

The Road to Riches: The Employment Effects of Road Construction in Rural India *

PRELIMINARY - PLEASE DO NOT CITE WITHOUT PERMISSION

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Abstract

Despite a broad consensus that high transportation costs are a large barrier to economic development, many of the world's poor live in rural communities without paved roads, impeding their access to outside markets and public services. Nevertheless, the impact of rural roads on economic activity has proven difficult for economists to assess. In this paper we take advantage of the allocation rules of a large-scale rural road construction program in India to estimate the impact of village feeder roads on nonfarm economic activity. We find that new paved roads lead to large increases in village employment. Roads lead to an increase in firm size, suggesting that firms are inefficiently small when transportation costs are high. Further, we find evidence that roads are most effective in promoting employment in the presence of electricity, suggesting complementarities between infrastructural investments.

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1 Introduction

Universal access to paved roads, much like clean water and consistent electricity, remains an unreachd goal in many developing countries, particularly in rural areas. Fifty-four years after independence, 33% of Indian villages did not have a paved approach road in 2001 (Population Census). The absence of such infrastructure raises trade costs and reduces access to both outside markets and government services. The high costs of infrastructure investments mean that both economic and political considerations tend to guide their placement, posing challenges for the estimation of their impact. In this paper we exploit the allocation rules of a large-scale rural road construction program in India to estimate the impact of feeder roads on rural nonfarm economic activity.

The Pradhan Mantri Gram Sadak Yojana (PMGSY) – the Prime Minister’s Village Road Program – was launched in 2000 with the goal of providing all-weather access to unconnected habitations across India. The government developed specific guidelines to prioritize large, unconnected habitations: those with populations above 1000 were to receive highest priority, followed by those with populations above 500. Eligibility lists were to be prepared at the district level, with the largest habitations not already connected to high quality roads receiving the highest priority in each district. At the outset, about 170,000 habitations were eligible for the program, a number that has grown as the guidelines have been expanded to include smaller habitations. By March 2011, over 420,000 km of roads had been sanctioned to connect nearly 110,000 habitations at a cost of 1.19 trillion INR (\$27 billion) (Ministry of Rural Development, 2012).

The program rules provide us with three distinct ways to estimate the impact of a new road on rural economic activity. First, we provide OLS estimates of the relationship between PMGSY road construction and employment growth, based on the timing of road construction in villages that eventually received roads under PMGSY. However, endogenous timing of road

construction creates unknown bias in these estimates. We address this in two ways. Program rules create discontinuities in the likelihood of receiving a road at populations of 500 and 1000, allowing us to use a fuzzy regression discontinuity approach to estimate the impact. Finally, we take advantage of the fact that planning and implementation was carried out at the district level. The probability of receiving a road early in the program was therefore a function not only of village size, but also of the relative size of a village within its district. We are thus able to instrument for road treatment with the within-district population rank, controlling flexibly for population.

We construct a new dataset that combines data on road construction with village characteristics and economic outcomes. We match Population Census data (1991, 2001) to Economic Census data (1998, 2005) to measure the economic consequences of road construction during the first five years of the PMGSY (2000-04). The Economic Census is a complete enumeration of nonfarm economic establishments in India, covering over 4000 towns and 500,000 villages. It contains, among other variables, data on employment and industrial sector for each establishment, allowing us to estimate the effect of rural roads on employment growth, firm size and formality.

We interpret the construction of a village feeder road under the PMGSY as a large reduction in the costs of moving goods, capital and people to and from a village. Theoretically, it is unclear what impact such a change in factor mobility should have on village economic activity. For example, out-migration may increase as the costs of travel decrease, or fall as economic opportunity expands in the village. Nonfarm employment may grow as firms serving outside demand now face sufficiently low transportation costs to be competitive in outside markets; alternatively, villages may further specialize in agriculture as trade for outside goods becomes more feasible. Increasing returns to scale, such as those due to fixed costs, would predict that certain firms may only exist when transport costs are low enough to enable them to access markets beyond the confines of a village. Thus road construction may

not result in the specialization predicted by simple trade models but rather diversification of the village economy as it becomes integrated into a larger trade network.

We find that the construction of a road results in a significant increase in nonfarm village employment. IV estimates predict greater than 50 percent growth in nonfarm employment upon receiving a road. As we assign treatment based on road completion, we interpret these not as temporary increases due to ongoing construction but medium-term changes in the level of village employment.

In addition to aggregate nonfarm employment, we find evidence that roads facilitate significant structural transformation and diversification of the local economy. Average village firm size increases, as does the number of industries present in the village. These findings are consistent with evidence from Nepal suggesting that villages closer to cities serve much larger markets, with greater specialization of household economic activities but greater diversification at the village level (Fafchamps and Shilpi, 2005). Further, we provide evidence that growth is higher in villages that also have a supply of electricity, suggesting significant complementarities between transportation and power infrastructure.

We also provide new estimates of the cost effectiveness of rural road construction. Under the assumption of no positive or negative employment spillovers to non-treated villages, we find that \$1,000,000 in rural road construction generates between 500 and 700 nonfarm jobs, or approximately \$1400 to \$2000 per non-farm job. Given that India's per capita GDP in 2005 was \$732, our findings suggest very high returns to rural road construction, a conclusion supported by other attempts to estimate the returns to infrastructure investment (Fan and Hazell, 2001). These results should be interpreted with caution, as we do not observe concurrent changes to agricultural employment, and thus are unable to estimate changes in total village employment.

The rest of the paper proceeds as follows: Section 2 summarizes the most relevant literature on transport costs and rural roads. Section 3 provides a description of the PMGSY

rural road construction program. Section 4 describes our empirical strategies. Section 5 explains the data used. Section 6 presents results and discussion. Section 7 concludes.

2 Literature

Recent years have seen a renewed interest in the importance of transportation costs in facilitating growth and development. Limao and Venables (2001) use quotes from a shipping company and other sources of data to estimate the impact of inter-country transportation costs on trade flows, concluding that much of the low trade volume in sub-Saharan Africa is due to high transportation costs that result from poor quality infrastructure. Djankov et al. (2010) estimate that every additional day required to ship a container between two countries is associated with a reduction in bilateral trade of more than 1%, in addition to causing a distortion in trade away from time-sensitive exports. Intra-national transport costs exacerbate the challenge of realizing gains from trade; Atkin and Donaldson (2012) estimate that internal trade costs in Ethiopia and Nigeria are 7-15 times larger than in the United States, greatly reducing the benefits of globalization.

Infrastructure has long been one of the priorities of economic development policy and research: fully 15% of World Bank spending between 1995 and 2005 was dedicated to infrastructure projects, with 42% of that amount spent in China and India alone (The World Bank, 2007). Recent research has utilized novel identification strategies to investigate the link between the expansion of infrastructure and local economic performance. Banerjee et al. (2012a) examine the impact of railroads in China, finding that while railroads caused a level increase in income, nearby locations grew no faster than farther locations during a nearly 20 year period of rapid economic growth. Storeygard (2012) interacts global oil price shocks with distances to the nearest port to investigate the impact of transport costs on urban economic activity in Africa, finding a significant inverse relationship between transport costs

and urban economic output, as proxied by nighttime luminosity. Donaldson (2012) develops a multi-region, multi-commodity trade model to assess the impact of railroad construction in colonial India, estimating that the expansion of the railroad network into a region increased real income by approximately 16% and greatly reduced trade costs. Michaels (2008) finds that the construction of the US Interstate Highway System generates sectoral and wage growth consistent with standard trade theory.

Another strand of research estimates the impact of changes in market access rather than average transportation costs generally. Redding and Sturm (2008) find that cities close to the border between West and East Germany experienced population loss relative to cities further from the border whose market access was less impeded by the partition of Germany following World War II. Hornbeck and Donaldson (2012) seek to unite the market access literature with the infrastructure literature by estimating the impact of railroads on agricultural land values using a market access approach, finding that the railroad network had by 1890 more than tripled the total value of agricultural land in the United States.

Of course, there are many reasons why rural roads may have very different economic effects when compared to core infrastructure projects such as interstate highways and long-distance railroads. Casaburi et al. (2012) use a fuzzy regression discontinuity design to examine the effect of village feeder roads on agricultural markets, finding that such roads significantly lower market prices of local agricultural goods. Gollin and Rogerson (2010) build a multi-sector model and calibrate it using data from Uganda to understand the relationship between agricultural productivity, transport costs and economic activity. They predict that high transport costs produce inefficiently high specialization in agriculture, and that investments in road infrastructure would lead to significant reallocation of labor to the nonfarm economy. Khandker et al. (2009) use propensity score matching to evaluate the impact of a rural road program in Bangladesh, estimating that receiving a road lowers village poverty by 5-6% while increasing household consumption by 8-10%, although subsequent work suggests

that some of these gains may not persist over time (Khandker and Koolwal, 2011). Most closely related to this paper, Banerjee et al. (2012b) study the impact of the PMGSY on a broad range of outcomes in a sample of 267 villages in Uttar Pradesh. They find that road construction results in greater access to government services, lower consumer prices, higher agricultural prices, increased employment outside of agriculture and less daily migration, with no effect on longer-term migration. While the majority of evidence points towards large economic gains from the construction of rural roads, some studies have suggested that low incomes and population densities in rural areas may not generate sufficient demand for transportation services on rural roads (Raballand et al., 2011).

Methodologically, our use of within-district population rank is similar to Andrabi et al. (2013), who use local population rank to instrument for the placement of a girls' secondary school. Banerjee et al. (2012b) also use within-district population rank to estimate the effects of the PMGSY although, as discussed above, their focus is on the response of households, rather than firms, to the construction of a new road.

3 Context and background

The Pradhan Mantri Gram Sadak Yojana (PMGSY) – the Prime Minister's Village Road Program – was launched in 2000 with the goal of providing all-weather access to unconnected habitations across India. The focus was on the provision of new feeder roads to localities that did not have access, although in practice many projects under the scheme upgraded pre-existing roads. Originally, the stated goal was to provide all habitations with populations greater than 1000 with connectivity by 2003 and all habitations with population greater than 500 with connectivity by 2007. These thresholds were to be lower in desert and tribal areas, as well as hilly states and districts affected by left-wing extremism.¹

¹Habitations are defined as clusters of population whose location does not change over time. They are distinct from, but form parts of, revenue villages used by the Economic and Population Censuses. See

Although funded and overseen by the federal Ministry of Rural Development, responsibility for road construction was delegated to state governments. District Rural Road Plans were drafted for every district in India. Funding comes by a combination of taxes on diesel fuel (0.75 INR per liter), central government support and loans from the Asian Development Bank and World Bank. By March 2011, over 420,000 km of roads had been sanctioned to connect nearly 110,000 habitations at a cost of 1.19 trillion INR (\$27 billion) (Ministry of Rural Development, 2012).² The mandate of the program has recently been expanded to include all habitations with populations above 100.

4 Empirical Strategy

Our goal is to estimate the effect of the construction of a new rural road on changes in village-level economic activity. We start by estimating the OLS relationship between road construction and village employment growth using the following estimating equation:

$$Y_{v,s,t} = \beta_0 + \beta_1 * newroad_{v,s} + \zeta X_{v,s,t-1} + \eta_s + \epsilon_{v,t-1}, \quad (1)$$

where $Y_{v,s,t}$ is log employment in village v in state s at time t , and $newroad$ indicates that a new feeder road was constructed in village v at time t , $X_{v,s,t-1}$ is a vector of village controls measured at baseline, and η_s is a state fixed effect.

The problem with this approach is that roads are not allocated at random. Roads are expensive infrastructural investments likely to be demanded by nearly all unconnected villages. Governments may target such investments to locations that are particularly needy, or have high potential for growth, or are politically connected or favored by powerful politicians. Controlling for baseline village characteristics or regional fixed effects will reduce this bias,

National Rural Roads Development Agency (2005) for more details.

²We use an exchange rate of 44.06 INR per USD, the average for 2005

but it remains a concern at the heart of the literature on infrastructure.

We undertake three strategies to mitigate bias from selection in the placement of roads: (i) using OLS to exploit variation in the timing of PMGSY road construction; (ii) using regression discontinuity to exploit population thresholds that determine road priority; (iii) using an instrumental variable approach to exploit within-district population ranking of villages, which is an additional determinant of road prioritization.

4.1 Road timing (OLS)

The naive OLS is biased because the types of villages that receive new rural roads differ on many unobserved characteristics from the types of villages that do not receive new roads. By limiting our sample to villages that eventually did receive PMGSY roads, and exploiting the timing of road construction, we can eliminate any confounders that differ between villages that did and did not receive new roads.

Table 1 shows the number of rural roads built under the PMGSY in each year. Of the 75,399 roads in our sample that were built by 2009, 25,354 were built by 2005, the year in which we measure employment outcomes.³ We then estimate Equation 1 on this limited sample, where the treatment variable indicates that a road was built before 2005.

Under the assumption that the order in which roads were constructed under the PMGSY is uncorrelated with other factors that affect growth, this would be an unbiased estimate of the effect of rural roads on village outcomes. However, this assumption is tenuous: order of construction is likely to be influenced by both political and economic factors that could bias OLS estimates either upwards or downwards.

³The 2005 Economic Census was conducted from late 2005 to early 2006.

4.2 Population priority thresholds (RD)

Timing of road construction is endogenous, which means the OLS estimates of the effects of roads are likely to be biased. In order to overcome this endogeneity, we exploit the population thresholds intended to guide the allocation of roads under the PMGSY. State implementing officials were instructed to target habitations in the following order: (i) habitations with population greater than 1000; (ii) habitations with populations greater than 500; and lastly, (iii) habitations with populations greater than 250.

Even if selection into PMGSY treatment is biased by political or economic factors, these factors are not likely to change discontinuously at these population thresholds. If these rules were followed to any degree by state officials, the likelihood of PMGSY treatment will discontinuously increase at these population thresholds, making it possible to estimate the effect of the program using a fuzzy regression discontinuity design.

Under the assumption of continuity at the treatment threshold, the fuzzy RD estimator (Imbens and Lemieux, 2008) estimates the local average treatment effect (LATE) of receiving a new road, for a village with population equal to the threshold:

$$\tau = \frac{\lim_{pop \rightarrow T^+} \mathbb{E}[Y_v | pop_v = T] - \lim_{pop \rightarrow T^-} \mathbb{E}[Y_v | pop_v = T]}{\lim_{pop \rightarrow T^+} \mathbb{E}[newroad_v | pop_v = T] - \lim_{pop \rightarrow T^-} \mathbb{E}[newroad_v | pop_v = T]}, \quad (2)$$

where pop_i is habitation population, T is the threshold population, and $newroad_i$ is an indicator variable for whether village v received a new road in the sample period.

A given population threshold increases the probability of receiving a road by a different amount in different states. For example, states with a large number of large, unconnected villages, are more likely to have large first stages at the high threshold of 1,000. Analysis of PMGSY documentation and discussions with public officials have led us to focus on the population threshold of 500, in five major states which cover a large share of the geographic and economic diversity of India: Gujarat, Chhattisgarh, Assam, Maharashtra and Tamil

Nadu.

We estimate the reduced form fuzzy RD using equation 3:

$$Y_{v,s,t} = \beta_0 + \beta_1(pop_{v,s,t-1} > T) + \beta_2 pop_{v,s,t-1} + \beta_3 pop_{v,s,t-1} * (pop_{v,s,t-1} > T) + \zeta X_{v,s,t-1} + \eta_s + \epsilon_{v,s,t}, \quad (3)$$

where $Y_{v,s,t}$ is log village employment at time t , T is the population threshold of 500, $pop_{v,s,t}$ is habitation population at time t , $X_{v,s,t-1}$ is a vector of village controls measured at baseline, and η_s is a state fixed effect. Village controls and state fixed effects are not necessary for identification but improve the efficiency of the estimation. The local average treatment effect of a road, identified in a village at the population threshold T , is $\beta_1 + \beta_3 * T$. For ease of exposition, we subtract the threshold value 500 from the population variable, such that $T = 0$, and β_1 fully describes the treatment effect.

The fuzzy regression discontinuity approach accurately identifies the treatment effect of rural roads, under the assumption that crossing the population threshold affects the probability of receiving a road, and nothing else of significance. There are two potential threats to this identification strategy. First, if other village characteristics vary discontinuously at the threshold in a way that we are unable to control for (e.g. if participation in other government programs uses the same thresholds), then our estimates will be biased. Second, if the running variable (habitation population) can be manipulated, randomness of assignment at the threshold is violated. We discuss this possibility when we describe results from the regression discontinuity strategy below.

4.3 Population rank (IV)

In addition to the population threshold rules, district-level planning and implementation of the PMGSY meant that prioritization was determined not only by population but also by relative population ranking within a district: a village would receive higher prioritization

than an equivalent village if it had fewer larger eligible villages in its district. Holding population constant, a village in a district with many larger unconnected villages is less likely to receive a new road under the PMGSY. Under the assumption that, after controlling flexibly for total population, the population rank of a village within a district does not affect a village’s growth prospects except through the likelihood of receiving a road through PMGSY, instrumental variable estimation provides an unbiased estimate of the effect of a rural road (Angrist and Lavy, 1999).

Our empirical specification is:

$$Y_{v,s} = \beta_0 + \beta_1 * newroad_{v,s} + \beta_2 f(pop_{v,s}) + \zeta X_{v,s} + \eta_s + \epsilon_{v,s} \quad (4)$$

where $Y_{v,s}$ is the outcome of interest in village v in state s , $newroad_{v,s}$ is an indicator for whether the village received a road under the PMGSY, $f(pop_{v,s})$ is a function of village population, $X_{v,s}$ is a vector of village controls and η_s is a state fixed effect. We estimate Equation 4 using $RANK_{v,s}$, the within-district population rank of village v , as an instrument for $newroad_{v,s}$. In alternate specifications, in order to reduce noise, we instrument for $newroad_{v,s}$ with a dummy variable indicating that $RANK_{v,s} < 75$.⁴

The estimation provides an unbiased estimate of the effect of a new rural road on employment growth, so long as the exclusion restriction is not violated: $RANK_{v,d,t-1}$ must affect growth only through the increased likelihood of obtaining a new road under the PMGSY. In Section 6 we discuss robustness checks to ensure satisfaction of the exclusion restriction.

⁴Our results are robust to different cutoffs for this dummy variable and are available upon request.

5 Data

5.1 PMGSY

Data on the PMGSY is generated through the Online Management and Monitoring System (OMMS), the software used in program tracking and implementation. These data are not a survey - they are the administrative records of the actual program. Data include but are not limited to road sanctioning and completion dates, cost and time overruns, contractor names, and quality monitoring reports.

PMGSY data are reported at either the habitation or the road level. There is a many-to-many correspondence between habitations and roads: roads serve multiple habitations, and habitations may be connected to multiple roads. Habitations are subsets of census villages, which tend to comprise between one and three habitations; approximately 200,000 villages consist of only a single habitation.

5.2 Economic and population census

The Indian Ministry of Statistics and Programme Implementation (MoSPI) conducted the 4th and 5th Economic Censuses respectively in 1998 and 2005.⁵ The Economic Census is a complete enumeration of all economic establishments except those engaged in crop production and plantation; there is no minimum firm size, and both formal and informal establishments are included.

The Economic Census records information on the town or village of each establishment, whether ownership is public or private, the number and demographic characteristics of employees, the sources of electricity and finance, and the caste group of the owner. The main product of the firm is also coded using the 4-digit National Industrial Classification (NIC), which corresponds roughly to a 4-digit ISIC code. More detailed information on income or

⁵The 6th Economic Census is ongoing at the beginning of 2013.

capital is not included. The main strengths of the data are its comprehensiveness, and rich detail on spatial location and industrial classification of firms.

We obtained location directories for the Economic Censuses, and then used a series of fuzzy matching algorithms to match villages and towns by name to the population censuses of 1991 and 2001.⁶ We were able to match approximately 93% of villages between 1998 and 2005. We also use data from the Population Census of India in 1991 and 2001, which includes village population and other demographic data, as well as information on local public infrastructure (roads, electricity, schools and hospitals).

We matched PMGSY data to economic and population census data at the village level, using population census codes where they were reported in the PMGSY, and a Hindi-language fuzzy matching algorithm to match village names across the two datasets. We successfully matched over 85% of habitations listed in the PMGSY to their corresponding population census villages.

Table 2 shows village-level summary statistics for the entire sample of villages used in our analysis.

6 Results

6.1 OLS

Table 3 presents OLS estimates of the relationship between log employment growth (1998-2005) and treatment, defined as having received a completed PMGSY road by 2005. The sample is all locations that received a PMGSY road before 2012. Column 1 presents the estimate only controlling for 1998 (log) employment and village population. Column 2 introduces state fixed effects. Column 3 introduces standard village level controls of share of

⁶The Economic Census of 1998 was conducted with the house listing for the 1991 population census, while the 2005 Economic Census used codes from the 2001 population census.

land irrigated, log land area, distance from nearest town and number of non-farm industries present in 1998. Column 4 limits to villages in which the largest habitation had fewer than 1500 people. Standard errors are clustered at the district level.

The table shows that villages that received a new PMGSY road by 2005 on average had non-farm employment growth that was 3-12 log points higher than villages that did not receive a new road. The point estimates fall as more controls are included, suggesting that selection of villages for roads is non-random. In particular, the falling coefficient as state fixed effects are included suggests that higher growth states were more likely to implement the program early - this is consistent with reports that state administrative capacity played an important role in early implementation of PMGSY.

6.2 Regression discontinuity

Table 4 presents regression discontinuity estimates of the effect of PMGSY prioritization on a village's likelihood of receiving a road. Habitations with a population greater than 500 should have received higher priority than habitations with population under 500. The dependent variable in these regressions is an indicator variable that is set to 1 if a village received a road by 2005. The running variable is the population of the largest habitation in the village. The treatment variable is an indicator that is set to 1 if the largest habitation has a population greater than or equal to 500. The value 500 has been subtracted from population values, so that the coefficient on the uninteracted treatment variable is the estimate of the treatment effect.

Columns 1-3 show estimates from the local linear specification (Equation 3). Column 1 is the baseline specification without controls. Column 2 adds state fixed effects, and column 3 adds village level controls from the 1991 population census, which are log land area, share of land that is irrigated, distance to the nearest town, and the number of different industries in the village in 1998. Column 4 adds a 4th degree polynomial in habitation population.

The estimations show a robust and highly significant effect of the population threshold on the probability of a village receiving a new road. A village is on average 3% more likely to receive a new road if the population of the largest habitation is just above 500 than if the population is just below 500. Figure 1 depicts graphically the increase in probability of receiving a new road when the largest habitation is just above the threshold.

The bandwidth used in all specifications is 250, so the sample for the estimation are villages with a largest habitation in the range of 250-750, but results are robust to alternate bandwidth choices. All standard errors are clustered at the district level to account for spatial correlation. Controls and fixed effects are not necessary for identification, but their inclusion increases the efficiency of the estimator.

Table ?? presents instrumental variable regression discontinuity estimates of the effect of receiving a new road under the PMGSY on log non-farm employment growth from 1998-2005. As above, the running variable is the population of the largest habitation in the village, and a dummy variable indicating population greater than 500 instruments for a village's receiving a PMGSY road by 2005. Columns 1-3 show local linear specifications. Column 2 adds state fixed effects, column 3 adds village-level controls, and column 4 adds a quartic in population. The estimates show a very large and statistically significant effect of a new feeder road on rural non-farm employment. A new feeder significantly increases the growth of non-farm employment.⁷ Controls, clustering and bandwidth are the same as in Table 4. All regressions include an additional control for non-farm employment in 1998.

A standard regression discontinuity validity test is that the density of the running variable is continuous across the treatment threshold. The standard test recommended by McCrary (2008) cannot be applied, because the population threshold affects both the probability of receiving a new road, and selection into the RD sample.⁸ The histogram of PMGSY-listed

⁷We omit villages with non-farm employment less than 10 or greater than 200 in 1998. The median village has employment of 180, so this effect is not driven by growth in villages with very small levels of employment.

⁸The sample for the RD is all villages in which a PMGSY project was sanctioned by 2012. Habitations

populations of habitations that received roads by 2011 (the RD sample) is displayed in Figure 2, with clear discontinuous increases in density at the population thresholds of 250 and 500. Figure 3 shows the histogram of village population in the 2001 population census, where there is no evident sign of a discontinuity at either of the PMGSY thresholds.

6.3 IV

In this section we present results from the IV specification described in Section 4.3. We first verify that within-district village population rank appears to be a valid instrument and then discuss results of this estimation strategy.

We define our sample to be villages listed as not having paved roads at the time of the 2001 Population Census. This is for two reasons. First, villages unconnected by paved all-weather roads to the road network are listed as the highest priority under the PMGSY. Second, we can be confident that roads to such villages are in fact new roads and not upgrades of existing roads, in order to be able to more cleanly interpret the results. The sample is further restricted to villages in districts in which the PMGSY built roads to more than 5% of villages by 2005. Finally, because few villages with very high within-district population ranks (very small villages) receive roads under the PMGSY, we drop villages with population ranks above 300. These sample definitions yield a sample of 12073 eligible villages in our rank IV sample, out of which 65 received PMGSY roads by 2005.

with populations greater than 500 are more likely to be prioritized and receive a road by 2005, which drives our empirical result. However, habitations with population greater than 500 are also more likely to receive a road by 2011, which drives selection into the sample. An alternate approach which would not face this issue would be to use the entire set of Indian villages as a control group - but with fewer than 40,000 out of 600,000+ villages connected, the increased probability of receiving a road under PMGSY is too small to detect.

6.3.1 First stage and reduced form

We define our rank instrument two ways. The first is a simple field rank that assigns a village a rank of the number of villages in the sample with populations greater than the village, plus one. The second creates a binary variable out of this rank that takes on the value 1 when a village rank is less than 75. Table 5 presents the results of the first stage, regressing an indicator for the completion of a PMGSY road by 2005 on these two rank instruments. For simplicity of presentation, the rank variable has been divided by 100. Columns 1 and 2 present the effect of rank on the probability that a village receives a road by 2005 with quadratic and quartic polynomial population controls, respectively. A reduction of rank of 100 is associated with a 4 to 5 percentage point increase in the probability of receiving a road, controlling for population. Columns 3 and 4 present the effect of our binary instrument on the likelihood of receiving a PMGSY road by 2005: being in the top 75 villages within one's district is, after controlling for population and other village characteristics, associated with an approximately 5.5 percentage point increase in the probability of receiving a PMGSY road. The results are little changed by adding additional population controls, which is reassuring for the validity of the instruments.

Table 6 presents the reduced form results. The dependent variable in all four columns is log nonfarm employment growth. Columns 1 and 2 show that an increase in rank of 100 (decrease in prioritization for PMGSY road) is associated with a reduction of approximately 7 log points of employment growth, with negligible change when going from quadratic to quartic population controls. Likewise, columns 3 and 4 show that having a rank of less than 75 is associated with an increase of approximately 6 log points of employment growth.

One concern is that the rank instrument may be correlated with prioritization not only in the PMGSY but in other government programs that are also carried out at the district level. We thus define a placebo sample of villages with equivalent rankings as our rank IV sample but in districts that did not construct PMGSY roads in more than 1% of villages.

Table 7 presents the results of the same reduced form specification discussed above but in this placebo sample. We find insignificant effects of both the continuous and binary population rank instruments on village nonfarm employment growth. We take this as suggestive, if not conclusive, evidence that the village population rank affects employment growth only through its impact on the likelihood of receiving a PMGSY road.

6.3.2 Rank IV estimates

Table 8 presents the results of the IV estimation based on Equation 4. As in the preceding tables, the first two columns use *RANK* as the excluded instrument for the construction of a road, while columns 3 and 4 use the binary low rank variable. We find that a new road leads to highly significant positive increases in nonfarm employment growth. Regardless of specification, a new road is associated with an increase of employment growth of over 100 log points. Table 9 seeks to unpackage these results, instrumenting for new road with only the binary rank variable. Column 1 estimates the effect of a new road on the number of economic establishments (in logs); in contrast to the highly significant positive results for employment growth, the estimated effect on firm count is smaller and less significant. Consistent with this result, column 2 finds that a new road is associated with a large and significant increase in firm size: the mean firm employs more than 1 additional employee than in villages that do not receive roads. Column 3 estimates the treatment effect on the percent change in economic diversity of the village. We follow Hidalgo and Hausmann (2009) in defining the diversity of a village economy as the number of industries present in the village.⁹ The outcome variable is defined as the proportional change in the economic diversity of a village, top-coded at 4 (400% increase) to reduce the effect of outliers. We find that a new road is associated with a positive significant increase of approximately 0.65 industries per village. Column 4 estimates

⁹The 1998 Economic Census reports 3 digit NIC-1987 codes for each establishment, while the 2005 Economic Census uses 4-digit NIC-2004 codes. We use correspondence tables published by the Ministry of Statistics and Programme Implementation to generate a list of 217 self-contained industries, which we use as the basis of all industry-level analysis in this paper.

the effect of a new road on the village share of employment in informal firms, defined as those not registered with the Indian government. We find a large increase in informality, although it is unclear how best to interpret this result. One hypothesis is that high transportation costs keep firms inefficiently small and informal by denying them access to larger markets. This theory would predict increased formalization in response to the construction of a new road, but if the employment response to falling transport costs is faster than the process of formalization, we should expect to see a short-term rise in informality. Future work with the Economic Census of 2012 should enable us to test this hypothesis.

Table 10 considers heterogeneity of our estimated treatment effect by village characteristics. Theoretically, we expect that firms with better access to productive inputs to grow most in response to a fall in transportation costs. Column 1 presents the full sample estimate of the effect of a road on total employment, while columns 2 through 7 present subsample results. We find suggestive evidence that electricity appears to be an important complementary input to a village feeder road: while we estimate a very small (if noisy) estimate for villages without electrical supply, we find significant, statistically larger effects in villages with electricity supply. This result should be interpreted with some caution, given that our identification strategy provides exogenous variation in road placement, not in the interaction of road construction and availability of electricity. Next, we estimate effects for villages above and below the median distance to the nearest town, which for our sample is 20 km. We estimate a larger treatment effect for villages far from towns, although both estimates are within one standard deviation of our full-sample estimate and are not statistically different from each other. Likewise, we find no significant difference in our estimates when dividing our sample on human capital, as measured by literacy.

Given the very high costs of infrastructure projects such as roads, it is of great interest to policymakers to understand the economic impact of such projects in terms of money spent rather than per project. The OMMS described in Section 5 contains data on total spending

per road, which we use to construct a village road expenditure variable that takes on the value 0 if a road is not built in the village by 2005 and otherwise equals the sum of all PMGSY road spending in habitations contained in that village.¹⁰ As our objective is to estimate the cost of job creation, we define our outcome variable to be the level change in employment between 1998 and 2005, rather than log growth as in the preceding tables. Table 11 presents the results of this estimation. Our estimates range, depending on the instrument used, between approximately 500 and 700 nonfarm jobs per million dollars spent on road construction, which results in a per job cost of between approximately 1430 and 2000 USD. Expressed differently, the per job cost of the PMGSY is roughly two to three times India's GDP per capita in 2005 (\$731.70). How should we interpret this result? As the Economic Census was conducted in late 2005 and early 2006, it is safe to assume that nearly all of the roads listed as completed by 2005 were finished by the time of data collection; thus, these results should be understood not as temporary jobs related to road construction, but rather short- to medium-term effects. These estimates also assume that the net employment effect of PMGSY spending in locations not receiving roads is zero. This is a strong assumption – one we intend to investigate in future work – as there may be either crowd-in or crowd-out of economic activity in villages and towns that are now better connected to PMGSY villages. Finally, all estimates assume that control villages do not receive any PMGSY road spending, an unlikely result given the multiple years that road construction generally requires, the multiple habitations per PMGSY road project and the many roads that were completed in 2006 and 2007. For this last reason, we consider our estimates to be likely lower bounds on the true effect of road construction in this context.

¹⁰We generate total road spending village in million USD, using an exchange rate of 44.06 INR per USD, the average for 2005. In the case of roads that connect multiple habitations, spending is allocated equally between the habitations.

7 Conclusion

Universal access to paved roads, easily taken for granted in many rich countries, is far from a reality for many of the world's poor. High transportation costs inhibit gains from the division of labor, economies of scale and comparative advantage. Nevertheless, little is known of the economic effects of road provision on rural economic activity. Theoretically, roads could facilitate migration to urban areas and the specialization of village economies in agriculture; alternatively, lower transportation costs could cause the emergence and expansion of rural economic activities, with potentially large consequences for economic development, urbanization and the spatial distribution of economic activity.

In this paper we estimate the economic impacts of a large-scale program that seeks to provide near universal access to paved “all-weather” roads in rural India. The program design provides two sources of exogenous variation to allow us to overcome the usual challenge of endogeneity of large infrastructure projects. First, the program calls for highest priority to be given to habitations above population thresholds, which may be 250, 500 or 1000 depending on the area. This creates a discontinuity in the probability of receiving a road at these cutoffs, allowing us to use a fuzzy regression discontinuity design to estimate the impact of these roads. A second identification strategy takes advantage of the fact that habitations are prioritized not only by population but also by the relative population rank within a district: a village of a certain size is more likely to receive a road if there are fewer larger villages within its district than an equivalent village that has a lower population rank. We instrument for road construction using this rank, conditioning on population, to provide a second set of estimates of the impact of village feeder roads.

We find that the provision of a new, paved village approach road produces significantly faster nonfarm employment growth. Rather than a simple proportional expansion of existing economic activity, new industries form in villages that receive roads. Firm size also grows,

which we take as supporting evidence of the theory that in the presence of high transportation costs, firms are inefficiently small. The responsiveness of nonfarm employment growth to lower transportation costs appears to be strongest in villages that also have access to the supply of electricity, suggesting significant complementarities between these different infrastructural investments. Finally, we provide some of the first well-identified estimates of the cost effectiveness of rural road construction: one job is created for every \$1400 to \$2000 in road construction costs, suggesting very high returns to such investments.

Future work will allow us to further disentangle the channels by which rural roads promote village nonfarm employment. The 2011 Population Census, not yet available at the village level, will provide the data necessary to examine the impact of roads on migration and agricultural employment, neither of which is covered in the Economic Census. We intend to use the 2012 Economic Census, the collection of which is still in progress, to differentiate between the short- to medium-run effects presented in this paper and sustained, longer-run changes to village economic activity.

Table 1
Tabulation of Villages Receiving PMGSY Roads by Year

Year Sanctioned	Year Completed										Total
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
2000	6	180	609	1080	990	605	300	450	111	61	4392
2001	0	0	21	719	1387	1377	702	313	161	158	4838
2003	0	0	0	2	403	1251	1153	685	369	266	4129
2004	0	0	0	0	0	300	774	794	871	468	3207
2005	0	0	0	0	0	0	179	1109	1583	1895	4766
2006	0	0	0	0	0	0	1	569	1046	2272	3888
2007	0	0	0	0	0	0	0	0	135	1145	1280
2008	0	0	0	0	0	0	0	0	0	148	148
Total	6	180	630	1801	2780	3533	3109	3920	4276	6413	26648

Table 2
Summary statistics

Variable	Mean	(Std. Dev.)	N
New road	0.049	(0.216)	182376
Employment (1998)	68.007	(100.266)	182376
Employment (2005)	84.31	(119.796)	182376
Ln employment growth	0.215	(0.876)	182376
Firm count (1998)	33.692	(45.609)	182376
Firm count (2005)	45.405	(59.987)	182376
Ln firm count growth	0.29	(0.842)	182376
2001 Population	1421.413	(1020.428)	182376
Pop growth 1991-2001	1.202	(0.263)	182376
Irrigation share	0.43	(0.365)	175671
Ln land area	5.369	(1.087)	175671
Distance from town	20.882	(19.464)	181927
Diversity (1998)	8.752	(6.51)	182376

Table 3
OLS: Employment growth on roads

	(1)	(2)	(3)	(4)
New road before 2005	0.113 (0.019)***	0.079 (0.016)***	0.058 (0.015)***	0.036 (0.017)**
Baseline log employment	-0.275 (0.009)***	-0.328 (0.008)***	-0.477 (0.013)***	-0.496 (0.014)***
Population	0.000 (0.000)***	0.000 (0.000)**	0.000 (0.000)**	0.000 (0.000)***
Share of land irrigated			0.099 (0.024)***	0.078 (0.026)***
Log(land area)			0.141 (0.008)***	0.126 (0.008)***
Distance from town			-0.002 (0.000)***	-0.002 (0.000)***
Baseline number of industries			0.024 (0.002)***	0.026 (0.002)***
Constant	1.115 (0.030)***	1.734 (0.063)***	1.305 (0.078)***	1.377 (0.078)***
N	48216	48216	46720	34888
r2	0.13	0.17	0.21	0.22

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

This table presents OLS estimates of the relationship between log employment growth (1998-2005) and treatment, as defined as having received a completed PMGSY road by 2005. The sample is all locations that received a PMGSY road before 2012. Column 1 presents the estimate only controlling for 1998 (log) employment and village population. Column 2 introduces state fixed effects. Column 3 introduces standard village level controls of share of land irrigated, log land area, distance from nearest town and number of non-farm industries present in 1998. Column 4 limits to villages in which the largest habitation had fewer than 1500 people. Standard errors are clustered at the district level.

Table 4

First stage: RD estimates of effect of population threshold on probability of new road

	(1)	(2)	(3)	(4)
1(Pop \geq 500)	0.034 (0.010)***	0.031 (0.010)***	0.030 (0.010)***	0.034 (0.016)**
Population	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Population * 1(Pop \geq 500)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.001)
Share of land irrigated			-0.004 (0.007)	-0.004 (0.007)
Log(land area)			0.001 (0.004)	0.001 (0.004)
Distance from town			-0.000 (0.000)	-0.000 (0.000)
Baseline number of industries			0.001 (0.000)*	0.001 (0.000)*
Constant	0.016 (0.006)***	0.012 (0.006)**	0.010 (0.018)	0.007 (0.018)
N	28747	28747	26440	26440
r2	0.01	0.02	0.02	0.02

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

The table presents regression discontinuity estimates from Equation 3 of the effect of PMGSY prioritization on a village's likelihood of receiving a road. The dependent variable is an indicator variable that is set to 1 if a village received a road by 2005. The running variable is the population of the largest habitation in the village, and the treatment variable is an indicator that is set to 1 if the largest habitation has a population greater than or equal to 500. Columns 1-3 show estimates from the local linear specification, and column 4 includes a quartic in population. Column 2 adds state fixed effects, and column 3 adds village level controls from the 1991 population census, which are log land area, share of land that is irrigated, distance to the nearest town, and the number of different industries in the village in 1998. The value 500 has been subtracted from population values, so that the coefficient on the uninteracted treatment variable is the estimate of the treatment effect. Standard errors are clustered at the district level.

Table 5
First stage effect of rank on probability of receiving road

	1	2	3	4
Pop rank	-0.127 (0.014)***	-0.126 (0.014)***		
Top pop			0.107 (0.014)***	0.108 (0.014)***
Ln baseline employment	-0.002 (0.011)	-0.002 (0.011)	-0.001 (0.011)	-0.002 (0.011)
2001 Population	0.000 (0.000)	0.001 (0.001)	0.000 (0.000)**	0.002 (0.001)*
2001 Population ²	-0.000 (0.000)	-0.009 (0.012)	-0.000 (0.000)**	-0.019 (0.012)*
2001 Population ³		0.036 (0.046)		0.070 (0.046)
2001 Population ⁴		-0.005 (0.006)		-0.009 (0.007)
Pop growth 1991-2001	-0.024 (0.010)**	-0.024 (0.010)**	-0.023 (0.010)**	-0.024 (0.010)**
Irrigation share	0.060 (0.026)**	0.061 (0.026)**	0.061 (0.026)**	0.061 (0.026)**
Ln land area	0.009 (0.009)	0.009 (0.009)	0.009 (0.009)	0.009 (0.009)
Distance from town	-0.001 (0.000)	-0.001 (0.000)	-0.001 (0.000)	-0.001 (0.000)
Diversity (1998)	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)
N	3647	3647	3647	3647
r2	0.13	0.13	0.12	0.12

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

This table presents first stage regressions using within-district population rank as a predictor of receipt of a PMGSY road by 2005. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Columns 1 and 2 define population rank as the count of in-district, in-sample villages with greater populations, plus 1. Columns 3 and 4 use a binary variable that takes the value 1 when this rank is less than 75. Columns 1 and 3 use quadratic population controls, while Columns 2 and 4 use quartic population controls. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Table 6
Reduced form effect of rank on employment growth

	1	2	3	4
Pop rank	-0.106 (0.031)***	-0.100 (0.032)***		
Top pop			0.059 (0.031)*	0.060 (0.031)*
Ln baseline employment	-0.675 (0.023)***	-0.675 (0.023)***	-0.672 (0.023)***	-0.674 (0.023)***
2001 Population	0.001 (0.000)***	0.003 (0.002)	0.001 (0.000)***	0.004 (0.002)*
2001 Population ²	-0.001 (0.000)***	-0.021 (0.022)	-0.001 (0.000)***	-0.028 (0.022)
2001 Population ³		0.071 (0.086)		0.095 (0.086)
2001 Population ⁴		-0.009 (0.012)		-0.012 (0.012)
Pop growth 1991-2001	0.005 (0.027)	0.005 (0.027)	0.006 (0.027)	0.005 (0.027)
Irrigation share	0.056 (0.051)	0.057 (0.051)	0.060 (0.051)	0.060 (0.051)
Ln land area	-0.000 (0.020)	-0.001 (0.020)	0.000 (0.020)	-0.001 (0.020)
Distance from town	-0.002 (0.001)***	-0.002 (0.001)***	-0.002 (0.001)***	-0.002 (0.001)***
Diversity (1998)	0.011 (0.004)***	0.011 (0.004)***	0.011 (0.004)***	0.011 (0.004)***
N	3647	3647	3647	3647
r2	0.37	0.37	0.37	0.37

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

This table presents reduced form regressions using within-district population rank as a predictor of log employment growth between 1998 and 2005. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Columns 1 and 2 define population rank as the count of in-district, in-sample villages with greater populations, plus 1. Columns 3 and 4 use a binary variable that takes the value 1 when this rank is less than 75. Columns 1 and 3 use quadratic population controls, while Columns 2 and 4 use quartic population controls. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Table 7
Reduced form effect of rank on employment growth (placebo sample)

	1	2	3	4
Pop rank	0.003 (0.033)	0.003 (0.033)		
Top pop			0.052 (0.045)	0.052 (0.045)
Ln baseline employment	-0.582 (0.024)***	-0.581 (0.024)***	-0.584 (0.024)***	-0.584 (0.024)***
2001 Population	0.001 (0.000)***	0.003 (0.003)	0.001 (0.000)***	0.003 (0.003)
2001 Population ²	-0.001 (0.000)***	-0.019 (0.026)	-0.001 (0.000)***	-0.019 (0.026)
2001 Population ³		0.067 (0.101)		0.066 (0.101)
2001 Population ⁴		-0.009 (0.014)		-0.009 (0.014)
Pop growth 1991-2001	-0.079 (0.070)	-0.078 (0.070)	-0.077 (0.070)	-0.076 (0.070)
Irrigation share	-0.117 (0.056)**	-0.118 (0.056)**	-0.122 (0.056)**	-0.123 (0.057)**
Ln land area	-0.026 (0.021)	-0.026 (0.021)	-0.026 (0.021)	-0.026 (0.021)
Distance from town	-0.001 (0.001)	-0.001 (0.001)	-0.000 (0.001)	-0.000 (0.001)
Diversity (1998)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)
N	2733	2733	2733	2733
r2	0.35	0.35	0.35	0.35

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

This table presents reduced form regressions using within-district population rank as a predictor of log employment growth between 1998 and 2005 for a placebo sample of villages in districts not receiving many PMGSY roads. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Columns 1 and 2 define population rank as the count of in-district, in-sample villages with greater populations, plus 1. Columns 3 and 4 use a binary variable that takes the value 1 when this rank is less than 75. Columns 1 and 3 use quadratic population controls, while Columns 2 and 4 use quartic population controls. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in less than 1% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Table 8
Probit IV effect of road on employment growth

	1	2	3	4
New road	0.599 (0.149)***	0.521 (0.143)***	0.536 (0.145)***	0.465 (0.137)***
Ln baseline employment	-0.613 (0.008)***	-0.613 (0.008)***	-0.613 (0.008)***	-0.613 (0.008)***
2001 Population	0.001 (0.000)***	0.001 (0.001)	0.001 (0.000)***	0.001 (0.001)
2001 Population ²	-0.001 (0.000)***	-0.004 (0.009)	-0.001 (0.000)***	-0.004 (0.009)
2001 Population ³		0.011 (0.036)		0.013 (0.035)
2001 Population ⁴		-0.001 (0.005)		-0.002 (0.005)
N	22016	22016	22016	22016
r ²	0.33	0.33	0.33	0.33

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

This table presents instrumental variable regression results for which the dependent variable is log employment growth (1998-2005) and the endogenous regressor is a dummy variable indicating the construction of a PMGSY road by 2005, instrumented by a population rank probit model. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Columns 1 and 2 define population rank as the count of in-district, in-sample villages with greater populations, plus 1. Columns 3 and 4 use a binary variable that takes the value 1 when this rank is less than 75. Columns 1 and 3 use quadratic population controls, while Columns 2 and 4 use quartic population controls. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Table 9
IV effect of road on firm characteristics

	Firm Count	Firm Size	Diversity	Informality
New road	0.159 (0.260)	1.096 (0.368)***	0.097 (0.254)	0.228 (0.093)**
2001 Population	0.002 (0.002)	0.002 (0.003)	0.002 (0.002)	-0.001 (0.001)
2001 Population ²	-0.009 (0.020)	-0.015 (0.025)	-0.016 (0.021)	0.005 (0.007)
2001 Population ³	0.027 (0.080)	0.048 (0.098)	0.067 (0.082)	-0.017 (0.028)
2001 Population ⁴	-0.003 (0.011)	-0.005 (0.014)	-0.010 (0.012)	0.002 (0.004)
Pop growth 1991-2001	0.013 (0.023)	0.014 (0.013)	-0.013 (0.026)	0.007 (0.004)*
Irrigation share	0.026 (0.050)	-0.024 (0.067)	0.084 (0.048)*	-0.047 (0.017)***
Ln land area	0.004 (0.019)	-0.059 (0.023)**	0.040 (0.018)**	0.005 (0.006)
Distance from town	-0.002 (0.001)***	0.001 (0.001)	-0.003 (0.001)***	-0.001 (0.000)***
Diversity (1998)	0.014 (0.004)***	0.004 (0.003)	-0.089 (0.004)***	-0.000 (0.001)
N	3647	3602	3647	3647
r2	0.45	.	0.33	0.05

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

This table presents instrumental variable regression results for which the endogenous regressor is a dummy variable indicating the construction of a PMGSY road by 2005, instrumented by a dummy variable indicating that within-district, within-sample population rank is less than 75. Dependent variables for columns 1 through 4 are, respectively: count of economic establishments, mean firm size (number of employees), proportional change in economic diversity and 2005 share of employment in informal firms. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Table 10
IV effect of road on employment growth by village characteristics

	All	No Electricity	Electricity	Far	Near	Low Literacy	High Literacy
New road	0.553 (0.294)*	0.439 (0.540)	0.609 (0.391)	0.534 (0.400)	0.493 (0.432)	0.229 (0.336)	0.891 (0.586)
Ln baseline employment	-0.673 (0.023)***	-0.760 (0.060)***	-0.666 (0.028)***	-0.709 (0.033)***	-0.630 (0.034)***	-0.640 (0.028)***	-0.725 (0.042)***
2001 Population	0.003 (0.002)	-0.011 (0.008)	0.006 (0.003)**	-0.001 (0.003)	0.006 (0.004)*	0.003 (0.003)	0.003 (0.004)
2001 Population ²	-0.017 (0.023)	0.108 (0.074)	-0.047 (0.026)*	0.012 (0.032)	-0.046 (0.033)	-0.022 (0.030)	-0.022 (0.038)
2001 Population ³	0.056 (0.091)	-0.421 (0.289)	0.168 (0.104)	-0.055 (0.127)	0.162 (0.131)	0.075 (0.117)	0.075 (0.151)
2001 Population ⁴	-0.007 (0.013)	0.058 (0.040)	-0.022 (0.015)	0.008 (0.018)	-0.021 (0.018)	-0.009 (0.016)	-0.010 (0.021)
Pop growth 1991-2001	0.019 (0.023)	0.039 (0.009)***	-0.053 (0.071)	-0.007 (0.076)	0.020 (0.022)	0.011 (0.029)	0.060 (0.060)
Irrigation share	0.026 (0.056)	-0.042 (0.149)	0.032 (0.067)	0.029 (0.075)	0.042 (0.084)	0.063 (0.076)	-0.033 (0.093)
Ln land area	-0.006 (0.020)	0.045 (0.038)	-0.040 (0.027)	-0.027 (0.027)	0.015 (0.030)	-0.013 (0.028)	0.008 (0.033)
Distance from town	-0.002 (0.001)**	-0.002 (0.003)	-0.002 (0.001)	-0.001 (0.003)	-0.002 (0.001)	-0.002 (0.001)*	-0.002 (0.002)
Diversity (1998)	0.010 (0.004)**	0.003 (0.010)	0.010 (0.005)**	0.012 (0.006)**	0.006 (0.007)	0.005 (0.006)	0.015 (0.007)**
N	3647	616	2543	2029	1618	1989	1658
r2	0.32	0.41	0.30	0.35	0.31	0.37	0.23

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

This table presents instrumental variable estimates of the effect of the construction of a PMGSY road on log employment growth (1998-2005) for different subsamples in order to estimate heterogeneous treatment effects. All subsamples are defined based on 2001 Population Census characteristics. Column 1 presents full sample results. Columns 2 and 3 are for villages with and without electricity supply, respectively. Column 4 presents results for villages with below median distance from the nearest town (20km). Column 5 presents results for villages above median distance from a town. Column 6 presents results for villages with below median literacy, and Column 7 for villages with above-median literacy. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

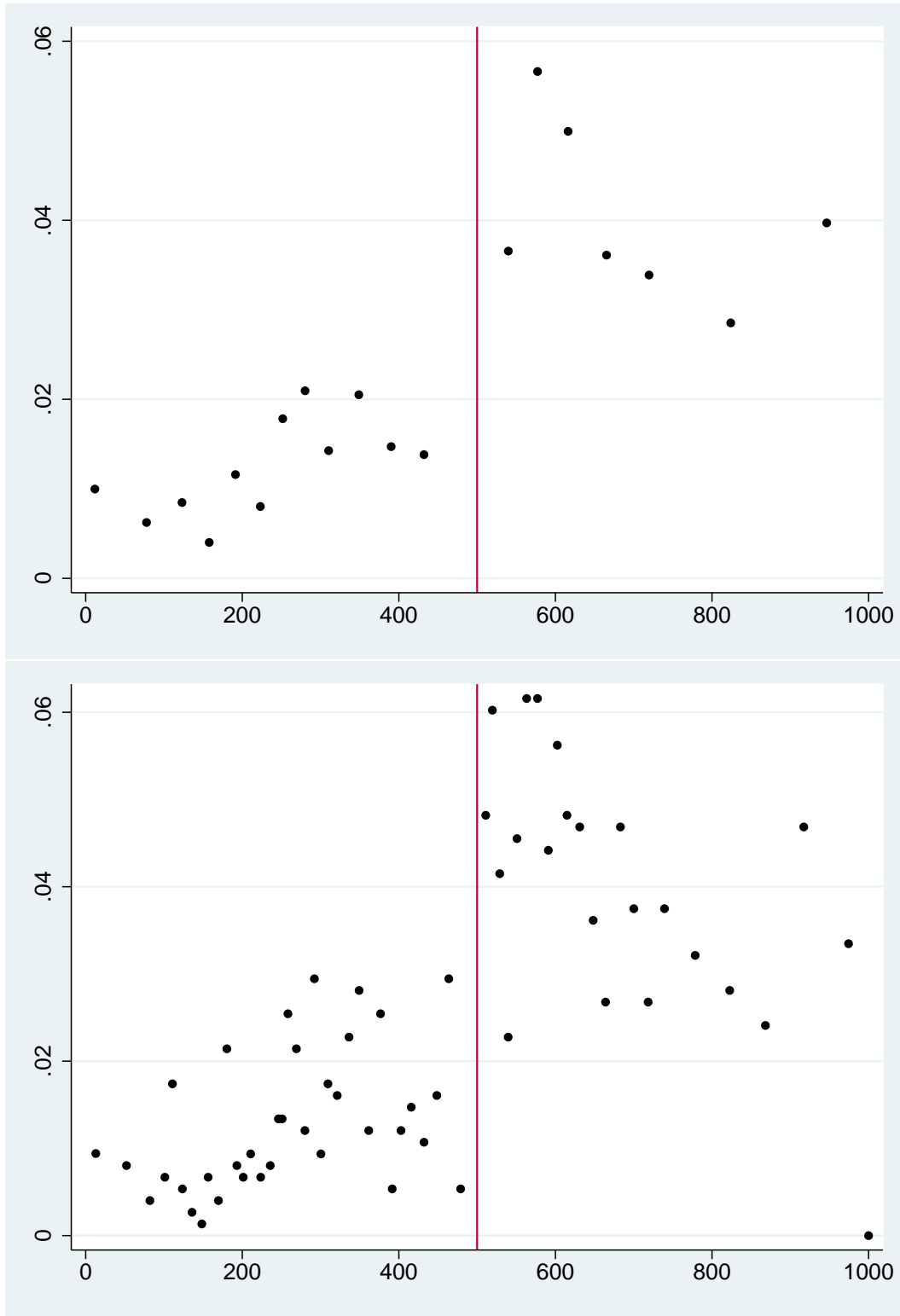
Table 11
IV effect of road spending on level change in employment

	1	2	3	4
Road cost (million USD)	215.161 (177.771)	229.722 (177.872)	212.388 (225.578)	236.573 (223.131)
Employment (1998)	-0.348 (0.075)***	-0.348 (0.075)***	-0.348 (0.075)***	-0.348 (0.075)***
2001 Population	0.035 (0.014)**	0.264 (0.217)	0.035 (0.014)**	0.262 (0.217)
2001 Population ²	-0.041 (0.039)	-2.369 (2.091)	-0.041 (0.039)	-2.358 (2.091)
2001 Population ³		9.818 (8.481)		9.775 (8.487)
2001 Population ⁴		-1.455 (1.224)		-1.450 (1.225)
Pop growth 1991-2001	0.879 (1.214)	0.898 (1.221)	0.874 (1.249)	0.911 (1.252)
Irrigation share	3.249 (4.457)	3.374 (4.466)	3.253 (4.451)	3.365 (4.461)
Ln land area	-3.539 (1.830)*	-3.546 (1.835)*	-3.533 (1.835)*	-3.561 (1.835)*
Distance from town	-0.096 (0.078)	-0.093 (0.079)	-0.096 (0.079)	-0.094 (0.079)
Diversity (1998)	-0.385 (0.488)	-0.395 (0.489)	-0.385 (0.489)	-0.395 (0.490)
N	3589	3589	3589	3589
r2	0.14	0.14	0.15	0.14

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

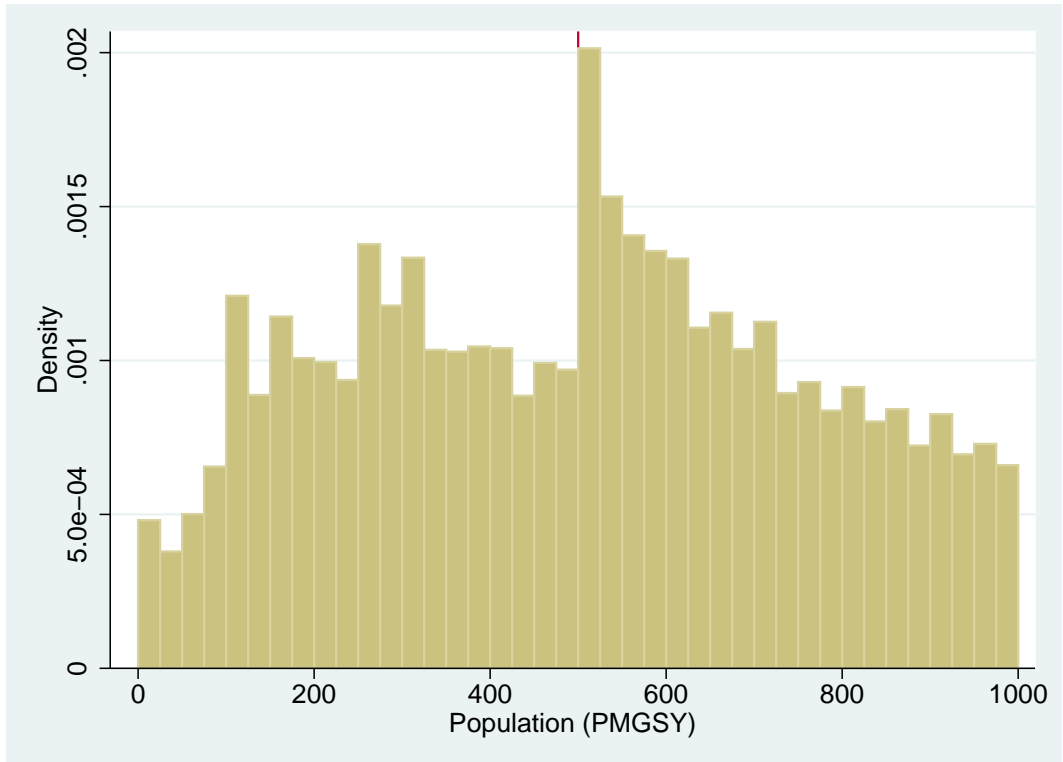
This table presents instrumental variable regression results for which the dependent variable is level employment growth (1998-2005) and the endogenous regressor is the amount of spending on a PMGSY road by 2005. For roads are not completed by 2005, this number is 0. All regressions weight by baseline log employment and include state fixed effects, as well as the following village level controls: 1991-2001 population growth, share of land irrigated, log land area, distance from nearest town and economic diversity as measured in the 1998 Economic Census. Columns 1 and 2 define population rank as the count of in-district, in-sample villages with greater populations, plus 1. Columns 3 and 4 use a binary variable that takes the value 1 when this rank is less than 75. Columns 1 and 3 use quadratic population controls, while Columns 2 and 4 use quartic population controls. Sample is comprised of villages listed as not having a paved approach road in the 2001 Population Census. We further limit to villages in districts that constructed PMGSY roads in more than 5% of villages and villages whose within-district population rank is less than 300. Reported standard errors are heteroskedasticity-robust.

Figure 1
First stage: population threshold and new rural roads



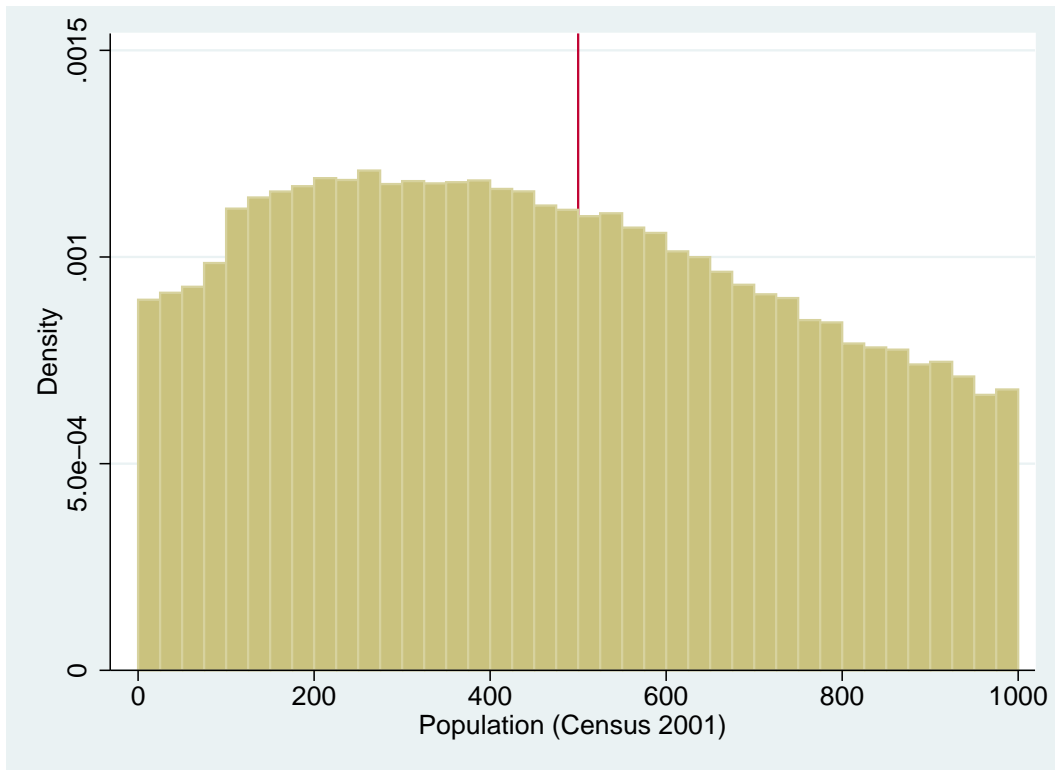
The figure shows the share of habitations that received a road, by population. Each point represents approximately 1000 habitations in the top panel, and 300 habitations in the bottom panel. The PMGSY instructed states to target roads to habitations with population greater than 500, the value indicated by the solid vertical line.

Figure 2
Histogram of PMGSY-project population (SP)



The figure displays a histogram of habitation population as recorded in the PMGSY project data. The density bulges at 250 and 500 reflect the project's prioritization of villages with population greater than 500, and then greater than 250.

Figure 3
Histogram of population (population census 2001)



The figure displays a histogram of village population as recorded in the 2001 population census. The PMGSY eligibility thresholds of 250 and 500 do not show obvious changes in density.

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