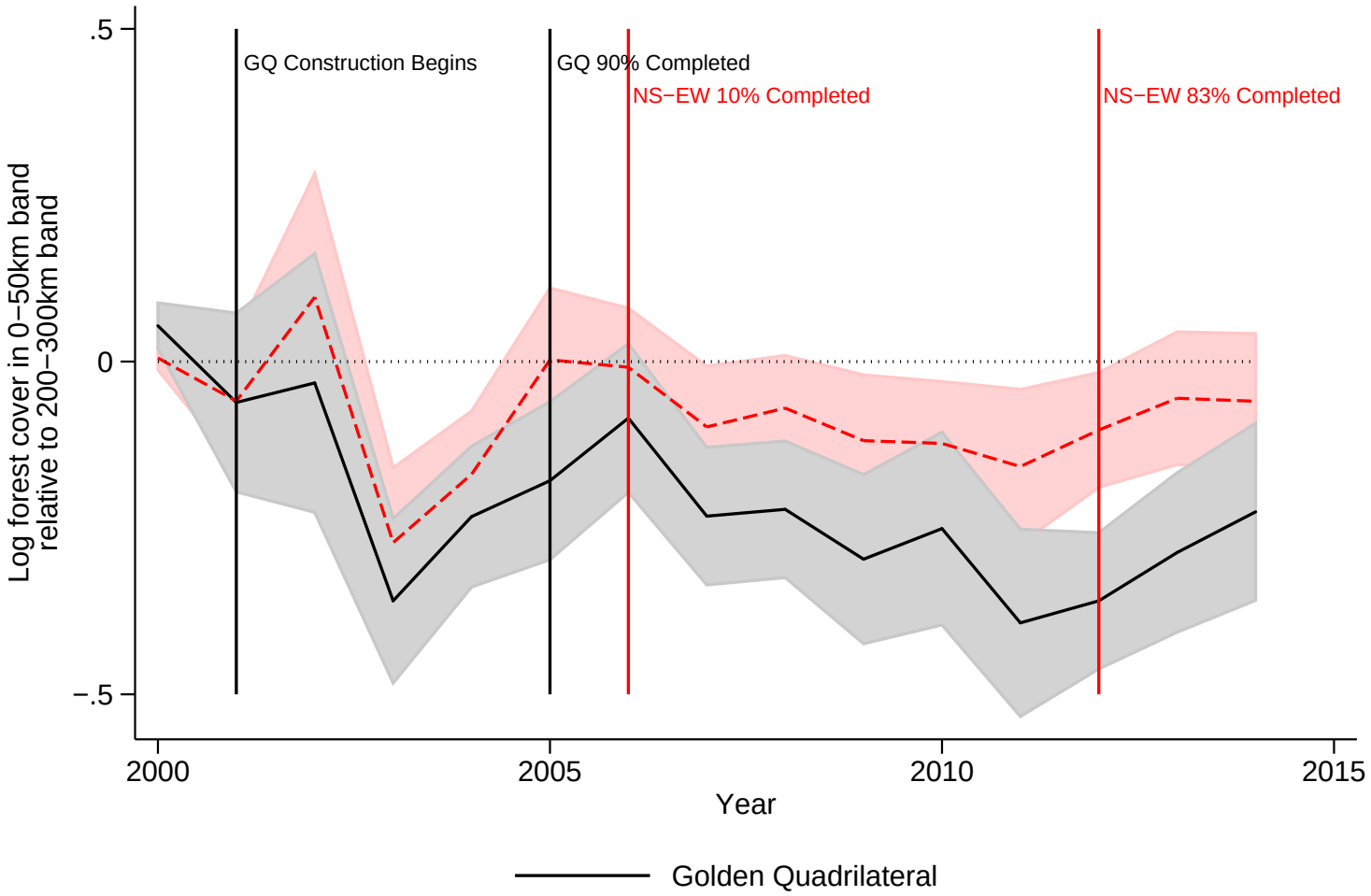


Figure: GQ and NSEW Effects by distance and time

Results: Highways

Over Time

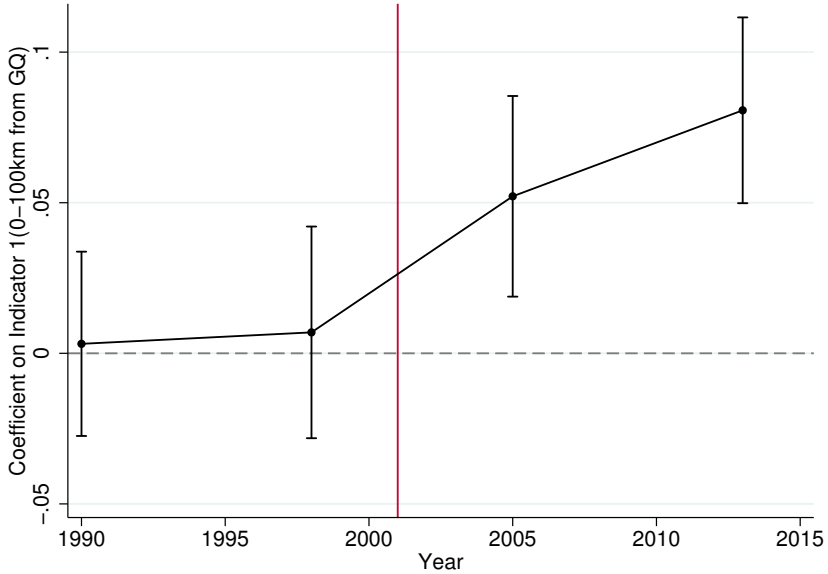
Figure: Difference-in-Differences Estimates of Impact of Highways on Proximate Forest Cover, Over Time



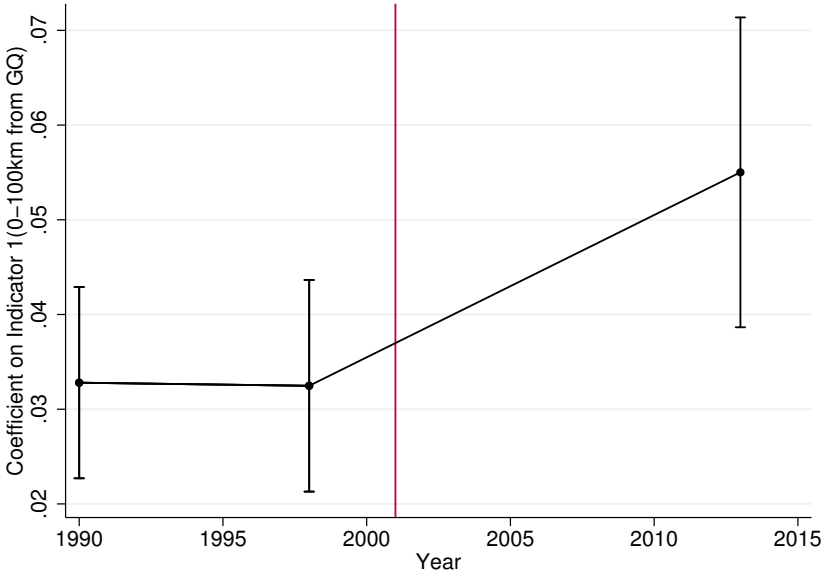
Mechanisms

Driven by expansion of wood-using and logging firms

Employment in Wood-Using Firms



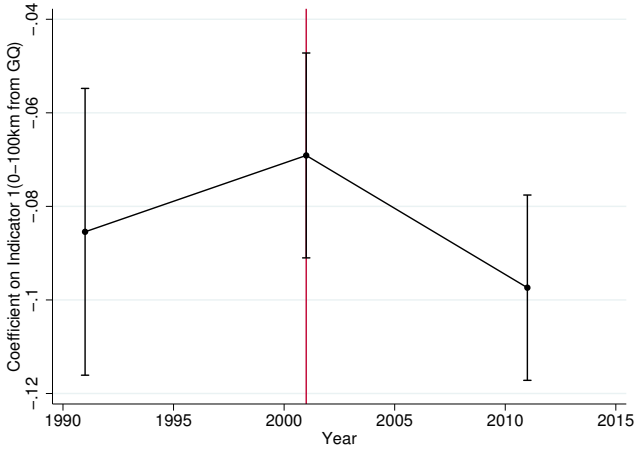
Employment in Logging Firms



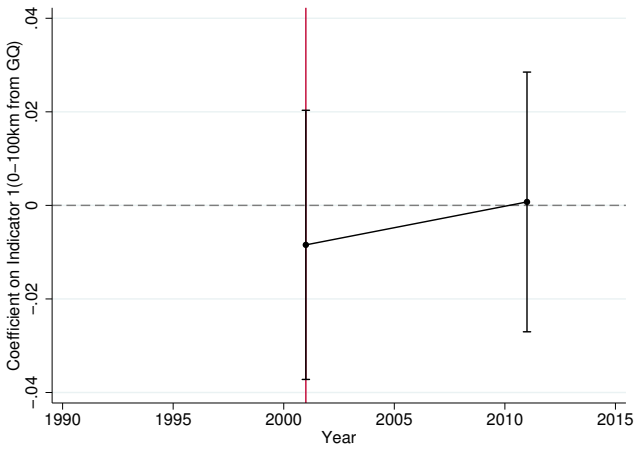
Mechanisms

Agriculture and fuel-use don't explain the result

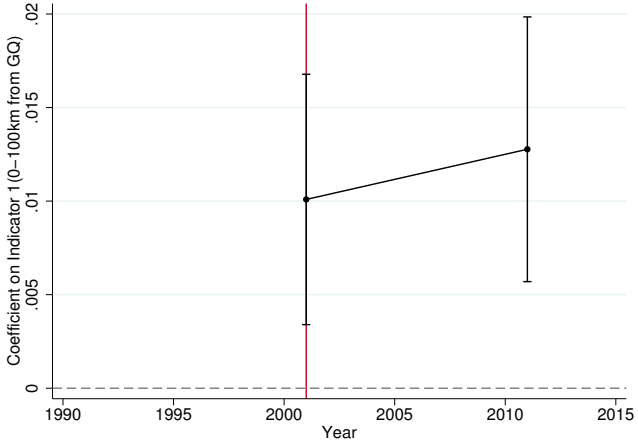
Village Land Ag (share)



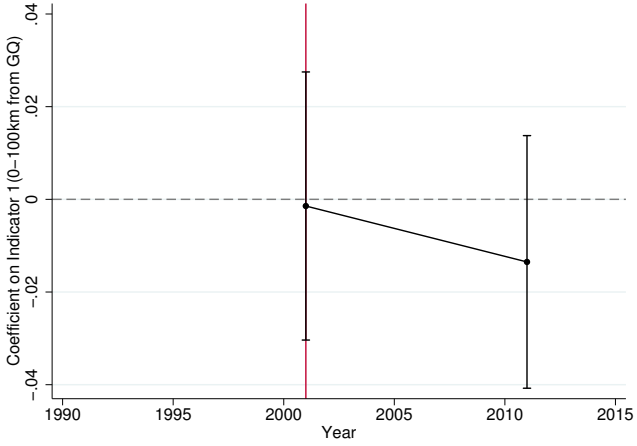
Firewood (share)



Imported Fuels (share)



Local Non-Wood Sources (share)



Quantifying the carbon costs

- Following Jayachandran et al. (2017)
- 130 metric tons of carbon per hectare in India (Global Forest Watch)
- 477.1 tons of CO2 emissions from each hect of forest loss
- \$39 per metric ton is social cost of carbon (SCC) using 3% discount rate (EPA median scenario)
  - Conservatively assume only 8 years of delayed forest loss $\rightarrow$ \$8.5
- \$4,055 SCC per hectare of forest cover loss (avoided for 8 years)
- Multiply by approx 860k hectares to get <u>\$3.51 billion</u> SCC arising from GQ
  - 25% of cost of construction
  - $>$ 100% if forest loss permanently averted
  - Lower estimates for NS-EW

Conclusion

- Road infrastructure to dramatically expand globally
  - By 2050, an additional 16 million miles are expected to be added (60% above 2010 levels)
  - 9 out of 10 of these will be built in developing countries
- The effects of roads on environment is heterogenous
  - Rural roads appear to have no effect, despite leading to exits from agriculture (Asher & Novosad, 2017) and improvements in educational outcomes (Adukia, Asher & Novosad, 2017).
  - Highways result in expansion of forest-intensive industries and large declines in forest cover
- Important to distinguish between stages of construction and post-completion when evaluating impact of transport infrastructure
- For future research: can protected area status or other regulations effectively reduce impacts of highways on forests?

Thank you!

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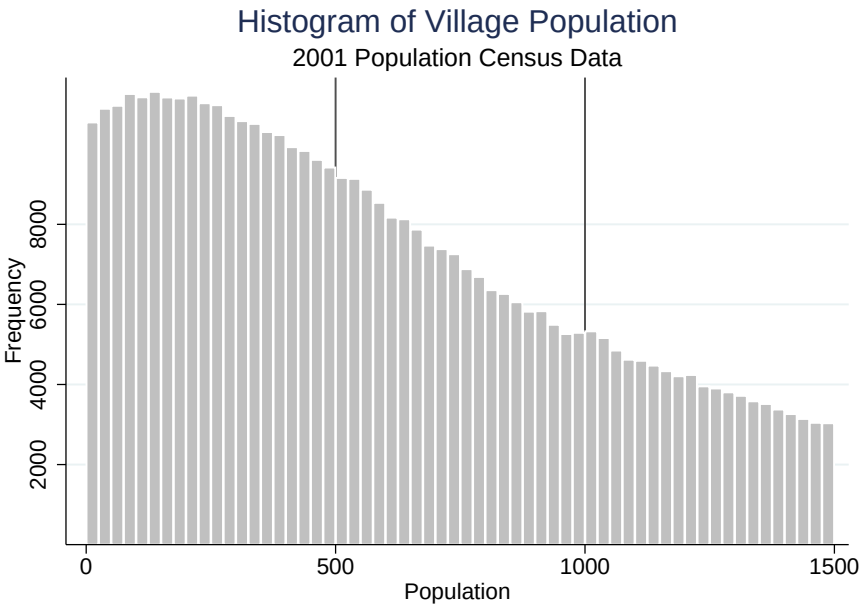
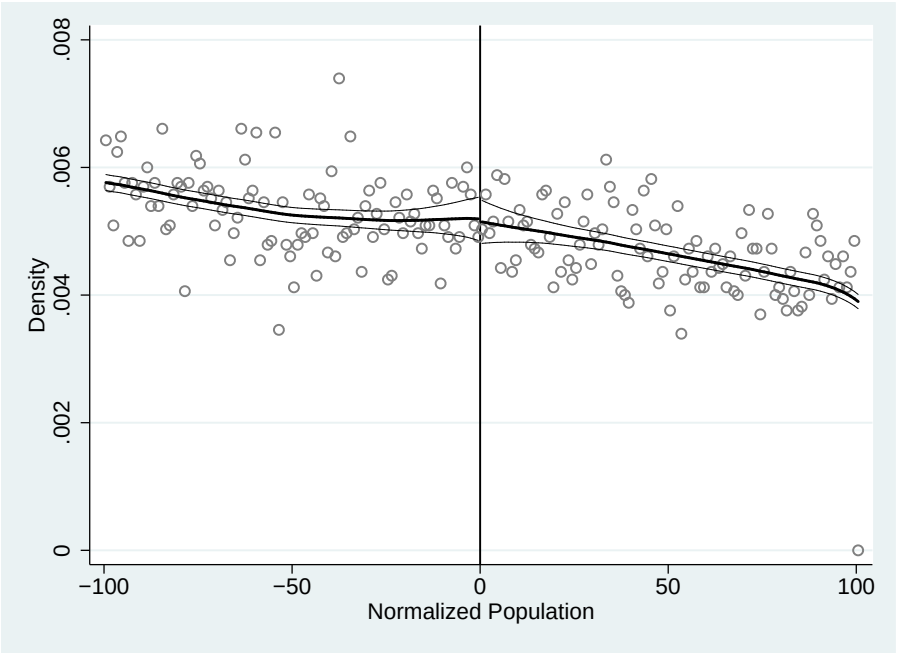
Appendix

Running variable smoothness

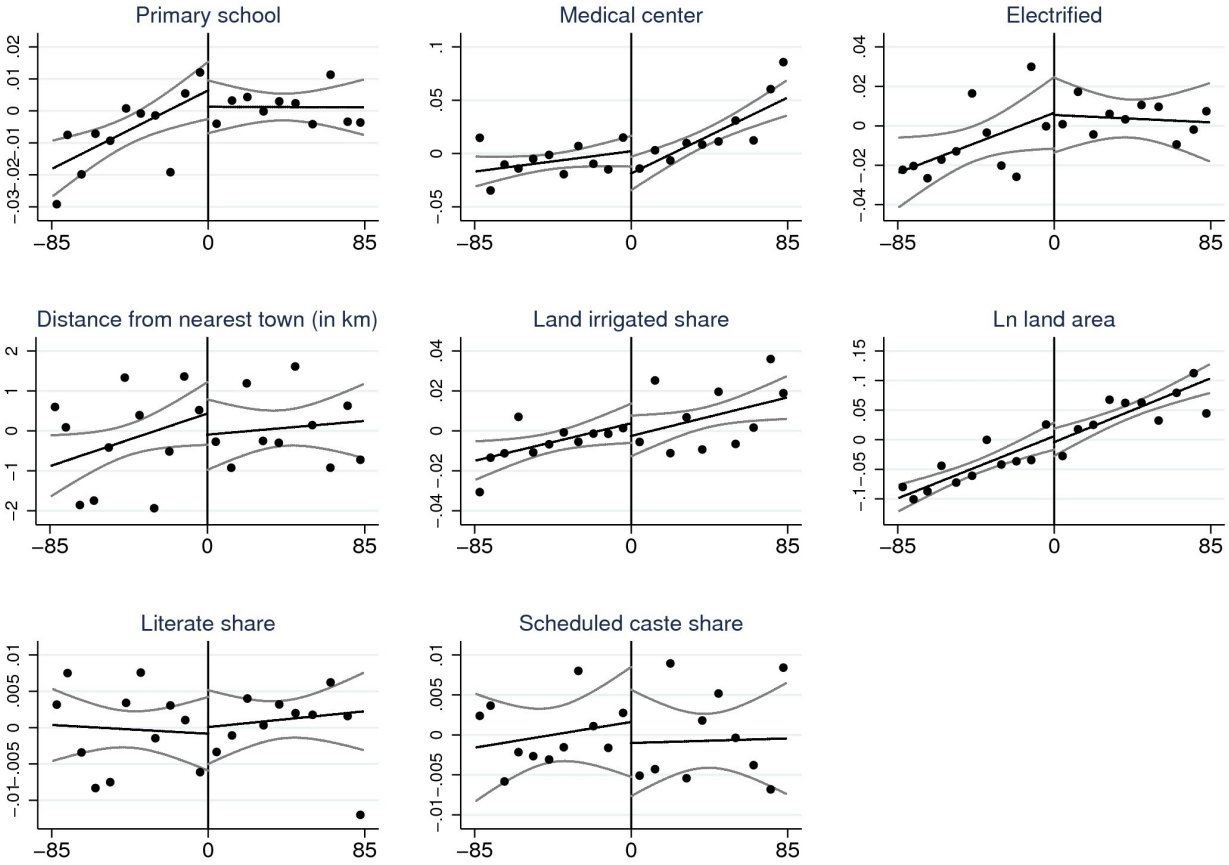
- RD test: density of running variable should be continuous at treatment threshold





Back

Balance of baseline village characteristics



Table

Potential confound: alternate program

- Total Sanitation Campaign used 1000 cutoff (Spears, 2015)

Table: Reduced form estimate of PMGSY road on major TSC variables

	Open Defecation	Latrine in Premises	Pit Latrine - with slab	Pit Latrine - without slab
Road priority	0.005	-0.004	0.007	-0.005
	(0.014)	(0.013)	(0.006)	(0.004)
N	1775	1775	1775	1775
r2	0.26	0.27	0.11	0.09

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Back