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ABSTRACT

Connectivity and Rural Development: Examining India's Rural Road Construction Scheme*

We examine the impact of rural road connectivity on economic and social outcomes in the context of India's PMGSY, the world's largest rural road program. Using a novel village-level survey explicitly designed around PMGSY's rollout, we exploit quasi-random variation in road placement to estimate causal effects. We find that roads increase producer prices by 1.4 SD, reduce consumer prices by 0.6 SD, shift labor from agriculture to local casual work, and decrease short-term migration. Additionally, road connectivity improves governance, delays marriages, and improves wedding quality. Our findings highlight the role of infrastructure in shaping rural economies and social institutions.

JEL Classification: I15, J43, O12, O18, R23, R42

Keywords: rural roads, PMGSY, prices, wages, migration, India

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1 Introduction

While global poverty has decreased substantially[1], approximately 700 million people continue to experience extreme poverty, and 79% of these individuals live in rural areas (World Bank, 2024). Poor people in rural areas are often isolated from pathways out of poverty, in part because of a lack of basic infrastructure and connectivity. Poor road connectivity is often considered a major barrier to poverty reduction and development in rural areas (Banerjee et al., 2020). This has spurred a growing body of research examining the impacts of rural roads on village economies (e.g., Aggarwal, 2018; Asher and Novosad, 2020; Chaurey and Le, 2022; Dasgupta et al., 2024; Shamdasani, 2021). While the available empirical evidence suggests that road connectivity impacts economic outcomes, the size and even direction of impacts are mixed and appear to be context-dependent. Moreover, as methodological and data constraints have limited our understanding of how rural roads impact village economies, this remains an open area of investigation for development policy.

We examine this question in the context of the world's largest rural road construction program, Pradhan Mantri Gram Sadak Yojana (PMGSY). The PMGSY program, which was launched by the central government of India in 2000, provides all-weather road connectivity to unconnected villages and, to date, has connected more than 170,000 habitations at a cost of $45 billion (O.M.M.A.S, 2023b). We evaluate the impacts of this program using novel village-level microdata collected in 267 villages in Uttar Pradesh (UP), one of India's most populous states.

A unique feature of the PMGSY program is that the village connectivity was determined by predefined population criteria, allowing us to address the usual challenge of endogenous road placement and draw causal conclusions. First, habitations above population cutoffs of 1,000 and then 500 were prioritized in respective waves of construction. Second, within these population ranges and within a given district, villages with larger populations received higher priority. This paper exploits the second fact — that within population size bands, higher-ranked villages were connected first — to causally isolate the impact of roads. Specifically, we use an Instrumental Variables (IV) approach to estimate the causal impacts of con-

[1]The share of the global population living in poverty has decreased from 36% to 10% in the past three decades.

nectivity via a paved road on economic, social, and institutional outcomes at the village level. We instrument for road connectivity using the village's population rank within its district.

Our empirical strategy is similar in spirit to previous work (e.g., Asher and Novosad, 2020; Aggarwal, 2018) that exploits the quasi-random variation in the rollout of the program but differs in important ways. First, our identification strategy is different: to our knowledge, this study is the first to use variation in the population rank within population bands, rather than variation across population bands, to study the impacts of PMGSY roads. Furthermore, the novelty of our primary data collection lies in its explicit design around the PMGSY rollout, distinguishing it from prior studies that rely on secondary datasets. Unlike other studies that often aggregate district-level data, our survey was conducted at the village level, ensuring a more granular and precise measurement of PMGSY impacts (Aggarwal, 2021). This approach allows us to capture previously unobserved effects, such as changes in migration patterns, social institutions, and governance, which are typically missing in secondary datasets. Given that the PMGSY rule was applied across villages and there are heterogeneity in the effects of roads by village characteristics, studying village-level microdata is suitable for estimating the impacts of rural roads (Asher and Novosad, 2020). Thus, this unique data set provides a richer, more localized understanding of how rural road connectivity influences economic and social outcomes, which distinguishes our study from the existing literature. Additionally, it explores novel outcomes not previously examined, including prices, land quality, and civic engagement. Finally, we assess the short-term impacts of roads, as the data was collected two to three years after the completion of the road.

We investigate the impacts of roads on agricultural, labor market, social, and institutional outcomes. We find that farmers receive higher prices for their crops, with producer prices increasing by 1.41 standard deviations (SD). Meanwhile, consumer prices for agricultural products decline, suggesting that improved connectivity makes agriculture more profitable in connected villages by reducing transaction costs. However, we do not find any behavioral changes resulting from farmers: our measures of investment in agriculture, agricultural yields, and land quality do not change. Turning to the labor market, we find that road construction leads to a positive and statistically significant increase in the likelihood of earning

income primarily through casual labor inside the village, indicating that the village labor market became more attractive for workers. Furthermore, the road construction program increased wages within the village and decreased migration to the nearest city for work. We also find that road construction improved connectivity in the political realm, with a higher frequency of visits by government officials, police visits and patrolling, and an increase in the delivery of newspapers. Finally, we find that road connectivity impacted the marriage market by reducing the number of marriages while enhancing their quality, as indicated by the increased presence of a musical band in weddings.

This paper contributes to the existing evidence base on the impact of rural roads on a variety of agricultural, labor, and social outcomes. Similarly to investments observed through the PMGSY program, investments in rural road infrastructure in Sri Lanka were found to increase input use and affected crop choices (Chen et al., 2023). Previous PMGSY evaluations have documented a shift of workers out of agriculture to other sectors of employment, the adoption of better technological practices in agriculture, the hiring of more labor, and the production of a greater variety of products (Aggarwal, 2018; Shamdasani, 2021). Additionally, Asher and Novosad (2020) find that the PMGSY program improved access to capital markets and thus increased investments in the rural economy. Interestingly, they find that the program led to a reduction in the share of workers in agriculture and, in contrast to other work, no changes in agricultural yields and investments. Our paper adds to our understanding of the impacts of roads on local economic activity. In particular, we find that labor shifts off the farm and toward casual labor within the village, where wages rise, while migration for labor decreases — especially daily commute to nearby cities for work.

Finally, we contribute to a strand of literature examining the social and institutional impacts of the PMGSY program. For example, previous work has shown that PMGSY roads increased educational enrollment (Adukia et al., 2020), improved health (Aggarwal, 2021), and reduced fertility (Dasgupta et al., 2024). Our findings generally confirm existing results on education and health and adds a new understanding of potential mechanisms by which fertility reductions occur: through delays of female marriage age and higher quality marriages. Finally, we are the first to examine institutional change in access to news and government

services.

2 Rural Roads in India: Pradhan Mantri Gram Sadak Yojana

Pradhan Mantri Gram Sadak Yojana is a flagship rural road program launched by the Government of India (GoI) in 2000 to provide all-weather road connectivity to unconnected villages in rural areas of the country (O.M.M.A.S, 2023b). At its inception, around 330,000 of the 825,000 villages in India lacked connectivity by all-weather roads (NRRDA, 2005).[2] The program was funded by the World Bank, the Asian Development Bank, and the GoI's Ministry of Rural Development.

Villages were prioritized to receive roads under the PMGSY scheme based on a set of criteria designed to efficiently increase rural connectivity. Potential roads were identified through a district rural road plan (DRRP), which designates routes that connect villages to essential services such as markets, health centers, and educational institutions. Each DRRP was developed jointly with initial input from the subdistrict block-level government, then the district-level government, and then the state government, and includes a set of proposed roads to efficiently link the largest number of people to critical services, according to the priorities of local governments.[3] The finalized DRRP are then compiled into a Core Network (CN) map, which gives a snapshot of existing roads and future roads required to provide all-weather connectivity to basic services.

Using the CN, the state government prepares a Comprehensive New Connectivity Priority List (CNCPL) of all proposed PMGSY roads at the district level, grouping them in the following order of priority: new connectivity to unconnected habitations with a population of 1000+, new connectivity to unconnected habitations with a population of 500-999, new connectivity to unconnected habitations with a population of 250-499. Based on the number of unconnected habitations and the length of new roads in the CNCPL for each district, states

[2]The unit for connectivity under PMGSY is 'Habitation' and not a Revenue Village or Gram Panchayat. Habitation is a cluster of populations living in an area, the location of which does not change over time. A revenue village / Gram Panchayat may comprise one or several Habitations. The population of all habitations within a radius of 500 meters may be grouped together to determine the population size.

[3]PMGSY Schemes and Guidelines

allocated funds to districts.

Finally, the funds allocated to the districts were spent on a subset of roads designed to service habitations within the priority population bands. Beyond the priority based on overall population bands (i.e., targeting villages above each population cutoff in turn), states prioritized unconnected villages within a district in large part according to their 2001 census population, with larger villages typically given higher priority. Factors such as political considerations, economic importance, and the type of link route also shaped prioritization, although population remained the main basis for road allocation (Lehne et al., 2018). The within-district population criteria meant that a village had a higher probability of receiving PMGSY road over a similar-sized village if it had fewer larger eligible villages within its district. Consequently, a village in a district with many larger unconnected villages was less likely to receive a new road, even when the population size was held constant (Asher and Novosad, 2020).

Since its launch in 2000, PMGSY has consistently aimed to improve market access and address infrastructure gaps between urban and rural areas, and the program evolved over the years. Initially, the scheme set ambitious goals to connect 135,436 habitations and upgrade 400,000 kilometers of rural roads. In 2013, the focus shifted to improving 50,000 kilometers of rural roads to increase infrastructure efficiency. By 2019, as most rural habitations had been connected, the program's priorities evolved to enhancing access to key rural facilities, such as Gramin Agricultural Markets, schools, and health centers. Currently, the scheme aims to construct, upgrade, or maintain 125,000 kilometers of roads by 2024-25. To date, PMGSY has significantly improved rural connectivity in India, with more than 742,000 kilometers of rural roads constructed or upgraded and more than 170,000 habitations connected at an estimated investment of $45 billion. (O.M.M.A.S, 2023a,b; Ministry of Rural Development, 2022).

3 Sampling and Data

3.1 Setting (Uttar Pradesh)

Using the participatory resource appraisal methodology (PRA), a method that has been shown to produce extremely accurate information, a village-level survey was conducted in the summer of 2007 in Uttar Pradesh (UP), India (Chattopadhyay and Duflo, 2004).[4] UP lies in the north-central part of the country and is the fourth largest and most populous state in India, with more than 200 million people in the state (Government of India, 2023). UP is currently divided into 75 districts, but at the time of our data collection, it had 70 districts. The state is primarily an agrarian economy where 65% of the population is directly dependent on agriculture for their livelihood, and approximately 38% of the population is poor (Agriculture Department, 2020). With respect to road connectivity in rural areas, UP also had the highest number of unconnected villages before the implementation of the PMGSY program, which presents a good setting to understand the potential impact of new road connectivity on the development of rural livelihoods (O.M.M.A.S, 2023b).

The PMGSY road program was launched in 2000, with a sequential implementation that lasted several years. Due to financial constraints, the program was not implemented statewide; instead, the selection of the village was prioritized according to the population of the village. Although the scheme was officially announced in 2000, road construction activities saw limited progress during the first two years.[5] Our study focuses on PMGSY road construction from 2003 to 2006. To derive our sampling frame, we collected a list of villages eligible for roads under the PMGSY scheme from 2003 to 2006, sourced from the PMGSY website (O.M.M.A.S, 2023b). As mentioned earlier, the phased road construction was driven by financial and logistical constraints, but within a particular year road construction was prioritized based on population cutoffs. The village list obtained from the PMGSY website included those that had already been connected or were scheduled for connectivity between 2003 and

[4] PRA is a field-based survey method to collect data from the local community about village infrastructures and resources. The PRA survey method is rapid, accurate, and less expensive, especially when the implementation of the project is at the village level and the majority of the villagers are likely to be affected by the project.

[5] Villages connected between 2000 and 2002 were not included in the study due to data limitations and uncertainties about adherence to program rules.

2006.

3.2 Sample

To measure the impacts of PMGSY, we surveyed a random sample of 267 villages in the 14 districts near Lucknow,[6] the capital of UP. The village-level primary data collection was conducted in 2007.

The surveyed villages were chosen to generate a representation of two sets of villages with otherwise similar characteristics: those with PMGSY roads already constructed and those sanctioned to receive PMGSY roads in the future, but without any construction. For the purposes of our study, we refer to villages sanctioned for road construction in 2003-04 as "Phase 3" villages, those in 2004-2005 as "Phase 4" villages, and those in 2005-06 as "Phase 5" villages, based on PMGSY documentation. At the time of the survey, most of the Phase 3 villages had completed roads, many Phase 4 villages had begun road construction, and most Phase 5 villages had not yet begun construction. Thus, we excluded Phase 4 villages from our sampling frame in order to avoid biasing our results by comparing villages with roads to those in the middle of the construction process. Instead, we surveyed villages classified as Phase 3 or Phase 5 in the PMGSY planning document. Among these, we selected villages within a population range of 950-1,175 people (as reported in the PMGSY program data). This process led to a total of 302 villages selected for the village survey: 159 Phase 3 villages and 143 Phase 5 villages. During the survey, 35 of the 302 villages were dropped for several reasons, including incorrect identifying information, road construction previously covered under other schemes, having been dropped from the PMGSY list, and our inability to find the village. We refer to Phase 3 villages as treated villages, while Phase 5 villages serve as counterfactual villages for the purpose of our study.

[6]Given that the PMGSY program is based on 2001 census information and that the separation of districts had recently occurred, the pre-2005 district definitions are used for this study. The 14 districts are Bahraich, Barabanki, Faizabad, Farrukhabad, Gonda, Sultanpur, Hardoi, Kanpur Dehat, Kanpur Nagar, Lakhimpur Kheri, Rai Bareilly, Shahjahanpur, Sitapur, and Unnao.

3.3 Data Collection

We trained enumerators who had prior experience in conducting community-based participatory surveys, such as PRA, to conduct the village survey in the 267 selected villages. Out of 267 villages, 144 were Phase 3 and the remaining 123 were Phase 5 villages. The survey team gathered the villagers at a village facility such as a temple, school, community hall, etc. to facilitate discussion about village resources. The survey was carried out mainly at dawn, a time when most of the villagers were available and had returned from work. The enumerators first drew a resource map of the village, clearly marking all the roads that lead to the village and details of the homes connected by these roads. The participation rate ranged from 25 to 450 villagers per village. Subsequently, a structured questionnaire developed by the study team was used to gather information from the villagers. The survey team encouraged participants to respond, cross-checked different responses, and relied on consensus or majority opinions for survey responses.

The village surveys consisted of an average of 132 respondents, the majority male. The survey collected village-level data on agricultural yields, agricultural inputs, outputs, employment, prices, wages, health outcomes, educational outcomes of children, transport and urbanization, migration, and other social aspects of village life, such as marriage and political participation.[7] The survey collected detailed information about connectivity, types of roads, issues related to transport and market access, etc. We collected data on village connectivity by a motorable road, which serves as the main independent variable in the analysis. The exact survey question used was "Is there a motorable road to the village that a car can travel on?" Because the PMGSY scheme funds both the construction of new roads and the upgrading of existing roads (from gravel/mud road to blacktop road), some of the phase 5 villages already had motorable gravel or mud roads despite being slated for future road construction.

[7] A typical survey question is as follows: (i) Approximately what percent of households in the village rely on agriculture as their main source of livelihood?; (ii) Approximately what percent of households in the village rely on casual labor as their main source of livelihood?; (iii) Approximately what percent of households work as casual laborers within the village, outside the village and both?

3.4 Descriptive Statistics

Table 1 provides an overview of the key variables from the village survey data. The responses of the numerical survey are standardized to the mean and variance of the counterfactual group (i.e., Phase 5 villages). [8] Panel A shows the mean and standard deviations for several outcome measures, such as the presence of transportation vehicles in the village, agricultural prices, wages, and migration patterns. For example, 16% of villages report that a commercial vehicle visits their village daily, and the agricultural prices fetched have a standardized mean of 0.11 with a standard deviation of 0.70. In addition, various labor and migration outcomes are reported, highlighting that 57% of households consider their own farm to be the main source of income, while 26% depend on casual labor within the village. Panel B shows variables from the 2001 census, including per capita income, irrigation availability, and village population, which are used in placebo analysis. The average PMGSY population in the villages is around 1,060 people. Panel C presents average values for the endogenous as well as the instrumental variable used in the analysis.

Specifically, we instrument the existence of a motorable road (70% of villages have one) using the within-district population rank of the village. Notably, among the motorable roads in our survey sample, 76% were blacktop, while 20% consisted of gravel or dirt roads. Although motorable roads could have been constructed through various government rural development programs, our survey data indicates that the majority—approximately 79%—were built under the PMGSY initiative. The average population rank is 75, ranging from 7 to 192.

4 Empirical Framework

To assess the effects of road connectivity on village-level outcomes, we estimate the following Ordinary Least Square (OLS) regression model:

$$Y_{vd} = \beta_0 + \beta_1 ROAD_{vd} + \beta_2 (PMGSY\_POP)_{vd} + \beta_3 (Census\_POP)_{vd} + \mu X_{vd} + \epsilon_{vd} \qquad (1)$$

[8] Responses are standardized using the following equation: $obs_{standarized} = (obs - mean_{control})/sd_{control}$

Where Y_{vd} denotes the outcome of interest in village v in district d. $ROAD_{vd}$ is an indicator variable for whether the village is connected to a motorable road (as defined in our survey data). $PMGSY\_POP_{vd}$ is the PMGSY population listed in the village v, $Census\_POP_{vd}$ is the population of the village v from the 2001 census, X_{vd} is a set of village controls from the 2001 census (per capita panchayat income, agricultural electricity, fraction of irrigated land and distance to the nearest town), and ϵ_{vd} is an error term.

The main coefficient of interest is β_1, the impact of road connectivity on each outcome. However, the possibility of endogenous road connectivity, even among Phase 3 and Phase 5 villages and conditional on the included covariates, may result in $ROAD_{vd}$ in equation (1) being endogenous, which can potentially result in a biased OLS estimate of β_1. For instance, if roads were built according to the perceived developmental potential, local officials may have chosen to connect the richer villages first — a common scenario in large infrastructure projects. In this case, the OLS coefficients for the road's impacts would be biased upward. To address these sources of bias and estimate the causal impacts of the PMGSY scheme on village welfare, we employ the IV method described in the next section.

4.1 Instrumental Variables Approach

We use an IV method to address the potential concern of endogenous road placement, where we instrument the presence of a motorable road in a village by the within-district population rank of the village. The empirical strategy rests on the fact that, within the set of approved PMGSY villages in a given district, local governments prioritized the larger villages first. This leads to a higher likelihood of a road being constructed in a village with a larger population relative to other PMGSY-eligible villages, even conditional on the overall village population. In other words, across two villages of the same size, the one in a district with fewer larger unconnected villages is likely to be connected first.

We use Two-Stage Least Square (2SLS) estimator of the IV model to estimate the causal impacts of road connectivity on outcomes of interest. Specifically, the two equations in the 2SLS estimator are as follows. In the first stage, the indicator for a motorable road to the village is regressed on the instrument, which is the population rank of the village ($RANK_{vd}$), as well

as our two measures of the village population size and additional covariates from the census data.

$$ROAD_{vd} = \alpha_0 + \alpha_1 RANK_{vd} + \alpha_2 (PMGSY\_POP)_{vd} + \alpha_3 (Census\_POP)_{vd} + \gamma X_{vd} + \nu_{vd} \quad (2)$$

In the second stage, we regress outcomes of interest on the predicted value of the endogenous variable $ROAD_{vd}$ from Equation (2) as well as the population size (PMGSY and census data) and other exogenous covariates:

$$Y_{vd} = \delta_0 + \delta_1 \widehat{ROAD}_{vd} + \delta_2 (PMGSY\_POP)_{vd} + \delta_3 (Census\_POP)_{vd} + \eta X_{vd} + \upsilon_{vd} \quad (3)$$

4.2 Identifying Assumptions

In a 2SLS model, two key conditions must be satisfied for the instrument ($RANK_{vd}$) to be valid: the instrument relevance and the instrument exogeneity (exclusion restriction). The instrument relevance condition implies that the instrument must be correlated with the endogenous explanatory variable, corr($RANK_{vd}$, $ROAD_{vd}$) $\neq 0$. This ensures that the instrument provides meaningful variation in the endogenous variable. The instrument exogeneity condition implies that the instrument must be uncorrelated with the error term, corr($RANK_{vd}$, ϵ_{vd}) $= 0$. This ensures that the instrument does not directly affect the outcomes; rather, it should affect outcomes indirectly through its effects on the endogenous variable $ROAD_{vd}$. If both conditions hold, 2SLS provides consistent estimates of the causal effect of road on outcomes of interest. Although we can test the relevance of the instrument by examining the statistical significance of the rank coefficient in the first-stage regression (2), the exogeneity condition is statistically untestable.

In our setting, the exogeneity assumption is that, conditional on the included covariates, the within-district population rank of unconnected villages affects village outcomes only through the additional likelihood of road connectivity. A key concern is that villages with larger populations will have a higher rank, and larger villages will also tend to have different outcomes for a number of reasons. We allay this concern by controlling for the population

size, both as measured at the village level from the census data and at the (potentially smaller) individual habitation level as reported in the PMGSY program data. A second concern is that our population rank variable, conditional on population size, could predict village outcomes through channels other than road construction. For example, the government may use the population rank to target other policies. One such policy that used population threshold is the "Total Sanitation Campaign", which constructed toilet facilities to reduce open defecation during 1999-2012 (Spears and Lamba, 2016). Asher and Novosad (2020) argue that there is no theoretical basis or empirical evidence to suggest that a sanitation program aimed at reducing open defecation would influence outcomes that are typically impacted by road infrastructure such as prices, migration, land quality, etc.

Although the exogeneity assumption is fundamentally untestable, we conduct a placebo test to check whether our village rank variable predicts village outcomes measured before the PMGSY program was implemented. If our population rank predicts village outcomes before the PMGSY period, it could indicate that rank is confounded with other factors that drive village development aside from PMGSY roads; if not, it lends credence to the exogeneity assumption. We therefore check that the presence of a motorable road, instrumented by village population rank, does not predict key census outcomes from 2001 (pre-PMGSY outcomes). Specifically, we used the 2001 census data to estimate equations (2) and (3) and examine any differential outcomes according to village population rank, conditional on population and other covariates. The placebo sample was constructed by matching Phase 3 and Phase 5 villages from the PMGSY list to their corresponding 2001 Census data, covering all 70 districts of the state. The final matched sample for the placebo analysis included 1,670 Phase 3 villages and 1,247 Phase 5 villages.

The 2001 census provides limited set of data on key village-level infrastructure and economic activities, including the availability of newspapers and magazines, communication facilities, postal and telephone services, access to drinking water, the proportion of forested and irrigated areas, agricultural electricity usage, medical infrastructure, and other related indicators. We used census outcomes that are similar to the survey outcomes in the placebo analysis to assess the exclusion restriction. As in the survey data, the census outcomes are

standardized based on the mean and variance of the Phase 5 villages. Since the PMGSY program was not yet introduced in 2001, there should be no statistically significant differences in census outcomes between the Phase 3 and Phase 5 villages. This absence of differences would further support the validity of the exclusion restriction.

5 Results

5.1 First-stage and Outside Connectivity

Table 2 shows the results of the first-stage regression for the survey and the census outcomes (panel A), estimating the effect of population rank on the probability of motorable road connectivity. In columns (1) and (2), the first-stage results are statistically significant in the survey and the census sample. The instrument passes the typical strength test as illustrated by the F-statistic of 15.95 (p-value < 0.0001) in the survey sample. Overall, it can be observed that for both the survey sample and the pre-PMGSY census data, the relative population rank significantly and positively affects the probability of receiving a motorable road, satisfying the relevance condition of the IV method.

In panel B of Table 2, we show the effects of the road on connections to the outside world. Column 1 outlines the effects of a road on vehicle traffic in the village, and column 2 outlines the effects of being a phase 3 village on having a road in the pre-intervention 2001 census. We find that villages with PMGSY roads are much more likely to observe a larger volume of vehicles passing through each day; however, our measure of PMGSY roads is not correlated with having a road in the 2001 census.

5.2 Effects on Agricultural Development

Given the high dependence on agriculture for the majority of the population in the state of Uttar Pradesh, our primary results revolve around agricultural prices, yields, investments, and land quality, as presented in Table 3. In Panel A, we show the results on outcomes related to agriculture, while Panel B shows the results on land quality. In Panel A, we find that

the PMGSY road increases the price of staples for producers (col 3) while simultaneously decreasing the prices paid by consumers at fair shop (col 1). Both of these price effects are statistically significant. Producers' prices increases by more than one standard deviation (1.4 SD), while consumer prices decline by 0.6 SD, suggesting that improved transportation reduces transaction costs and enhances agricultural profitability. The average prices paid by consumers in the nearest market decrease, but the coefficient is imprecisely estimated (col 2).

There could be several mechanisms that may be driving these results. For example, a decrease in asymmetric information between farmers and buyers–particularly in India, where farmers primarily sell to the informal sector and intermediaries–through increased awareness of market prices could lead to improved processes for producers.(Mitra et al., 2018; Negi et al., 2018). Furthermore, producer prices can also be increasing due to observed shifts in employment; individuals are moving out of agriculture and to other casual labor jobs (Asher and Novosad, 2020; Shamdasani, 2021). However, the decrease in consumer prices can possibly be attributed to increased access to the village by bus, truck, or commercial vehicle, thus decreasing the barriers associated with selling in the village (Aggarwal, 2018).

One may expect a rise in yields due to higher rewards for effort, but we do not see any evidence of this. The coefficient is positive, but it is imprecisely estimated (Table 3, col 4). Furthermore, we do not find any evidence of an increase in investment and infrastructure in agriculture in the village. Agricultural investment is measured by the share of households that use chemicals, fertilizers, and pesticides on their farms. Agricultural infrastructure is measured by the share of households with motorized agricultural equipment (i.e. tractors, threshers, trolleys, etc.).

Panel B of Table 3 examines the impacts of the road on the quality of agricultural land. It is likely that because of the better prices, the land is used intensively and this can decrease the quality of the land. In the village survey, the villagers were asked about the percentage of agricultural land that suffers from flood proneness, alkalinity, water logging, and erosion problems. The responses were recorded on a scale of 1 (almost none) to 6 (almost all). We find no evidence that roads reduced the quality of land over two to three years after road construction once we address the endogeneity of road placement. The overall results imply

that short-term benefits of access to roads are primarily in pricing efficiency rather than productivity gains. We also report the F-statistic to assess the strength of the first stage for each regression, and they are always greater than 10, indicating evidence of a strong instrument relevance (Stock et al., 2002).

5.3 Effects on Labor Market

Table 4 presents the 2SLS estimates of the impacts of roads on labor market outcomes in Panel A and the outcomes related to migration in Panel B. Road connectivity significantly reduces the dependence on agriculture as the main source of income by 0.56 SD, while increasing local opportunities for casual labor within villages by 0.52 SD. We do not find statistically significant effects on the dependence on casual labor outside the village as the main source of household income. This shift is accompanied by wage increases, particularly in government construction jobs of 1.8 SD. Wages for agriculture and non-government construction jobs increase, though these are not statistically significant. These findings are consistent with those of previous studies, which find that road connectivity leads to a decreased dependence on agricultural income (Asher and Novosad, 2020; Shamdasani, 2021). Our results suggest that residents opt for local casual employment, meaning that, given the increased connectivity from a road, local employment opportunities in villages have expanded. The statistically significant positive impact on wages aligns with previous evaluations of the PMGSY (Asher and Novosad, 2020), which highlight the importance of proximity and access to government offices in driving government activity. This suggests that wage increases in government construction projects are likely a direct result of a higher local demand for labor to support other government-sponsored development initiatives.

Furthermore, improving rural road connectivity may have nuanced and ambiguous effects on migration. Although new roads make traveling to outside areas easier, higher wages in government jobs, better agricultural prospects, and increased local non-farm employment opportunities in the village reduce the need for villagers to migrate for work. The results in panel B in Table 4 indicate that road connectivity leads to a statistically significant decline in daily migration, suggesting improved local employment opportunities in villages that re-

duced the need for villagers to look for work outside their communities. Roads led to a significant decrease in daily migration, with a coefficient of -0.62, indicating that improved local employment opportunities reduce the need for daily commutes outside the village for employment opportunities. Although the effects on weekly and monthly migration are smaller and less precise, the overall share of migrating households decreases by 0.48 SD, significant at the 1% level of significance (Table 4, col 5). This decline in daily migration aligns with increased employment opportunities outside agriculture and higher wages in local government construction projects. In summary, labor market dynamics shift following road construction. Employment moves away from agriculture toward casual labor, with a rise in local job opportunities. Wages increase, particularly in government construction jobs, with a 1.8 standard deviation rise. Additionally, migration patterns change as local employment improves, leading to a significant decline in daily commutes to urban areas.

5.4 Effects on Social Status, Local Governance, and Civic Engagement

Beyond economic effects, road connectivity improves governance and social institutions. Villages with new roads experience a greater presence of government officials, more frequent police patrols, and increased access to news and civic engagement. Social dynamics also change, with fewer marriages, a higher average age of marriage, and enhanced wedding quality, as indicated by a greater presence of musical bands at marriage ceremonies.

In Table 5, we examine the effects of the presence of a road on social and political connectivity. In India, weddings are used as a signal of status. Panel A in Table 5 shows that road construction leads to a decrease in the number of boys and girls married in the village in the year before the survey, suggesting delayed marriages, possibly due to better employment and educational opportunities. There is a statistically significant decline in the number of boys' marriages by 0.68 SD. The results in columns 3 and 4 in Panel A provide suggestive evidence that the decline in the number of marriages may have been due to delayed marriages as road construction had a positive impact on the average age of marriages for boys and girls, although the estimates are imprecisely estimated. Another interesting and novel finding pertains to the quality of weddings. We find statistically significant and positive impacts on the

quality of weddings, as indicated by a significant increase in the number of bands present at weddings within the village.

Lastly, panel B of Table 5 explores how road connectivity affects local governance and political engagement. Given the introduction of a road, we find that road connectivity significantly increases visits by government officials (0.75 SD), police visits (1.76 SD), and police patrolling activity (0.80 SD). These findings, combined with the increase in local job opportunities, suggest a growing population presence in the village with better rural connectivity, which enhances more local activities related to politics or local governance. Furthermore, Table 5 also shows that more residents are receiving newspapers in PMGSY villages, reflecting the preference for improved access to information about the outside world and greater civic engagement. Although the effect on political campaigns and events is positive (0.279 SD), the estimates are not statistically significant. Together, these findings highlight improved political connectivity and governance in villages due to improved road infrastructure.

Overall, these findings illustrate the local-level adjustments following the introduction of PMGSY roads. Agricultural workers benefit from higher prices for their products, while those transitioning out of agriculture are finding better-paying local casual jobs. Consumers enjoy lower staple prices, and social changes are evident with improvements in the quality of weddings. Additionally, road connectivity boosts political engagement, as seen through increased visits by government officials, more frequent police patrols, and greater access to information via newspapers. Together, these outcomes highlight the diverse economic, social, and political transformations brought about by improved rural connectivity.

5.5 Effects on Health and Education

Table A1 in the Appendix presents the 2SLS estimates of the impacts of road connectivity on infant and adult health (panel A) and educational outcomes (panel B). Improved road connectivity led to improved health outcomes for infants but not for adults. Under-5 mortality decreases by 2.24 SD, highlighting better health outcomes for children due to improved access to healthcare. Better road connectivity also facilitates easier access to health services, evidenced by the increased use of motorized transport (e.g., trucks or buses) for healthcare.

Additionally, there are positive impacts on health worker visits to villages, but the coefficients are imprecisely estimated. The findings also suggest that the speed of accessing healthcare improves marginally, reflecting reduced travel times to medical facilities.

Panel B examines school attendance, availability of primary and middle schools, teacher absenteeism, and travel time to higher education institutions. There is a significant positive effect on the fraction of girls and boys attending primary schools, suggesting improved access to education due to road connectivity. A significant improvement is observed in the speed of reaching middle and secondary schools (primary school is usually in the village), highlighting reduced travel times. No significant effects are seen for outcomes such as the presence of primary schools in villages or days when schools closed early.

5.6 Placebo Results/Exclusion Restrictions

As discussed above, there is no formal statistical test to assess the exclusion restriction. However, we conduct a placebo test to support the excludability of the instrument. Specifically, the placebo test uses the 2001 census data to check that a road dummy, instrumented by rank, does not predict the village outcomes from the 2001 census. Given that, at this point in time, the intervention has not been administered, the treatment and control villages should be similar, and thus, the road dummy should not have statistically significant effects on census outcomes. Table A2 in the appendix reports the results of the 2SLS placebo analysis, examining the effects of roads on pre-program (2001 census) outcomes. Panel A shows placebo results for census outcomes related to road connectivity and agricultural development, while panel B shows placebo results for outcomes related to health and education. All regression models control for the census population as well as the PMGSY population.

Columns (1)-(4) in Panel A further control for census controls as defined before, while columns (5)-(7) do not control for census variables because the census controls are the census outcomes in these columns. Regression models in panel B continue to control for census controls as before. The analysis includes several outcomes related to village infrastructure, agricultural development, health, and education before the implementation of the road program. None of the 2SLS coefficients is statistically significant except for communication

(Post/telegraph/phone) facilities) and the availability of primary schools, which can be described as complementary infrastructure investments that are essential for other forms of access improvement (Chaurey and Le, 2022). The coefficient in column (2) in panel A is statistically significant, but the sign is negative, implying that phase 3 villages (road dummy) have fewer communication facilities compared to phase 5 villages. The availability of health infrastructures and access to healthcare are not affected by road connectivity. Regarding educational infrastructure, the placebo test fails for primary school–the coefficient is positive and statistically significant (Table A2, col 5, panel B). However, our main analysis of educational outcomes controls the availability of educational facilities in the census. Overall, this table provides strong evidence that road placement, as proxied by phase 3 villages, does not correlate strongly with preexisting village conditions, helping to address concerns about endogenous road placement and excludability of the instrument.

6 Conclusion

A persistent question in economic development is the role of road infrastructure in improving livelihoods in rural areas. Given the importance of road infrastructure in the development of the local economy, many countries have implemented policies to build new roads to improve rural connectivity. However, evaluating the effectiveness of these large-scale infrastructure projects, such as roads, especially in developing countries, remains challenging due to limited data availability and concerns over endogenous road placement. We make an attempt to answer these questions by estimating the short-term impacts of the world's largest rural road construction program, PMGSY, in India. To address potential endogeneity in road placement, we use the IV method to estimate the causal impacts of road connectivity on village-level outcomes. We leverage within-district population rank as the instrument for the endogenous road placement. The data analyzed come from the village survey conducted by us in the early years of implementation of PMGSY in Uttar Pradesh.

This paper makes several interesting findings about the multifaceted impacts of rural road development on local development in rural areas. The results show that improved rural connectivity led to an improvement in agricultural development, labor market outcomes, and

social aspects of village life. The overall findings show how the local economic landscape changes in response to improved transportation networks and connectivity. The study's findings contribute to the existing literature by offering a localized perspective on the impacts of roads on village outcomes.

The main results can be summarized into three categories: (1) impacts on the agricultural economy, (2) local employment and migration patterns, and (3) social and cultural impacts. The study finds that the introduction of PMGSY roads leads to positive price changes for producers and consumers and shifts employment from farm work to local casual labor, indicating broader job opportunities. In addition, the program led to increased wages for government construction jobs and a decline in daily migration, highlighting an improvement in local employment prospects. The study also uncovers social and cultural changes, such as delayed marriages and improved wedding quality, reflecting changes in social norms. Finally, roads increase political participation, with more government visits and greater civic participation in connected villages.

The findings reinforce the importance of investing in rural infrastructure to drive local development and alleviate poverty. Although acknowledging the positive impacts of the PMGSY program, it is important to recognize that road development alone may not be sufficient to address all the challenges faced by rural communities. Future policies should aim to complement road connectivity with investments in agriculture, education, healthcare, and other critical areas to ensure that rural communities can fully leverage the opportunities created by improved access. Continued efforts must be made to integrate the road infrastructure with targeted interventions in other social sectors to ensure holistic progress in rural areas.

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Table 1: Descriptive statistics

	Summary		
	N	Mean	SD
Panel A: Outcome Variables			
Shared Truck/Bus/Commercial Vehicle Comes to Village Each Day	267	0.16	0.36
Avg of staple fair prices	254	-0.02	0.54
Avg of staple prices at nearest market	227	-0.01	0.52
Agricultural price fetched	205	0.11	0.70
Agricultural yields	206	-0.05	0.97
Adult agricultural daily wage	222	0.13	0.87
Male daily govt construction wage	249	0.03	1.01
Male daily non-govt construction wage	266	0.07	0.96
Labor on own farm most important source of livelihood	267	0.57	0.50
Casual labor in village most important source of livelihood	267	0.26	0.44
Casual labor outside village most important source of livelihood	267	0.16	0.36
Daily migration normalized to total HHs	265	0.06	1.19
Weekly migration normalized to total HHs	265	0.05	1.16
Month-long migration normalized to total HHs	264	-0.06	0.79
More than month-long migration normalized to total HHs	264	0.01	1.02
Migration shares normalized to total HHs	258	0.01	0.56
Number of village boys married in previous year	267	-0.17	0.80
Number of village girls married in previous year	267	-0.15	0.79
Avg age of village boys married in previous year	266	-0.00	1.49
Avg age of village girls married in previous year	266	0.16	2.24
Number of Weddings with a Band	266	0.39	1.55
Fertilizer company has visited at least once in past year	267	0.26	0.44
Fruit/vegetable seller comes to village	266	0.56	0.50
Political Campaign Visits and Events	267	0.08	0.89
Govt visits	266	0.24	1.01
Times police came to village	265	0.19	1.27
Police patrolling activity	262	0.07	1.00
Any HHs Receives Paper	263	0.30	0.46
Panel B: Control Variables			
Per capita panchayat income: 0 if missing	253	0.10	1.53
Electricity for agriculture: 0 if missing	253	-0.21	0.85
Fraction of cultured area irrigated	253	-0.11	1.07
Distance from the Nearest Town (km)	253	-0.04	1.37
Census Pop. (thousands)	253	1.75	1.62
PMGSY Pop. (thousands)	267	1.06	0.06
Panel C: Endogeneous and Instrumental Variable			
Motorable road to village that a car can travel on	267	0.70	0.46
Population rank (small to large)	267	75.63	41.06

Note: Except in the case of dummy variables, variables are standardized using the mean and standard deviation of the control villages in the sample ($obs_{standarized} = (obs - mean_{control})/sd_{control}$). Population is in the thousands.

Table 2: 2SLS estimates of the impacts of roads on connection to the outside world

	Motorable road to village (survey data) (1)	Phase 3 village (census data) (2)
Panel A: First stage		
Population rank (small to large)	0.003***	0.001***
	(0.001)	(0.000)
Cragg-Donald Wald F statistic	20.97	50.39
Kleibergen-Paap Wald rk F statistic	15.95	7.98
	Tuck/bus/comm vehicle comes each day	Village has: mud or paved road
Panel B: 2SLS estimates		
Motorable road to village	0.644***	
	(0.180)	
Phase 3 village		0.011
		(0.310)
Census controls	✓	✓
Observations	253	2879

Notes: Standard errors clustered by district are in parentheses. The controls comprise the census variables per capita panchayat income, agricultural electricity, fraction of irrigated land, distance to the nearest town, and PMGSY population. The sample for column 1 uses primary survey data and column 2 uses 2001 census data. ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.

Table 3: 2SLS estimates of the impacts of roads on agricultural development

	Avg of staple prices paid at fair shop (1)	Avg of staple prices at nearest market (2)	Agricultural staple prices fetched (3)	Agricultural yields (4)	Village investment & infrastructure (5)
Panel A: Agricultural prices, yields, and investments					
Motorable road to village	-0.635**	-0.342	1.391***	0.282	0.153
	(0.304)	(0.347)	(0.238)	(0.369)	(0.117)
Census controls	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	18.36	18.18	14.16	13.82	21.08
Kleibergen-Paap Wald rk F statistic	13.34	20.57	24.65	26.25	16.66
Observations	242	215	195	196	244

	Agricultural flood-proneness	Agricultural alkalinity	Agricultural water logging	Agricultural erosion
Panel B: Agricultural land quality				
Motorable road to village	0.707	0.630	0.266	0.421
	(0.853)	(0.445)	(0.473)	(0.283)
Census controls	✓	✓	✓	✓
Cragg-Donald Wald F statistic	21.36	19.88	20.15	21.17
Kleibergen-Paap Wald rk F statistic	15.05	14.85	14.69	15.67
Observations	250	252	251	252

Notes: Standard errors clustered by district are in parentheses. The census controls include per capita panchayat income, agricultural electricity, fraction of irrigated land, distance to the nearest town, and census population from the 2001 census and also control for PMGSY population. Outcomes are standardized using the control mean and standard deviation of survey data ($obs_{standarized} = (obs - mean_{control})/sd_{control}$). ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively

Table 4: 2SLS estimates of the impacts of roads on labor market outcomes

	Main source of income from:			Daily wages		
	Own farm	Casual labor inside village	Casual labor outside village	Agriculture	Government construction	Non government construction
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Casual labor and wages						
Motorable road to village	-0.558***	0.522***	0.035	0.597	1.811**	0.685
	(0.177)	(0.163)	(0.134)	(0.585)	(0.782)	(0.939)
Census controls	✓	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	20.90	20.90	20.90	19.45	18.95	20.83
Kleibergen-Paap Wald rk F statistic	15.84	15.84	15.84	11.83	12.57	15.98
Observations	253	253	253	209	237	252

	Shares of households migrating				
	Daily	Weekly	Monthly	More than a month	Average of migration shares
Panel B: Migration outcomes					
Motorable road to village	-0.616*	-0.252	-0.389	-0.946	-0.485***
	(0.381)	(0.423)	(0.289)	(0.670)	(0.190)
Census controls	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	21.57	20.41	21.61	19.77	20.47
Kleibergen-Paap Wald rk F statistic	15.85	15.45	16.10	14.61	14.66
Observations	251	251	250	250	244

Notes: Standard errors clustered by district are in parentheses. The census controls include per capita panchayat income, agricultural electricity, fraction of irrigated land, distance to the nearest town, and census population from 2001 census and also control for PMGSY population. Outcomes are standardized using the control mean and standard deviation of survey data ($obs_{standarized} = (obs - mean_{control})/sd_{control}$). ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.

Table 5: 2SLS estimates of the impacts of roads on social status, local governance, and civic engagement

	In the village last year:				
	Number of boys married	Number of girls married	Average age of boys married	Average age of girls married	Weddings with band
	(1)	(2)	(3)	(4)	(5)
Panel A: Wedding outcomes					
Motorable road to village	-0.682***	-0.221	0.289	0.950	2.06***
	(0.226)	(0.213)	(0.907)	(1.13)	(0.613)
Census controls	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	21.72	21.72	21.57	22.49	21.81
Kleibergen-Paap Wald rk F statistic	13.21	13.21	13.21	13.66	13.37
Observations	253	253	252	252	252
	Political campaigns visits & events	Govt official visits to village	Police visits to village	Police patrolling activity	Household in Village receive newspaper (Y/N)
Panel B: Political connectivity outcomes					
Motorable road to village	0.279	0.755**	1.765*	0.805***	0.248*
	(0.432)	(0.327)	(0.899)	(0.193)	(0.147)
Census controls	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	20.90	21.00	21.17	21.63	18.82
Kleibergen-Paap Wald rk F statistic	15.84	15.95	16.04	16.28	15.00
Observations	253	252	251	248	249

Notes: Standard errors clustered by district are in parentheses. The census controls include per capita panchayat income, agricultural electricity, fraction of irrigated land, distance to the nearest town, and census population from 2001 census and also control for PMGSY population. Outcomes are standardized using the control mean and standard deviation of survey data ($obs_{standarized} = (obs - mean_{control})/sd_{control}$). ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.

Appendix

Table A1: 2SLS estimates of the impacts of roads on health and education

	Under 5 mortality (1)	Truck or bus for complicated delivery (2)	Dai/ANM presence indicators (3)	Home birth share (4)	Adult mortality (5)	Speed to receive health care (6)	Truck or bus to receive health care (7)	Healthworkers visit to the village (8)
Panel A: Infant and Adult Health								
Motorable road to village	-2.243**	0.027	0.476	0.541	-0.766	0.005	0.399***	0.063
	(1.028)	(0.113)	(0.538)	(0.897)	(0.609)	(0.613)	(0.148)	(0.152)
Census controls	✓	✓	✓	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	20.16	20.16	20.16	20.16	20.16	20.16	20.84	20.01
Kleibergen-Paap Wald rk F statistic	16.15	16.15	16.15	16.15	16.15	16.15	16.99	16.15
Observations	251	251	251	251	251	251	248	251
	School attendance indicators	Fraction of girls in primary schools	Fraction of boys in primary schools	Fraction of girls in middle schools	Primary school in village	Fraction of primary teachers absent	Days primary school closed early	Speed to middle and secondary school
Panel B: Education								
Motorable road to village	0.711	0.920***	0.899**	0.469	0.227	-0.436	0.661	1.193*
	(0.483)	(0.291)	(0.345)	(0.711)	(0.231)	(0.666)	(0.827)	(0.649)
Census controls	✓	✓	✓	✓	✓	✓	✓	✓
Cragg-Donald Wald F statistic	20.51	20.51	20.51	21.13	21.13	21.87	21.13	17.83
Kleibergen-Paap Wald rk F statistic	13.97	13.97	13.97	14.70	14.70	14.51	14.70	14.73
Observations	250	250	250	251	251	251	251	170

Notes: Standard errors clustered by district are in parentheses. The census controls include per capita panchayat income, agricultural electricity, fraction of irrigated land, distance to the nearest town, and census population from the 2001 census and also control for PMGSY population. In panel A, models include additional census controls related to health infrastructures: any medical facility, any health center or sub-center, any community health worker, and any registered medical practitioner. All outcomes in panel A are standardized except col(2) using the control mean and standard deviation of survey data ($obs_{standarized} = (obs - mean_{control})/sd_{control}$). ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.

Table A2: 2SLS effects of roads on pre-program outcomes (2001 census data - placebo)

Panel A: Connectivity and agricultural development							
	Village receives newspapers magazine	Village has communication facilities	Village has Post/telegraph/ phone facilities	Village has Drinking water facility	Fraction of total area forested	Fraction of cultivated area irrigated	Electricity for agriculture
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Phase 3 village	-0.005	-0.224**	0.082	0.003	0.015	-0.122	-0.165
	(0.145)	(0.110)	(0.198)	(0.017)	(0.047)	(0.217)	(0.216)
Census controls	✓	✓	✓	✓	×	×	×
Cragg-Donald Wald F stat	50.39	50.39	50.39	50.39	16.38	47.22	67.69
Kleibergen-Paap Wald rk F stat	7.98	7.98	7.98	7.98	6.19	7.36	16.72
Observations	2879	2879	2879	2879	2450	2917	2159
Panel B: Health and education							
	Medical facilities	No. of health centers/ sub-centers	Community health worker in the village	Private health workers in the village	Primary school in the village	Middle school in the village	Secondary school in the village
Phase 3 village	-0.149	-0.102	-0.306	-0.047	0.478**	0.039	0.035
	(0.155)	(0.70)	(0.206)	0.058	(0.194)	(0.120)	(0.057)
Census controls	✓	✓	✓	✓	✓	✓	✓
Cragg-Donald Wald F stat	50.39	50.87	50.87	50.87	5.87	50.87	50.87
Kleibergen-Paap Wald rk F stat	8.02	8.02	8.02	8.02	8.02	8.02	8.02
Observations	2879	2917	2917	2917	2917	2917	2917

Notes: Standard errors clustered by district are in parentheses. All outcomes are binary variables, except for outcomes in columns (5)-(6). The census controls include per capita panchayat income, agricultural electricity, fraction of irrigated land, and distance to the nearest town. All columns control for 2001 census population and for PMGSY population. ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.