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JUE insight: Infrastructure and Finance: Evidence from India's GQ highway network☆

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ABSTRACT

We use data from Reserve Bank of India to study the impact of India's Golden Quadrilateral (GQ) highway project on finance-dependent activity. Loan volumes increase by 20%–30% in districts along GQ and are stronger in industries more dependent upon external finance. Loan growth begins with increases in average branch size and in places with more pre-GQ loan activity. New branch openings come later, consistent with short-run adjustment costs to expanding branch networks. These patterns are not evident in placebo tests using delayed investments in NS-EW highways. Results suggest the depth of initial financial infrastructure shapes how infrastructure investments impact localities.

1. Introduction

Infrastructure spending is a key lever to promote economic growth. In addition to its role in stimulating demand, an important policy question is whether major infrastructure investments can reduce disparities in economic activity across regions by also unlocking complementary inputs, such as the greater availability of financial capital. Despite a rich literature examining the economic consequences of large-scale road construction (e.g., Chandra and Thompson, 2000; Duranton and Turner, 2011), the role of financial intermediaries in funding new activity remains underexplored.

We study this question using India's Golden Quadrilateral (GQ) highway investment as a natural experiment, examining the spatial development of bank lending at the district-industry level. The GQ network connects Delhi, Mumbai, Chennai, and Kolkata and is the fifth-longest highway in the world. Conceived in 1999, GQ upgrades began in 2001, with a target completion date of 2004, and 95% of the work was completed by the end of 2006. Prior studies show significant impact of GQ on the placement and operation of organized formal-sector manufacturing firms, trade flows, and deforestation, with weaker consequences for the informal sector and aggregate nighttime lights.

We contribute to this growing literature by using comprehensive data on bank lending drawn from the Reserve Bank of India (RBI). This database details each outstanding loan above a threshold of approximately $4000, reported annually by every branch of all scheduled commercial banks in India. While limited to finance-dependent economic activity, RBI data have the unique advantage of enabling the study of economic activity at narrowly defined geographic and industry levels beyond manufacturing. The mandatory reporting across all private sectors of the economy makes lending among the most comprehensive metrics available, while maintaining industry differences not feasible with nighttime lights. While some businesses do not need loans, banking inputs are usually important for the bigger economic endeavors that policy makers seek to encourage with infrastructure projects. For example, about 85% of organized manufacturing firms in India report having a bank loan.

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Beyond this comprehensive aspect of the RBI data, the availability of financing is often thought to also shape the rate, direction, and location of real economic activity (e.g., King and Levine, 1993a,b; Levine, 1997). This makes it important to also understand how finance adjusts to infrastructure investment. On one hand, finance follows real activity because infrastructure spending can enable business activity that leads to greater loan demand. New branches might also enable funding of investment opportunities through increased lending capacity. However, there are also reasons to believe that the supply of bank credit is not perfectly elastic, at least in the short run (e.g., von Lilienfeld-Toal et al., 2012). Given the importance of local knowledge and expertise to effectively screen loan applicants in the face of asymmetric information, banks would need, for example, to employ more loan officers, particularly in new regions, invest in new bank branch infrastructure, and potentially reorganize their operations as their client base changes. This takes time and can entail significant adjustment costs. How banks and their branch networks adjust to infrastructure investment therefore has the potential to impact the location, magnitude, and timing of economic activity stimulated. Our analysis of loan activity and bank branch expansions speaks to this question.

Our main estimates quantify loan development along the GQ network using econometric models comparable to prior studies. These models measure the net change in total loan activity, inclusive of supply and demand forces. This work contributes to the GQ literature through its universal data and cross-industry comparisons. We find stronger loan growth in districts adjacent to the GQ network compared to those further away, driven largely by an increase in the number of bank loans rather than larger loan sizes. Impacts are strongest in districts where there was new construction (as opposed to upgrades), and dynamic specifications suggest the effect took hold quickly after the upgrades commenced. Moreover, our results hold in IV estimates and are not present in a placebo test using planned, but subsequently delayed, upgrades to the North–South and East–West (NS–EW) highway system. Interaction estimations show that GQ's impact was largest in industries more dependent on external finance.

These results speak to an increase in finance-dependent economic activity arising from improved transportation infrastructure. Indeed, the dynamics of loan data around the reform lend new support for how one interprets the causal nature of prior GQ studies. In terms of magnitude, the growth of bank loans is less than some of the outcomes measured among large manufacturers due to GQ, but loan growth exceeds the impact seen with nighttime lights and the informal sector.

The final analyses of the paper attempt to make headway on how bank branch networks evolved across the GQ network, and the degree to which an inelastic potential supply of capital in the short run may have shaped the economic activity unlocked from GQ's infrastructure investment. We are limited in how much we can disentangle demand and supply because the natural experiment of GQ's construction is not coupled with a second natural experiment regarding the banking sector. Thus, while we are confident in claiming GQ leads causally to a growth in loan activity along the highway system, our results on the potential inelastic supply of capital shaping activity become more speculative.

We use the term ‘supply’ to capture GQ leading to an increase in lending capacity. This increase could come from the extensive margin (in terms of new branch openings) or the intensive margin (in terms of expansion at existing bank branches). Examining RBI data on bank branch counts and branch entry, we observe that the most significant growth in loans along GQ happens before a material growth in new bank branches. Moreover, GQ's impact was largest in areas with higher levels of pre-GQ lending per capita. Together, these results suggest that the supply of capital through new bank branches played a weaker role in the surge of loan activity, consistent with larger adjustment costs in setting up new branches compared to expanding capacity at existing banks.

Our results suggest that financing capacity and infrastructure development are complements in enabling economic activity. In areas with pre-existing bank activity, GQ infrastructure investment unlocked business activity faster, including activity that is more dependent on external finance. By contrast, there is less evidence for the road construction leading to loan demand being met by new bank branches. This could be, for example, because it is easier for banks to scale up on the intensive margin where they already had a presence, as opposed to having to grow at the extensive margin. While suggestive, these results highlight that adjustment costs can lead to differential elasticity of capital supply in response to improved infrastructure investment, shaping which industries and locations economic activity is most likely to enable.

Our study contributes to the literature on the economic impacts of infrastructure projects in developing economies. Studies of GQ upgrades document its importance for the operations and growth of organized manufacturing activity (Datta, 2011; Ghani et al., 2016, 2017; Chatterjee et al., 2021), with resulting stronger allocative efficiency for industries positioned on the network. Alder (2016), Khanna (2016), and Chanda and Kabiraj (2020) examine growth in nighttime luminosity due to GQ upgrades, and Allen and Atkin (2022), Asturias et al. (2019), and Abeberese and Chen (2022) quantify the intra-national trade implications. Naaraayanan and Wolfenzon (2023) examine differential impacts on business groups and stand alone firms, and we describe additional studies later.[1] Beyond India, recent studies find mixed evidence regarding economic effects for non-targeted locations due to transportation infrastructure in China or other developing economies.[2] These studies complement the larger literature on the United States and those undertaken in historical settings.[3] Our study is the first to consider in depth how these massive investments interact with the pre-existing financial conditions and the subsequent local development of loans.

Similar to Agarwal et al. (2023), we also contribute to the finance literature. Prior research documents the impact of local financial development[4] and explores firm dynamics (e.g., Robb and Robinson, 2014; Krishnan et al., 2015; Ayyagari et al., 2017; Akcigit et al., 2022). While these studies establish the causal link between the financial sector and the real economy, our study explores how initial financial conditions shape the impact of exogenous infrastructure spending.

2. India's highways and the GQ project

To meet its transportation needs, India launched its National Highways Development Project (NHDP) in 2001.[5] This project, the largest

[1] A broader literature also evaluates the performance of Indian manufacturing, with some authors noting the constraints of inadequate infrastructure (e.g., Mitra et al., 1998; Ahluwalia, 2000; Besley and Burgess, 2004; Kochhar et al., 2006; Gupta et al., 2008; Gupta and Kumar, 2010; Bloom et al., 2013; Desmet et al., 2015). See also Agarwal et al. (2022).

[2] For example, Brown et al. (2008), Ulimwengu et al. (2009), Roberts et al. (2012), Faber (2014), Baum-Snow et al. (2017), Baum-Snow and Turner (2017), Baum-Snow et al. (2020), Xu and Nakajima (2017), Qin (2017), Aggarwal (2018), Chauvin (2019), and Banerjee et al. (2020). Related literatures consider non-transportation infrastructure investments in developing economies (e.g., Duflo and Pande, 2007; Dinkelman, 2011) and the returns to public capital investment (e.g., Aschauer, 1989; Munell, 1990; Otto and Voss, 1994).

[3] For example, Fernald (1998), Chandra and Thompson (2000), Lahr et al. (2005), Baum-Snow (2007), Michaels (2008), Duranton and Turner (2012), Fretz and Gorgas (2013), Hsu and Zhang (2014), Duranton et al. (2014), Garcia-López et al. (2015), Donaldson and Hornbeck (2016), Holl (2016), Agarwal et al. (2017), Couture et al. (2018), and Donaldson (2018). Redding and Turner (2015) provide a broader review of transportation investments, and Rosenthal and Strange (2004) review agglomeration economies.

[4] For example, Jayaratne and Strahan (1996), Rajan and Zingales (1998), Black and Strahan (2002), Hasan and Marton (2003), Guiso et al. (2004), Burgess and Pande (2005), Paravisini (2008), Hasan et al. (2009), Nguyen (2019), and Greenstone et al. (2020).

[5] This section draws from Ghani et al. (2016).

highway project ever undertaken by India, aimed at improving the GQ network, the North–South and East–West (NS–EW) Corridors, Port Connectivity, and other projects. The NHDP evolved to include seven phases, and we focus on the first two. NHDP Phase I was approved in December 2000 with an initial budget of Rs 30,300 crore (about USD 7 billion in 1999 prices). Phase I planned to improve 5846 km of the GQ network (its total length), 981 km of the NS-EW highway, and 671 km of other national highways. Phase II was approved in December 2003 at an estimated cost of Rs 34,339 crore (2002 prices). This phase planned to improve 6161 km of the NS-EW system and 486 km of other national highways. About 442 km of highway is common between GQ and NS-EW.

The GQ network connects Delhi, Mumbai, Chennai, and Kolkata. Appendix Figure 1 contains a map. The GQ upgrades began in 2001, with a target completion date of 2004, and 128 separate contracts were awarded. In total, 23% of the work was completed by the end of 2002, 80% by 2004, 95% by 2006, and 98% by 2009. Differences in completion were due to initial delays in awarding contracts, land acquisition and zoning challenges, and funding delays.

The NS-EW network spans 7300 km. This network connects Srinagar in the north to Kanyakumari in the south, and Silchar in the east to Porbandar in the west. Upgrades equivalent to 13% of the NS-EW network were initially planned to begin in Phase I alongside GQ upgrades, with the remainder to be completed by 2007. However, work on the NS-EW corridor was pushed into Phase II and later due to issues with land acquisition, zoning permits, etc. In total, 2% of the work was completed by the end of 2002, 4% by 2004, and 10% by 2006. These figures include overlapping portions with GQ that represent about 40% of NS-EW progress by 2006. As of January 2012, 5945 of the 7300 km in the NS-EW project had been completed.

3. Data

We study how GQ impacted the financing of economic activity and how this varied by industry and the initial financial development of districts. To do so, we build a dataset based upon the Basic Statistical Return (BSR)1 A, maintained by the Reserve Bank of India (RBI). BSR-1 A details each loan outstanding (above a threshold), reported annually by every branch of every scheduled commercial bank in India. The data count each bank-borrower relationship separately. The threshold over which individual account data is reported was Rs. 25,000 until 1998 and Rs. 200,000 from 1999 onwards (the latter is about $4000 using historical exchange rates). The universal, comprehensive nature of these financial data exceed most countries, including the United States, and features in research by Cole (2009), Das et al. (2016), Kumar (2016), and Das et al. (2018).

While the micro-data are confidential, the RBI allowed us to aggregate these data for external use. Our aggregations focus on borrowing by private non-financial corporations, sole proprietorships, and partnerships at the district x industry x year level. Districts are administrative subdivisions of Indian states or union territories. We prepare our platform to resemble studies of manufacturing for comparability.[6] Accordingly, the core sample contains 311 districts that account for over 80% of the population and 90% of manufacturing. Excluded districts have limited economic activity. Districts in our analysis average around 2.7 million in population with a land area of 10.1k km squared.[7]

Industry categories are two-digit NIC for manufacturing and one-digit for all other industry groups. Our analyses concentrate on 1999 to 2009 when almost all of the work was completed along the GQ highway and only a minority of work was completed on the NS-EW highway.

Through the RBI, we also obtained data on the opening and closures of bank branches by district via the Master Office File. The data include more than 151k branch openings, many of which predate 1999, and 5.8k branch closures. We match about 85% of the branch data to our focal districts and create an estimate of operating branches by district and year. The average district in our sample has 123 operating branches and 6.8 annual openings during 1999–2009.

4. Analysis of net loan activity

4.1. Baseline estimations

We use long-differenced estimations, typical of studies where treatment is not a sharp event, and compare district x industry loan activity in 1999, just prior to the start of the GQ upgrades, with loan activity in 2009. About 98% of the upgrades were completed by 2009. Indexing districts with d and industries with i,

$$\Delta Y_{d,i} = \sum_{j \in D} \beta_j \cdot (0,1) GQDist_{d,j} + \eta_i + \varepsilon_{d,i}. \quad (1)$$

$\Delta Y_{d,i}$ is the change in the log loan volume in a district-industry from 1999 to 2009. We also decompose this change into the changes in the number of loans versus average loan size.

Our explanatory variables in the set D of distance bands comprise three bands with respect to GQ: a nodal district (9 districts), 0–10 km from GQ (69 districts), and 10–50 km from GQ (37 districts). Following Datta (2011), the 9 nodal districts include contiguous suburbs of Delhi, Mumbai, Chennai, and Kolkata placed on GQ by design. The excluded category includes 196 districts more than 50 km from the GQ network. The β_j coefficients thus measure the average change in outcome $Y_{d,i}$ for each distance band relative to the reference category. Our focus is on the non-nodal districts. We measure and report effects for nodal districts, but their interpretation is difficult as the highway projects were intended to improve their connectivity. The appendix describes the data further.

All estimations control for industry fixed effects η_i, which is equivalent to including industry-year fixed effects in a panel regression. These fixed effects control for different growth rates of industries that might be spatially correlated with distance to highways. Regressions further control for the baseline level of financial development of each district to flexibly capture economic convergence across districts. Observations are weighted by log district population in 2000.

Table 1 reports results with specification (1). Columns 1–4 consider the change in log loan volume for a district-industry over the 10-year period. Columns 5 and 6 separate out this overall change into the parts coming from the change in log number of loans and the change in log of the average loan size. Column 2 introduces state-industry fixed effects, which are equivalent to including state-industry-year fixed effects in a panel regression. Column 2 therefore controls for time-varying unobserved differences in state-industry cells such as state policies (in general or towards certain industries), business cycles and growth, and so forth that might be correlated with proximity to the GQ. Identification in these estimations comes solely from within-state-industry variation in the proximity of districts to GQ highways.

While we cannot include district fixed effects, Column 3 includes quartiles of district-level factors that might contribute to different growth rates and could be unevenly distributed spatially. These controls include district population, percentage of population in urban areas, shortest distance to a state or national highway, shortest distance to a railroad, a composite index of local infrastructure quality, and the share of households with bank accounts. Finally, our most stringent specifications in Columns 4–6 include all fixed effects together.

[6] See Fernandes and Pakes (2008), Hsieh and Klenow (2009, 2014), Hasan and Jandoc (2010), Kathuria et al. (2010), Nataraj (2011), Ghani et al. (2014) and Ghani et al. (2016).

[7] In the 2011 Census, India's 640 districts held an average population of 1.9 m and land area of 4.9k km squared, about 19x and 1.8x the population and land area of a US county, respectively. The districts in our sample are larger. The 35 states of India average 6x and 0.57x the average population and land area of US states, respectively.

Table 1
Impact of GQ on Financial Development.

	Change in log loan volume				Change in log count	Change in log av size
	(1)	(2)	(3)	(4)	(5)	(6)
A. Intensive margin for district-industries with 1999 and 2009 lending						
Nodal districts	1.792+++ (0.307)	1.705+++ (0.343)	1.372+++ (0.323)	1.398+++ (0.360)	0.567+++ (0.185)	0.976+++ (0.202)
Districts 0–10 km from GQ highway	0.315+++ (0.091)	0.317+++ (0.108)	0.237++ (0.091)	0.196++ (0.089)	0.150+++ (0.055)	0.045 (0.050)
Districts 10–50 km from GQ highway	−0.144 (0.128)	−0.079 (0.126)	−0.006 (0.108)	0.004 (0.105)	0.100 (0.062)	−0.095 (0.061)
Linear difference of 0–10 to 10–50 km	0.459+++ (0.141)	0.396+++ (0.141)	0.243++ (0.123)	0.192 (0.119)	0.050 (0.070)	0.140+ (0.071)
B. Extended sample allowing entry or exit from district-industries						
Nodal districts	3.083+++ (0.355)	3.009+++ (0.417)	1.919+++ (0.372)	1.965+++ (0.431)	0.651+++ (0.194)	1.134+++ (0.237)
Districts 0–10 km from GQ highway	0.452+++ (0.152)	0.483+++ (0.175)	0.333+++ (0.126)	0.294++ (0.123)	0.153+++ (0.052)	0.112 (0.074)
Districts 10–50 km from GQ highway	−0.216 (0.193)	−0.050 (0.197)	0.010 (0.164)	0.053 (0.163)	0.092 (0.061)	−0.050 (0.103)
Linear difference of 0–10 to 10–50 km	0.668+++ (0.221)	0.533++ (0.226)	0.323+ (0.178)	0.241 (0.174)	0.062 (0.066)	0.162 (0.112)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State x Industry Fixed Effects	No	Yes	No	Yes	Yes	Yes
Fixed Effects for District Traits	No	No	Yes	Yes	Yes	Yes

This table reports the results of long-differenced estimations between 1999 and 2009. Panel A includes district-industries with positive loan activity in 1999 and 2009 (9050 observations). Panel B extends the sample to allow for entry or exit of lending by recoding zero loan activity to a value of 0.1 (12,403 observations). The dependent variable for Columns 1 – 4 is the log change in loan credit for a district-industry over the 10-year period; the dependent variable in Column 5 is the log change in loan counts and in Column 6 is the log change in average loan size. Panel B winsorizes these changes at their 0.1% and 99.9% levels. Regressions model three sets of districts (i) Nodal districts that the GQ highway network connects; (ii) Non-nodal districts that are 0–10 km from the GQ highway network; and (iii) Non-nodal districts that are 10–50 km from the GQ network. These coefficients are measured relative to districts more than 50 km from the GQ network. Regressions include controls for baseline level of financial development and industry fixed effects, which is equivalent to including industry-x-year fixed effects in a panel regression. Regressions in Columns 2, 4, 5, and 6 further include state-x-industry fixed effects, which is equivalent to including state-x-industry-x-year fixed effects in a panel regression. Columns 3-6 include fixed effects for quartiles of district-level covariates, all measured in year 2000: district population, percentage of population in urban areas, shortest distance to a state or national highway, shortest distance to a railroad, a composite index of local infrastructure quality, and share of households with bank accounts. Observations are weighted by log district population in 2000. Standard errors are clustered by district and reported below coefficients; *, **, and *** refer to statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A analyzes 9050 district-industries with loan activity in both 1999 and 2009. Looking across Table 1, the first row shows enormous increases in loan activity for nodal districts after GQ implementation. We do not emphasize these results as the upgrades were done with the explicit goal of improving the connectivity of nodal cities. The higher standard errors of these estimates, compared to the rows beneath them, reflect that there are only nine nodal districts. Yet, these changes in financing activity are substantial enough in size that one can reject statistically that the growth is zero.

Our primary emphasis is on the second row that considers non-nodal districts 0–10 km from GQ. To some degree, the upgrades of the GQ network are exogenous for these districts. Column 4 suggests a 20% increase in aggregate loan volume for these districts relative to districts more than 50 km from the GQ system over the 10-year period. Columns 5 and 6 show that this is mostly driven by increases in loan counts rather than changes in loan size. For comparison, the third row provides the results for districts that are 10–50 km from the GQ network. None of the effects that we measure for districts within 0–10 km of GQ are present in this next distance band.

We further report the linear difference between districts that are 0–10 versus 10–50 km from the GQ network. These differences are also sizable in economic magnitude, although we cannot reject at a 10% level that the patterns are the same in our most stringent specification in Column 4 (p-value = 0.106).

In Panel B, we examine the robustness of our focus on district-industries with positive loan volume. We now include 12,403 district-industries, recoding zero loan volume to 0.1 to enable the log transformation. We further winsorize changes in the dependent variable at their 0.1% and 99.9% levels. These estimates are even stronger, implying a nearly 30% increase in loan volume for districts within 10 km of the GQ network relative to districts more than 50 km away.[8]

While the techniques and sample periods vary across studies, Table 1's magnitudes sit intuitively in the middle of existing estimates of GQ's impact. Our most stringent specifications estimate a relative growth in loan activity of about 22% for district-industries along the GQ highway. Studies of the formal manufacturing sector find larger effects of GQ upgrades, with for example Ghani et al. (2016) estimating an output growth for 0–10 km districts of a bit less than 50% from the GQ's start until 2009. Asher et al. (2020) describe a large loss of forest cover. Yet, Ghani et al. (2017) and Chatterjee et al. (2021) measure that the large gains for formal manufacturing firms from the GQ upgrades are not evident in the informal manufacturing sector. Studies of luminosity also find smaller effects, closer to a 5% growth.[9]

Appendix Tables 1–8 show robustness checks and extensions: for example, using alternative weighting strategies, using Conley (1999, 2008) spatial errors as implemented by Fetzer (2014), using one-digit

[8] The RBI data capture realized loans and cannot speak to the frequency of financing use by firms. Tabulations from the Annual Survey of Industries (ASI) provide suggestive evidence. Contemporaneous to the organized manufacturing growth documented in multiple studies, the share of ASI plants in 0–10 km districts that held a loan fell slightly from 92% in 2000 to 90% in 2010. For young plants, the share with loans rose slightly from 22% to 23%. This stability in loan shares suggest the financing growth likely followed more from differences in growth rates across industries, which we find evidence of in Section 5.

[9] Alder (2016) finds GQ Highways are associated with 5.1% change in luminosity in 2000–2009, corresponding to a 1.53 percent change in income. Khanna (2016) and Chanda and Kabiraj (2020) show the decline in luminosity with distance from GQ. Melecky et al. (2018) consider other social measures.

Table 2
Comparison with of GQ with NS-EW highway system.

	Change in log loan volume				Change in log count	Change in log av size
	(1)	(2)	(3)	(4)	(5)	(6)
Nodal GQ districts	1.311+++	1.309+++	0.966+++	1.113+++	0.425++	0.840+++
	(0.297)	(0.358)	(0.326)	(0.379)	(0.211)	(0.235)
Districts 0–10 km from GQ highway	0.325+++	0.296+++	0.233+++	0.193++	0.141++	0.046
	(0.087)	(0.102)	(0.088)	(0.085)	(0.056)	(0.048)
Districts 10–50 km from GQ highway	−0.115	−0.056	0.003	0.017	0.104+	−0.088
	(0.130)	(0.125)	(0.107)	(0.103)	(0.061)	(0.061)
Nodal NS-EW districts	1.018+++	0.797+	0.885+++	0.684++	0.304+	0.344
	(0.281)	(0.406)	(0.287)	(0.347)	(0.178)	(0.251)
Districts 0–10 km from NS-EW highway	0.070	−0.028	0.027	0.023	−0.014	0.020
	(0.093)	(0.095)	(0.085)	(0.082)	(0.049)	(0.051)
Districts 10–50 km from NS-EW highway	−0.079	−0.228++	−0.024	−0.065	−0.080	0.003
	(0.107)	(0.101)	(0.093)	(0.091)	(0.054)	(0.053)
P Value: GQ 0–10 = NS-EW 0–10	0.038	0.013	0.071	0.111	0.014	0.679
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
State x industry fixed effects	No	Yes	No	Yes	Yes	Yes
Fixed effects for district traits	No	No	Yes	Yes	Yes	Yes

See Table 1. Estimations include district-industries with positive loan activity in 1999 and 2009 (9050 observations). This table contrasts distance from the GQ highway network with distance from the NS-EW highway network that was planned for partial upgrade at the same time as the GQ project but was then delayed. Coefficients are measured relative to districts more than 50 km from both highway systems.

NIC codes, using alternative spatial bands, using different controls for initial conditions, and using Poisson pseudo-maximum likelihood regressions. We additionally report dynamic specifications showing most of the loan surge for 0–10 km districts happens by 2005, which is akin to the rapid plant inventory and input sourcing impact measured by Datta (2011) or the plant entry estimations of Ghani et al. (2016). Most of the new loan activity is also in the segments that experienced new construction vs. upgrades.

4.2. Comparison of GQ to NS-EW highway system

The stability of the baseline results is reassuring, but we may not observe all of the factors that policy makers used when choosing to upgrade the GQ network and designing its layout. For example, policy makers might have known about the latent growth potential of districts and attempted to aid that development through highway investment.

We address this concern by comparing districts proximate to the GQ network to districts proximate to the NS-EW network that was not upgraded. This comparison to the NS-EW corridor provides a stronger potential reference group than districts further away from GQ, as its upgrades were planned to start close to those of the GQ network before being delayed. The identification assumption is that unobserved conditions such as regional growth potential along the GQ network were similar to those for the NS-EW system (conditional on covariates).

We identified the segments of the NS-EW project that were to begin with the GQ upgrades versus those that were to follow in the next phase. Of the 90 districts lying within 0–10 km of the NS-EW network, 40 districts are covered in the 48 NS-EW projects identified for Phase I. Appendix Table 9 compares characteristics of non-nodal districts along the GQ and NS-EW highways. While NS-EW districts have lower population on average, they are similar in terms of other district traits, including the level and growth of loan volumes in the pre-period. The log count of bank branches per capita in 2000 is very similar. The top of Fig. 1 also shows parallel loan trends from 1996 to 2000, when GQ upgrades commenced.

Table 2 reports regressions that augment specification (1) to include three additional indicator variables regarding proximity to the NS-EW system. Indicator variables are not mutually exclusive, as some districts lie within 50 km of both networks, and coefficients are measured relative to districts more than 50 km from both networks. The first three rows show little quantitative change in our measured impact from GQ upgrades, implying that the baseline results are not sensitive to the change in reference group. The fourth row shows that nodal districts on NS-EW also experience robust loan growth, confirming our hesitation to infer much from coefficients for the nodal GQ districts.

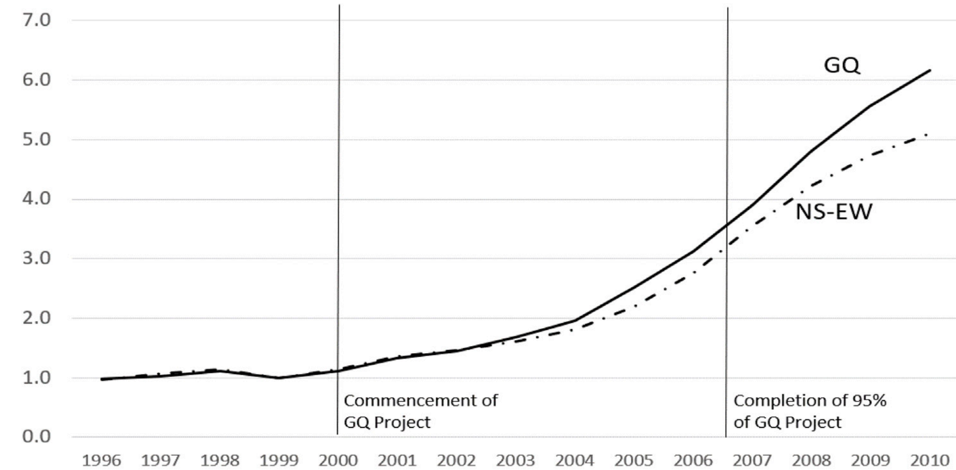
By contrast, estimates in the last two rows are very comforting for our primary results. None of the loan growth evident for districts in close proximity to GQ are evident for districts lying on NS-EW, even if these latter districts were scheduled for a contemporaneous upgrade. The placebo-like coefficients along the NS-EW highway are small and never statistically significant. The lack of precision is not due to too few districts along the NS-EW system, as the district counts are comparable to the distance bands along the GQ network and the standard errors are of very similar magnitude. With the precision that we estimate the positive responses along the GQ network, we estimate a lack of change along the NS-EW corridor. The bottom row further shows that in most specifications we reject that the 0–10 km bands are equal to each other. Appendix Table 10 shows similar findings when extending Panel B of Table 1 to model NS-EW proximity.

4.3. Straight-line instrumental variables estimations

Another check for the endogeneity of road placement comes through IV analyses. Such analyses address a concern that GQ planners were better able to shape the network layout to touch upon growing regions and that NS-EW planners were not as good at this, had less discretion, or had fewer good choices. Duranton and Turner (2011) highlight endogenous placement could bias findings in either direction. Infrastructure investments may target the development of regions with high growth potential, which would upwardly bias measurements of economic effects that do not control for this underlying potential. However, infrastructure investments that target struggling regions or non-optimal locations (i.e., ‘bridges to nowhere’) would bias results downward.

Rather than use the actual GQ layout, Appendix Table 11 instruments for a district being 0–10 km from GQ with it being near a straight line between the nodal districts of the GQ network. The idea behind this IV approach is that endogenous placement choices in terms of weaving the highway towards promising districts (or struggling districts) can be overcome by focusing on what the layout would have been if the network were established based upon minimal distances only. This approach relies on the positions of the nodal cities not being established as a consequence of the transportation network. Similar to Banerjee et al. (2020), the four nodal cities of the GQ network were established hundreds or thousands of years ago, minimizing this concern. The IV estimates show strong first stages, with second stages somewhat larger

A. Credit in non-Nodal Districts on GQ and NS-EW Highways relative to 1999



B. Growth of non-Nodal Banking on GQ relative to NS-EW

	Credit	Accounts	Branches	Credit / Branch	Accounts / Branch
1999	1.00	1.00	1.00	1.00	1.00
2000	0.97	0.99	1.00	0.97	0.99
2001	0.98	1.03	1.00	0.97	1.02
2002	0.99	1.10	1.01	0.98	1.09
2003	1.05	1.14	1.00	1.05	1.14
2004	1.08	1.17	1.01	1.07	1.16
2005	1.15	1.25	1.04	1.11	1.21
2006	1.13	1.23	1.07	1.09	1.15
2007	1.10	1.21	1.13	1.01	1.07
2008	1.14	1.21	1.07	1.04	1.13
2009	1.18	1.24	1.08	1.10	1.14

Fig. 1. Banking growth in non-nodal districts along indian highways.
Notes: Panel A plots credit volumes in non-Nodal districts along the two highway systems relative to year 1999, just prior to GQ project commencement. Panel B tabulates the relative growth of banking outcomes on GQ from 1999 compared to NS-EW. The appendix provides base values.

than the OLS estimates. We do not, however, reject the hypothesis that the OLS and IV estimates are the same. These results provide confidence that the GQ investment impacted loan activity in a causal manner.

5. Industry heterogeneity

Our estimations thus far have expanded the analysis of GQ beyond manufacturing and controlled for industry trends, but we can also characterize the differential growth rate across industries in loan development. Beginning with Rajan and Zingales (1998), many studies quantify whether growth in activity is strongest for the industries likely to be the most dependent upon financing. We adopt the spirit of this methodology and characterize whether loan activity growth during 1999–2009 is strongest in industries where the observed cost per establishment is highest. In many respects, our cost metric is indicative of the average scale of an establishment in an industry, with the assumption that external financing is more likely to be needed in higher average scale sectors.

We measure average cost per establishment by combining data from the National Sample Survey and the Annual Survey of Industries. These data are available for manufacturing and services industries (n=7549 district-industries), and thus we do not incorporate agriculture, fishing, mining, utility supply, and construction (NIC 1, 5, 13, 40, 45). We average values for the 2000–01 and 2009–10 end points of our sample. Our main interaction metric is the log average cost per establishment, with costs aggregating outlays for land, assets, labour, and raw materials. We demean these cost averages to keep main effects for district proximity to the GQ network similar to our baseline analysis.

Column 1 of Table 3 repeats our most stringent specification (Column 4 of Table 1) with the added interactions of the GQ variables and average cost per establishment in an industry. The state-industry fixed effects absorb the main effect of industry interactions. The main effects for the GQ network in the first three rows are similar to Table 1. Additionally, the interaction term on 0–10 km from GQ is well measured and suggests an industry with 10% higher costs has an additional 3% greater loan growth ($= 0.1 * 0.065/0.213$) when in close proximity to the GQ network during upgrades.

Columns 2–5 provide extensions. Columns 2 and 3 separate land and assets, which tend to be more fixed inputs, from the operating components of labour costs and raw materials. While the interaction term is stronger in the former, these differences are not substantial. Column 4 further includes interactions of the GQ variables with a measure of average industry cost per unit of output, which does not impact the results. Finally, Column 5 instead uses a dummy variable for industry cost per establishment being above the median, showing that most of the original main effect was concentrated in the upper half of the average cost distribution. Appendix Tables 12 and 13 show these industry interactions are also strongest in the initial years of GQ investment, similar to the main effects, and are not evident along the NS-EW system.

Table 3
Industry heterogeneity.

	Baseline model with industry interactions (1)	Focus on land and asset inputs (2)	Focus on labour and raw material inputs (3)	Column 1 with a control for cost shares of output (4)	Column 1 using dummy variable for above median (5)
Nodal GQ districts	1.476+++	1.481+++	1.474+++	1.473+++	1.256+++
	(0.356)	(0.357)	(0.356)	(0.357)	(0.362)
Districts 0–10 km from GQ highway	0.213++	0.216++	0.211++	0.213++	0.124
	(0.097)	(0.098)	(0.096)	(0.097)	(0.087)
Districts 10–50 km from GQ highway	−0.002	−0.002	−0.002	−0.002	−0.027
	(0.113)	(0.114)	(0.112)	(0.112)	(0.104)
Interacted with industry cost per establishment					
Nodal GQ districts	0.227+++	0.301+++	0.134+++	0.300+++	0.463+++
	(0.055)	(0.064)	(0.039)	(0.061)	(0.166)
Districts 0–10 km from GQ highway	0.065++	0.076++	0.045+	0.072++	0.185++
	(0.032)	(0.037)	(0.025)	(0.035)	(0.085)
Districts 10–50 km from GQ highway	−0.008	−0.004	−0.002	−0.015	0.059
	(0.039)	(0.046)	(0.029)	(0.046)	(0.096)
P Value: GQ 0–10 = GQ 10–50 main effects	0.092	0.091	0.095	0.092	0.189
P Value: GQ 0–10 = GQ 10–50 interactions	0.096	0.109	0.138	0.303	0.239
Observations	7549	7549	7549	7549	7549
Fixed effects for district traits	Yes	Yes	Yes	Yes	Yes
State x industry fixed effects	Yes	Yes	Yes	Yes	Yes

See Table 1. Estimations include district-industries with positive loan activity in 1999 and 2009 that are also mapped to industry level cost share data. Estimations further interact regressors with industry-level cost shares as described by column headers. Cost shares are demeaned prior to interaction to restore main effects.

Table 4
Industry analysis with initial district financial development.

	Baseline model with industry interactions (1)	Focus on land and asset inputs (2)	Focus on labour and raw material inputs (3)	Column 1 with a control for cost shares of output (4)	Column 1 using dummy variable for above median (5)
Nodal districts	1.490+++	1.495+++	1.488+++	1.487+++	1.272+++
	(0.358)	(0.358)	(0.357)	(0.358)	(0.363)
Districts 0–10 km from GQ highway	0.250+	0.252+	0.248+	0.249+	0.123
* above median financial dev. pre GQ	(0.133)	(0.134)	(0.133)	(0.133)	(0.122)
Districts 0–10 km from GQ highway	0.137	0.135	0.137	0.137	0.138
* below median financial dev. pre GQ	(0.111)	(0.113)	(0.109)	(0.111)	(0.103)
Districts 10–50 km from GQ highway	−0.004	−0.003	−0.004	−0.004	−0.029
	(0.113)	(0.114)	(0.112)	(0.113)	(0.104)
Interacted with industry cost per establishment					
Nodal districts	0.225+++	0.300+++	0.133+++	0.299+++	0.460+++
	(0.054)	(0.063)	(0.039)	(0.061)	(0.165)
Districts 0–10 km from GQ highway	0.097+++	0.115+++	0.069+++	0.105+++	0.268+++
* above median financial dev. pre GQ	(0.033)	(0.038)	(0.026)	(0.035)	(0.095)
Districts 0–10 km from GQ highway	−0.009	−0.015	−0.007	−0.004	0.001
* below median financial dev. pre GQ	(0.050)	(0.057)	(0.038)	(0.054)	(0.119)
Districts 10–50 km from GQ highway	−0.008	−0.005	−0.002	−0.015	0.059
	(0.039)	(0.046)	(0.029)	(0.046)	(0.096)
Observations	7549	7549	7549	7549	7549
Fixed effects for district traits	Yes	Yes	Yes	Yes	Yes
State x industry fixed effects	Yes	Yes	Yes	Yes	Yes

See Tables 1 and 3. This table separates GQ 0–10 km districts by median financial development before the start of the GQ upgrades. Financial development is measured by loan volume per capita.

6. Complementarity of finance and infrastructure

Growth in loan volume following the GQ upgrades is likely to be shaped by both demand and supply factors. Demand for loans may rise with the entry and expansion of firms along the highway system, with financial capital following real activity. Loan growth can also occur if banks expand their lending capacity through the creation of new branches and expansion of existing ones. This greater lending capacity (e.g., loan officers) looking for local opportunities could feasibly also spur new real activity. As noted in the introduction, the GQ upgrades only allow us to make a causal assessment of the net effect as we do not have exogenous variation in the banking sector. However, this section provides additional data and analyses to shed some light on the distribution of lending activity across new versus existing branches, providing suggestive evidence that the distribution of bank activity in the pre-GQ period may have shaped post-GQ growth of loan activity.

We first consider new bank branches. As physical proximity helps overcome asymmetric information challenges, the development of new branches is an important lever for extending financial access to new regions. Panel B of Fig. 1 reports the relative growth of loan and branch activity in the 0–10 km GQ districts relative to their NS-EW peers. To construct these measures, we first summed activity in districts along the two highways and measured their relative growth from 1999, as is shown for the credit series in Panel A of Fig. 1. We then divided development along GQ by the development along NS-EW to provide a simple statistic on their divergence. Appendix Tables 14a–14d show each step in this tabulation and provide similar data on all distance bands.

Compared to the large surges in credit volumes and accounts as GQ starts, Panel B shows that growth in bank branches comes later and is more muted. Indeed, most or all of the relative loan differential occurs by 2005, while bank branch growth starts to pick up at this point. Consequently, the last two columns report that most of the initial loan growth is coming through an increase in credit and accounts per branch. While not definitive, this descriptive analysis is consistent with adjustment costs associated with expanding bank branch networks leading to a more inelastic supply of credit. The growth in average branch size suggests the more elastic response was coupled with existing branches proximate to GQ expansion.

Second, Table 4 repeats the industry estimations of Table 3 with a split based upon whether the district was more developed financially at the start of the GQ upgrade, measured as being above the district-level median in loans per capita. The industry differential is stronger in districts that had greater initial loan activity. Recognizing we should be cautious given the multiple uses of the RBI data, this pattern is again consistent with lending being easiest to scale in settings where established industries and banks faced lower adjustment costs.

7. Conclusions

Although our understanding of how infrastructure investment can facilitate real economic activity has advanced greatly in recent years, less is known about how complementary factors such as the availability of bank finance respond to increased infrastructure investment. Such an understanding is important, because the availability of finance has been shown to shape the rate, direction, and location of real economic activity. We overcome previous empirical barriers by combining unique data from the Reserve Bank of India with the upgrades of India's GQ network.

The GQ upgrades brought about substantial growth in finance-dependent economic activity for non-nodal districts located 0–10 km from the network, relative to those located further away. The results are strongest for areas where there was new construction and in industries most likely to benefit from bank finance; most of the growth came in the first few years after the upgrades commenced. Placebo tests using the NS-EW highway network, as well straight-line IV analyses, support a causal interpretation. These results using loans from many sectors, and controlling for aggregate industry trends, sit in-between studies of GQ that have mostly considered the extremes of organized manufacturing advancement and growth in nighttime lights.

While our causal assessment is limited to the net growth in loans, we also make forays to characterize how the disproportionate share of the response came from districts with existing bank branches and with greater pre-GQ lending. Entry of new bank branches lagged the GQ construction and appeared to play a more muted role, with most of the initial surge in loan supply coming through a growth in average bank branch size. Our results are consistent with larger adjustment costs associated with new branches relative to existing ones shaping the elasticity of credit supply and hence the locations where GQ-enabled opportunities were most able to get financed.

Motivated by the promise of using infrastructure to reduce disparity across regions, many policy makers ask a question along the lines of "build it and they will come?" Our analysis of the GQ experience suggests a nuanced answer. To begin, the very rapid and substantial response in loans in precisely the industries and locations predicted suggests a strong elasticity in the supply of credit to meet demand enabled by the GQ. However, we also find descriptive evidence that initial credit supply growth is tightly linked to places where banking loans were already happening before GQ. This suggests that understanding how finance responds to infrastructure may be key to understanding the distributional effects of infrastructure investments. If adjustment costs are substantial, the complementarity between finance and infrastructure can exacerbate, rather than attenuate, pre-existing differences in economic activity prior to infrastructure investment, at least in the short run.

CRediT authorship contribution statement

Abhiman Das: Data, Conceptualization, Methodology. **Ejaz Ghani:** Data, Conceptualization, Funding acquisition. **Arti Grover:** Data, Conceptualization, Methodology, Software, Analysis. **William Kerr:** Conceptualization, Methodology, Software, Analysis, Writing. **Ramana Nanda:** Conceptualization, Methodology, Software, Analysis, Writing.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jue.2023.103593.

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