

The road to safety- Examining the nexus between road infrastructure and crime in rural India

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Abstract

This study examines the relationship between road infrastructure and crime rate in rural India using a nationally representative survey. On the one hand, building roads in villages may increase connectivity, boost employment, and lead to better living standards, reducing criminal activities. On the other hand, if the benefits of roads are non-uniformly distributed among villagers, it may lead to higher inequality and possibly higher crime. We empirically test the relationship using the two waves of the Indian Human Development Survey. We use an instrumental variable estimation strategy and observe that building roads in rural parts of India has reduced crime. The findings are robust to relaxing the strict instrument exogeneity condition and using alternate measures. On exploring the pathways, we find that improved street lighting, better public bus services and higher employment are a few of the direct potential channels through which road infrastructure impedes crime. We also find a negative association between villages with roads and various types of inequality measures confirming the broad economic benefits of roads. Our study also highlights that the negative impact of

roads on crime is more pronounced in states with weaker institutions and higher income inequality.

Keywords- crime, roads, rural development, India

JEL codes-R41, O18, K42, R10

1. Introduction

The adverse impact of crime is of utmost importance in developing economies that are already plagued with low growth, low investment trap, and uncertain economic environment. Further, due to informal markets, weak institutions and poor quality of infrastructure, the probability of being caught and convicted of a crime are lower in developing countries than the developed ones. Further, countries that are characterised by higher inequality have a higher incidence of crime due to various reasons (Ehrlich, 1974; Fajnzylber et al., 2002). Firstly, in societies with a high degree of inequality, the legal wage for low-skilled workers may be too low compared to expected earnings from indulging in illegal activities. Second, the cost of crime is the combination of the probability of being caught and prison time. Again when inequality is high, one may argue that the quality of life within and outside the prison may not differ substantially, making crime a high expected return and low-risk activity compared to low inequality scenarios. Since developing countries have higher inequality (Van der Hoeven, 2019), the vulnerability of individuals and exposure to crime is likely to be high in this setup. Frequent criminal activities may affect productivity in developing economies hindering life. Thus, research on factors and interventions that may control and deter crime may be highly relevant for the developing world. Becker (1986) pioneered the economics of crime and suggested that criminals were rational agents deciding whether to indulge in criminal practices based on their benefits and costs.

Following Becker (1986), a large body of literature has emerged that has explored the determinants of crime (Fajnzylber et al., 1998; Cahill and Mulligan, 2003; Imrohoroglu et al., 2006; Bunanno and Montolio, 2008). These papers identify several attributes such as unemployment rate, urbanization extent, the fraction of foreigners, previous incidence of crime and quality of institutions. On the other hand, sociological literature focuses on how the social theory of relative deprivation may be one of the significant determinants of crime (Merton, 1968; Blau and Blau, 1982; Bernburg et al., 2009, O'Mahony, 2018). The theory posits that more impoverished and more unequal societies have higher crime counts due to people feeling deprived relative to their peers. Besides these socio-economic factors, spending on road infrastructure may also influence crime rates (Hughes, 1998). Our paper also attempts to examine how building road infrastructure may impact criminal activities.

We explore various channels through which roads may influence crime. First, local development through roads may lead to better employment opportunities. A revisit to Becker's (1968) model then implies that the opportunity cost of crime rises with better employment

opportunities. As a result, individuals may substitute their time spent on crime with formal employment. Hence, Becker's (1968) framework implies that building road infrastructure should impede and deter crime. However, if the economic benefits of employment due to roads disproportionately favour the skilled and endowed individuals more, the unskilled ones may still indulge in criminal activities. In some instances where the benefiting group forms a minuscule share of the population, it may lead to a rise in criminal activity.

Another channel that determines how road infrastructure may influence crime stems from the infrastructure development implementation itself. Roads reduce the time costs and increase mobility, both critical for criminal activities and economic activities. A well-connected road network may catalyze movements of criminals to potential hot spots with ease. These contrasting channels provide an interesting backdrop to test the empirical validation of how building road infrastructure may affect crime in developing economies.

Against this background, we attempt to examine how building road infrastructure impacts crime in rural India. The focus on rural India stems from the weak infrastructure and scarce non-farm opportunities (Jha, 2006)¹. With heavy reliance on agriculture for employment, infrastructure development in rural parts of India has been slow. Despite receiving attention in several development plans and policies since independence, the slow pace had been persistent until the late nineties. In 2000, the central government of India introduced the Pradhan Mantri Gram Sadak Yojna (PMGSY) that aimed to connect all villages with an all-weather pucca road in a phased manner. Rule-based population cutoffs determined the sequence of phases. However, in 2011, the PMGSY rollout was extended to all the villages in India.

We use data from the India Human Development Survey (IHDS) conducted in two waves-2004-05 and 2011-12. Among several socio-economic attributes, the survey explored whether the household faced any type of criminal activity in the last twelve months. We use multiple measures of crime as our dependent variables. Both waves of IHDS also have a separate questionnaire for village-level amenities, population composition and occupation structure, among other attributes. Using information from the village questionnaire on whether the village

¹ From the perspective of crime, crime is generally viewed as a byproduct of poverty, inequality and urbanization. According to the Indian Human Development Survey, crime rates (defined as the share of households that were subjected to some type of crime) in urban India was 7% between 2004-05 to 2011-12. During the same period, rural India witnessed a crime rate from 6.1%. Thus, crime in India is not substantially different between the sectors.

was accessible through an all-weather pucca road or kaccha road or was inaccessible, we construct our focal variable- the presence of a pucca road in the village.

We employ an instrumental variable estimation strategy to account for omitted unobservable factors that may simultaneously influence road and crime measures. We find that households living in villages connected with an all-weather pucca road experience 5% less criminal activities than households living in villages without it. Our effect size doubles when we control population composition, inequality and income uncertainty at the village level. A closer examination of the specific type of criminal activity reveals that the effect is limited to types of crime that have a higher possibility of happening outside home premises- female harassment and burglary.

We explore several channels that may drive our main findings. We posit that roads as a deterrent to crime may work through two channels- direct effect of better street lighting, higher likelihood of bus service and increased employment opportunities. Additionally, it will also bear the indirect benefit of higher income for the households and lower inequality at the village level. We test these channels by examining the impact of a pucca road on street lighting, and bus stops in the village, employment and income status of households. We find strong evidence that households in villages with better-connected roads have greater access to public programs related to street lighting and bus services. Additionally, we also find evidence for increased employment, higher income and equal land distribution for villages with better roads. These results outline the primary channel through which roads reduce crime.

We extend our model in two broad ways. These extensions are based on institutional factors and pre-existing socio-economic conditions in the state where the village is located. In the first extension, we attempt to examine if our impact is uniform for states with better quality of institutions vis-à-vis states that do not. We use measures that capture the efficacy of crime deterrence and management at the state level and divide our states according to high and low categories. We find that road infrastructure reduces crime only in states that have a lower quality of institutions. This outlines the critical importance of roads in helping these states catch up with better institutions. As a second extension, we test if our effects are conditioned by the level of inequality and the coverage of public employment programs at the state level. Again, we find that our impact is limited to relatively more unequal states and that have better coverage of public employment program. These results underline the importance of building road infrastructure in rural India.

The paper is organized as follows: Section 2 lays down the relationship between crime and road infrastructure. We discuss the Indian experience in Section 3 and data and descriptive statistics are presented in Section 4. The econometric methodology is discussed in section 5. We present our results in Section 6 and conclude in section 7.

2. Relationship between crime and road infrastructure

2.1 Economic effects of road infrastructure

The need for infrastructure is of paramount importance in developing countries due to weak institutional factors (Sawada et al., 2014). These countries invest a large amount of resources in restructuring and building a broad and well-connected road network. An established road infrastructure setup leads to a wide range of impacts on urbanisation, population and environment. These impacts may be beneficial or harmful depending on the broader context (Khanani et al., 2021). For instance, the building of roads and transportation services accompany peripheral residential development, the emergence of commercial establishments and other forms of spatial segregation. Additionally, infrastructural development also enhances mobility, consequently reducing barriers to labour force participation (Akee, 2006; Lei et al., 2019), improving access to schools (Adukia et al., 2020) and health care facilities (Aggarwal, 2021).

The socio-economic benefits of roads are driven by the primary channel of reduced transportation costs and higher mobility. The resultant ease of access may open up job opportunities and public services that were previously inaccessible. For instance, Khandker (1989) finds that government investment on roads in Indian districts between 1961 and 1981 was associated with new non-farm employment and higher wages. Several recent studies have also documented the Indian experience of the creation of non-farm jobs due to rural road infrastructure investment (Aggarwal, 2018; Asher and Novosad, 2016).

However, roads may have some adverse outcomes as well. Past studies have examined the direct negative effect of environmental degradation, higher chances of landslides and road accidents (Forman and Alexandar, 1998; Paul and Meyer, 2001; Slabbekoorn and Peet, 2003; Coffin, 2007). Besides these, it may also have non-uniform impacts across various sections of society. For instance, people who own land and vehicles may use the roads to their advantage, whereas the landless may not benefit as much. Consequently, road infrastructure development may lead to rising inequality with the impact of roads favouring the rich and endowed more

than the poor. However, Ferriera (1995) argues that if infrastructure investment in underdeveloped areas increases connection between core economic activities, it may lead to more productive opportunities for the poor that may reduce inequality. In summary, the direction of the impact of roads on inequality is ambiguous depending on the context and the country.

2.2 Roads and crime

An additional aspect related to road networks that has received relatively less attention is criminal activity. Criminal activity is as spatially segregated as economic opportunities. The ease of mobility and better connectivity due to road infrastructure that benefits economic opportunities is also relevant for illegal activities. Further, the choice of committing crime stems from limited viable economic opportunities (Becker, 1968). In a developing country like India, where 11.90% of the population is unemployed², and a mere 20% of employed individuals are employed as waged and salaried workers³, most individuals face a lack of dignified job opportunities. While there are several contributing factors to the employment situation in India, weak and inadequate infrastructure exacerbates it. Consequently, it can be related to a higher possibility of low or unskilled individuals indulging in criminal activities in given lack of job opportunities along with low wage returns. Against such backdrop, investing in road infrastructure may be an effective tool in reducing barriers to entering the labor force and reducing criminal activity.

Further, if infrastructure benefits the elite and non-poor more than the poor and economically vulnerable sections of the society, it may make the society more unequal. Road infrastructure may then increase crime as a consequence of a rise in inequality. Becker (1968) explains that to catch up with high-income individuals, crime is an easier tool for low-income individuals than the low returns from the labor market. Several papers have extended this model (Ehrlich, 1973; Block and Heineke, 1975; Chiu and Madden, 1998). Bourguignon (2000) also finds a positive association between observed inequality and levels of crime. Bourguignon (2001) revisits this issue with a particular focus on urbanization and reiterates that crime is a byproduct of uneven economic development or processes. Inequality and poverty, even if transitory, have large and persistent societal losses through crime.

² This is the unemployment rate in India as of May, 2021. Source- <https://unemploymentinindia.cmie.com/>

³ This is the data for May 2019. Source- <https://timesofindia.indiatimes.com/business/india-business/why-bad-employment-is-a-bigger-problem-than-unemployment/articleshow/70099901.cms>

A similar positive association between crime and inequality is presented in Merton (1938). The strain and disorganization theory by Merton (1938) posits that individual alienation due to low income, marginalized status, or discrimination may lead to indulging in criminal activities. The empirical evidence of these theories, however, remains inconclusive. While Blau and Blau (1982) and Bourguignon et al. (2003) find support for it, Land et al. (1990), Kelly (2000) and Kang (2016) find an insignificant relationship between crime and inequality. Bourguignon et al. (2003) investigate the relation for the seven largest cities in Colombia and find that probability of being a criminal was higher for individuals living in households that had a per capita income below 80 percent of the mean. In contrast, Kang (2016) emphasizes that crime is primarily driven by economic segregation instead of within neighborhood inequality.

A second dimension to the relationship between road infrastructure and criminal activities is related to the physical network of roads. According to criminology literature, road infrastructure may work as a skeletal structure to criminals that may aid in identifying and easily accessing the hot spots (Davies and Johnson, 2015). This may perpetuate criminal activities in areas that are well connected. However, one may argue that infrastructure activities require casual employment that benefits the unskilled category of the local population. Hence, considerable investments in infrastructure projects like road construction may boost employment among the poor and unskilled, leading to lower criminal activities.

The above discussion highlights the possibility of the association between road infrastructure and criminal activities to move in either direction. Against these contrasting channels, we attempt to evaluate the Indian experience of the impact of road infrastructure on crime.

3. The Indian experience

3.1 Crime procedures and the issue of underreporting

There are two possible ways to gather information on criminal activities in India- crime records maintained by the respective nodal agency in the country and information collected from victims directly through a survey. Using police records of crimes from National Crime Records Bureau (NCRB), the nodal agency, may have several limitations in capturing the pattern of actual crime, since various crimes in India go unreported due to poor quality of infrastructure, weak institutional factors and social stigma. In fact, reporting of crime is a problem across countries- according to the International Crime Victim Survey data only 40 percent of

committed crimes are reported at the global level. However, under-reporting of crime is more pervasive in developing economies.

Ansari et al. (2015) report that people in India do not report crimes due to the paucity of police stations, lack of awareness and inadequate trust in the criminal justice system. Further, under reporting of crime in India, this issue is a dual consequence of victims choosing not to report and police deciding not to record it. While police records are valuable information, using victim-reported crime may reduce the scale of an understatement. Such data is gathered from surveys directly by asking respondents if they faced any crime in the past year. Prasad (2013) documents that while police-recorded crime patterns are well represented in Indian regions where institutions function efficiently, the difference in the two types of crime measures is enormous in the rest of the country. Given the issues surrounding police-recorded crimes, we primarily use household survey wherein victims report incidence of crime, however, in our robustness analysis, we also employ the reported crime from the NCRB reports and re-estimate our results.

Road infrastructure in India

Despite experiencing high economic growth in the early 2000s, India has been grappling with a weak and inadequate infrastructure network. While necessary for urban areas, access to better infrastructure is critical for poverty alleviation and economic development in the rural sector. Within the infrastructure sector, roads have been at the forefront of economic development in India, with rural road development plans receiving attention since independence. Despite receiving considerable attention, a lack of planning, improper design and low monitoring lead to several deficiencies in the rural road network (Samanta, 2015). Inadequate embankment and poor drainage network implied that most of these roads were not accessible during rough weather.

Against this background, a centrally sponsored scheme, PMGSY, was launched in 2000. The scheme's primary objective was to provide rural habitations (defined as a cluster of the population that resides at the same location along the lines of a hamlet) with an all-weather pucca road within 500 meters. While it was a scheme introduced by the central government of India, state and local governments were active participants in the implementation of the project. PMGSY was implemented according to population criteria in a phased manner. Villages that had a population of 1000 or more were prioritized in the first phase with few exceptions. The second phase involved villages with a population of 500 and finally the third one for villages

with 250⁴. However, in 2010 the scheme was universally opened to all villages. Additionally, the roads being built were to be connected with the core network of roads within the state.

In 1951, a mere 20% of Indian villages had access to an all-weather road⁵ that increased to 60% in 2000 (Lei et al., 2019). As of 2019, the access has spread to 73% of Indian villages⁶. This broad coverage of road networks reflects that road infrastructure since the 2000s has grown. Using measures based on the PMGSY data to capture road infrastructure quality provides an accurate picture of capturing how uniform the growth has been across various regions.

4. Data and variables

We use the India Human Development Survey (IHDS), a nationally representative survey of more than 40,000 households. With comprehensive coverage of socio-economic variables such as health, education, gender relations, social networks, crime, confidence in institutions and so on, the IHDS dataset is well suited for addressing the impact of road infrastructure and crime. The survey was conducted twice, wherein the first wave was in 2004-05 and the second wave was in 2011-12. Thus, the dataset consists of a household-level panel for two years.

IHDS also collected information at the village level in both the waves from focus group discussions among village officials, people in business, and similar people in the village. The information spans various issues such as infrastructure, public programs, occupation structure, and population composition. We merge this village-level information with the household questionnaire. Since the village level information is collected only for rural areas, we drop all households dwelling in the urban sector⁷. Our final data set comprises more than 27,000 rural households for 2004-05 and 2011-12.

The dependent variable for our analysis is criminal activities experienced by victims (households) in the recent past. IHDS has four questions on whether households faced burglary, threats, female harassment and breaking into homes or not. Based on these criminal activities, we construct four measures of crime- (i) a dummy variable that takes a unit value if anyone in the household is a victim of either of the four types of crime and zero otherwise, (ii) a simple

⁴ There were few exceptions to the rule. For instance, if a habitation with less than 1000 population lies on the straight path of a road that was built for a habitation with higher than 1000.

⁵ Source- https://niti.gov.in/planningcommission.gov.in/docs/aboutus/committee/wrkgrp12/transport/wgrep_rural.pdf

⁶ Source- <https://theprint.in/india/governance/piyush-goyal-hails-indias-newly-connected-villages-but-26-still-await-pucca-roads/186739/>

⁷ An additional reason for focusing on rural areas is that PMGSY scheme was introduced only in rural India. We discuss this in detail in the next few paragraphs.

average of the four crime incidences and the first two principle components obtained by using factor analysis⁸. Additionally, we also use each of the types of crime as dependent variables in independent models for our main findings and extensions.

Our interest variable is related to road infrastructure in Indian villages. We exploit the stock nature of road infrastructure and use measures from the IHDS directly to measure the connectivity of villages with all-weather pucca roads. The village questionnaire asks whether the village is connected with a pucca (all-weather) road, a kaccha road or is not connected by a road at all. We use this information to construct a dummy variable for villages that are connected by an all-weather road. Consequently, villages not connected by any road or connected by a kaccha road get a zero value.

We use a set of control variables at the village and household levels that may influence crime. These variables broadly span across the presence of police stations in the village, confidence that households have in institutions critical to crime deterrence and management, land distribution in the village between the largest and the rest of the caste and religion groups and other socio-economic variables. We present the definition, measures and basic summary statistics of each of these variables in Table 1.

<Table 1>

As a first step in measuring aggregate patterns between road infrastructure and crime, we present how various economic outcomes differ between villages with pucca roads and villages without them. We compile the results in Table 2.

<Table 2>

Table 2 presents that most crime measures have a lower value for households dwelling in villages with an all-weather pucca road than households that reside in villages without it. Further, we find that villages with pucca roads also have a higher probability of getting street lights through a public program. Similarly, this group of villages also have a bus stop that is closer to the village than the group of villages that do have a pucca road. Finally, families dwelling in villages with well-connected roads exhibit better labour force participation rates and higher family income. These patterns lean towards the possibility of rural road

⁸ The principle component analysis is based on the matrix of polychoric correlations since our crime measures are dummy variables. We use the first two principle components based on the high eigen values obtained. The detailed results can be made available upon request.

infrastructure being effective in tackling crime in India. We explore this further in the next section, wherein we discuss our identification strategy.

5. Identification strategy

We aim to examine the impact of road infrastructure on crime. To meet this objective, we estimate the following model-

$$Crime_{hvd t} = \alpha_1 + \beta_1 Road_{vdt} + X_{hvd t} \gamma_1 + \varepsilon_{1hvd t} \text{-----} (1)$$

where h , v , d and t denote household, village, district and time respectively. $Crime_{hvd t}$ is the measure of crimes that household h faces in the v^{th} village, d^{th} district and t^{th} year. $Road_{vdt}$ is a dummy variable that indicates if the v^{th} village is connected with an all-weather pucca road or not. $X_{hvd t}$ is a vector of household confounders, including religion, caste, and other economic variables. We also control for the district, state, and year to account for administrative quality, job opportunities, state specific police expenditure, and over time change in crime trends. $\varepsilon_{1hvd t}$ is the error term that captures the impact of all unobserved omitted factors.

For obtaining estimates of the impact of road infrastructure on crime, road infrastructure must be exogenous in our estimation model. However, the possibility of a set of unknown variables influencing both crime and road infrastructure may lead to an omitted variable bias and consequently render our road infrastructure variables endogenous to criminal activity. This requires using an instrumental variable estimation strategy wherein the first stage we estimate road infrastructure measures using a set of exogenous variables used in (1) and an additional instrumental variable⁹. We estimate the following equation as the first stage of our model-

$$Road_{vdt} = \alpha_2 + \beta_2 PG_{vdt} + X_{hvd t} \gamma_2 + \varepsilon_{2hvd t} \text{-----} (2)$$

where all notations denote the same variables as in equation (1). The instrumental variable, denoted by PG_{vdt} , is based on the rationale that it affects road infrastructure but has no direct impact on criminal activities faced by households in that village. Since provisioning of different types of public goods, is correlated with each other at the village level, we use the proportion of households with access to piped drinking water as an instrument for building all-weather roads in villages (Banerjee and Somanathan, 2007). We suggest that our instrumental variable, public piped drinking water is a good candidate for being correlated with road infrastructure in

⁹ We discuss the plausibility of using an alternate estimation design, the difference in difference estimation in Annexure I.

the village and uncorrelated with crime incidence. IHDS examines the availability of public piped drinking water in the village making it closely associated with the provisioning of other public goods including road infrastructure. Further, since the survey focuses on public piped drinking water and not piped drinking water within the household compound, it does not have any influence on crime against women since they are still as likely to step out and collect water. To substantiate this point, we focus on patterns of other activity that require women to leave their houses- for instance, fuel usage and toilet facility access.

The village level questionnaire of IHDS-II covers questions related to fuel usage and toilet facilities available. Of the 1407 villages surveyed, 655 villages answered public piped drinking water to be the most common source of drinking water. Of these villages, more than 70% of the villages report using traditional forms of fuel such as firewood as the most common fuel used, collection of which would require women to collect it from outside the home premises. Similarly, 60 percent of the households on average used a pit latrine or open field as toilet facility in these 655 villages. This provides some suggestive evidence against women dwelling in villages with piped drinking water facing a lower likelihood of being harassed since at least 60% of these villages still had firewood and open defecation as the most common forms of fuel wood and toilet facility respectively.

To substantiate this observation further, we examine the share of households that have these facilities within the household premise for the two categories of villages- with public piped drinking water and without it (Table3).

<Table 3>

We find that the share of women collecting water from outside the house compound in villages with piped drinking water is higher than those without piped drinking water. Secondly, share of households with a toilet facility within the household compound is only marginally higher in villages with public piped drinking water. Finally, the share of households that use cleaner cooking fuel that reduces their likelihood to step outside to collect firewood is lower in villages with piped drinking water. These household level patterns further strengthen our choice of instrument as women dwelling in villages with public piped drinking continue stepping out of their houses as much as their counterparts in villages with no public piped drinking water. These village and household level patterns make piped drinking water a good candidate as an instrument to road infrastructure.

The predicted values from model (2) is then used as an explanatory variable in the second stage, denoted by eq (1). In the presence of valid and relevant instruments, this estimation yields causal impact of road infrastructure on crime. We discuss our findings in the next section.

6. Results

6.1 Main findings

Table 4 presents the estimates of the impact of road infrastructure on criminal activity as obtained from the second stage of the instrumental variable regression. Model 1 uses a dummy variable for incidence of crime, Models 2 and 3 use the first and second principle components and Model 4 uses the simple average of the four crime types.

<Table 4>

Table 4 demonstrates that the presence of pucca roads is negatively associated with crime. According to Models 1(a)-4(a), villages connected with pucca roads have a lower incidence of criminal activities than villages not connected with pucca roads.

As a next step, we try to consider the focal employment generation activity in rural India-agriculture and the related income uncertainty. According to the Periodic Labor Force Survey of 2018-19, 58% of rural employment in India is generated from agriculture¹⁰. Hence, certainty in income for rural households will be closely aligned with prices and wages in the agricultural market. To account for that, we include the seasonal wage difference between the agricultural harvest and non-harvest time of the year in Models 1(b)-4(b). Further, to capture unequal land distribution within the village, we also include the difference in land ownership between the largest and the rest of the religious and caste categories. Finally, we account for the presence of migrants within the village using a dummy variable. Model 4(b) depicts that our effect size increases to 14.3% as compared to 5.3% in Model 4(a). Broadly, we find that road infrastructure in India leads to a negative impact on crime.

We find that criminal activity is associated with households' confidence in various institutions in the country. Specifically, crime is negatively associated with confidence in public institutions such as police, panchayat and courts. Additionally, the presence of a police station in the village is also associated with fewer criminal activities. Finally, we control for household-level attributes that may affect being affected by some criminal activity. To account

¹⁰ Source- <https://www.thehindubusinessline.com/opinion/why-agriculture-sectors-share-in-employment-is-declining-in-rural-india/article32900228.ece>

for unobserved effects, we include fixed effects at the district, caste, religion and year level. The impact of pucca roads on crime in all the Models of Table 4 requires that the instruments are valid and exogenous. We present the estimates of our instrument, proportion of households in a village that has access to public piping water in Table 5. In the bottom panel of Table 5, we present the tests of instrument validity for it.

<Table 5>

Table 5 indicates that households with public piped drinking water are positively associated with households that have an all-weather pucca road confirming that patterns of provisioning of different types of public goods are correlated with each other at the village level (Banerjee and Somanathan, 2007). Further, the bottom panel confirms that our instrument is valid and relevant. As a next step, we examine the effect of pucca roads on different types of criminal activities- theft, attack or threats, female harassment and breaking into homes. Of the four types of activities, breaking into homes is the only type of crime that one is subjected to at the residential facility. We compile these results in Table 6.

<Table 6>

Interestingly, we observe that pucca roads have a negative and significant impact on the propensity of being robbed and for females to be harassed (Table 6). However, it has a positive effect on burglars breaking into homes and is insignificant for getting attacked. These overall results confirm that robbing and harassment have a higher incidence on poorly built paths. This result aligns with Mahajan and Sekhri (2020) wherein building in-home toilets reduces the risk of violent crimes against women. Along similar lines, building an all-weather road makes it easier for women to access different places than walking in secluded areas with no roads. A weak but qualitatively similar argument may be plausible for being robbed in rural areas with no well-connected roads. In contrast, the rise in burglars breaking into homes due to pucca roads aligns well with Davies and Johnson (2015). This affirms that road infrastructure may work as a skeletal structure to criminals that may aid in identifying and easily accessing the hot spots.

6.2 Robustness tests

6.2.1 Relaxing the exogeneity assumption

Our instrument validity tests confirm that our Kleinbergen-Papp F statistic is above the thumb rule of 10. While our instruments are relevant, the assumption of exogeneity is challenging to

assess. To account for this aspect, we employ three alternate models to test our main finding that roads reduce crime. First, we use the Conley et al. (2012) 'plausible exogenous' estimation of our main effects. It enables us to examine the impact of road infrastructure on crime even if the instrument is not entirely exogenous. We start with estimating the reduced form equation of crime on the instrument and other controls but excluding the endogenous variable and obtain the estimate for the lower bound of gamma¹¹ (Das, 2018; Biswas and Das, 2022). Using gamma values between 95% of estimated gamma min and zero, we examine if the effect of road infrastructure is still negative. Additionally, we also employ Lewbel's method that relies on the use of an internally generated instrument instead of piped drinking water. Finally, we use an OLS estimation (except for incidence of crime wherein we use probit) after matching villages according to population category, population composition in religion and social background, average income, land based inequality among social groups, availability of other amenities such as police station, railway station and so on. We compile the results of these three alternate specifications in Table 7.

<Table 7>

Table 7 provides evidence that road infrastructure is negatively associated with crime and this finding is robust to violation of the strict exogeneity assumption of the instrument.

6.2.2 Alternate dataset to measure crime

IHDS is a database that captures and measures crime as reported by victims. To test if our main findings will hold with an alternate datasource of crime, we use officially reported crime data from the NCRB volumes. Since NCRB is a district level dataset, we collapse all our IHDS village and household level variables at the district level. We use the share of villages with access to pucca road as the main variable of interest. Next, we use data on total crime reported as under the Indian Penal Code and construct three measures- total crime incidence in the district, standardized crime index and a normalized crime index¹². Given the rare nature of crime, we estimate a standard poisson model followed by a district level instrumental variables estimation for the other two measures. Our instrument at the district level is the share of villages in a district that have access to drinking water. We compile our results in Table 8.

¹¹ Gamma is the association between the instrument and the endogenous variable and the reduced form regression estimate acts as lower bound for gamma.

¹² We standardize crime by taking the ratio of (crime- minimum crime) to the range of crime in each state. We use the standard normal transformation within each state for calculating the normalized crime index.

<Table 8>

We find that the negative coefficient on the share of villages with pucca road continues to be negative and significant across the three models of aggregate crime (Table 8). Thus, our main finding is consistent to both the data sets- victim reported data and officially documented crime data¹³.

6.2.3 Impact of road infrastructure or some other effect?

One may argue that since PMGSY was one of the largest flagship programmes that was instrumental in building rural road network, we may be capturing the impact of PMGSY. However, besides PMGSY, there were other means that affected road development in Indian villages. For instance, the Member of Parliament Local Area Development Scheme (MPLADS) is a scheme wherein each member of parliament is allotted a sum of Rs. 5 crore each year that can be spent on development projects including infrastructure provisioning. It involves creation of durable community assets in the areas of drinking water, education, roads and so on¹⁴. Secondly, besides PMGSY state-level rural road network is also constructed under various state schemes like Chief Minister's Rural Road Networks¹⁵ and international organizations¹⁶. Since the main focus of the current study is to examine the impact of all-weather roads on crime in rural India, we consider the existence of pucca road as our main variable of interest.

However to disentangle the impact of PMGSY from the presence of all-weather roads, we extend our main findings by controlling for the impact of PMGSY and road infrastructure separately. Specifically, we estimate a difference-in-difference estimation model using the village level population categories to estimate the impact of PMGSY and control for the existence of all-weather roads in that estimation. Since the population categories of the village questionnaire correspond to whether the village has a population of greater than or equal to 1000 people, we define our treatment variable as villages that have a population of greater than

¹³ We do not compare effect sizes from Table 8 since IHDS may not be representative at aggregate levels.

¹⁴ Source: <https://pib.gov.in/PressReleasePage.aspx?PRID=1770522#:~:text=The%20MPLADS%20is%20a%20Central,%2C%20sanitation%20and%20roads%2C%20etc.>

¹⁵ Source: https://www.business-standard.com/article/economy-policy/govt-states-connect-85-eligible-rural-areas-with-roads-under-pmgsy-scheme-117121300455_1.html, https://megcnrd.gov.in/guidelines/CMSRDF_Guidelines.PDF, <https://www.thehindu.com/news/national/karnataka/cm-grameena-sumarga-for-rural-roads/article27944379.ece>, <https://pmgsy.nic.in/sites/default/files/publications/gidILO25july17.pdf>

¹⁶ Asia Development Bank supports the Rural Roads Sector II Investment Program that among other things, also provides better road connectivity in rural areas. Under the project as of 2014, about 3000 kilometres of roads were built in Assam, Odisha and West Bengal. Source: <https://www.adb.org/results/building-rural-roads-prosperity-india>

1000 people in the first wave of IHDS. We interact it with the time dummy to capture the impact of PMGSY (Table 9).

<Table 9>

We find that the negative association between all-weather road and criminal activity is strong even after controlling for PMGSY roads. Finally, since the village leaders play a significant role in both building infrastructure and overseeing the management of crime, we use information on whether a female leader was present at the local panchayat level (which is available only in the second wave of IHDS). We find that our results are robust to including a dummy variable for the presence of female leaders (Table 10).

<Table 10>

6.3 Potential channels driving the main effect

We explore the potential pathways through which road infrastructure reduces crime. We postulate that there may be direct and indirect benefits of road infrastructure in the village that may reduce crime. Perkins et al. (2015) find that reducing streetlights in England leads to an increase in burglary in more deprived areas. Similarly, Desai and Vanneman (2019) find that road infrastructure is followed by public bus services that may enable easier access to farmers to get their produce to nearby markets, the older children to take admission in schools and colleges further away get to health centers and hospitals easily. With easier accessibility, villagers can commute greater distance to find better-suited job opportunities (similar to the findings of Khandker, 1989; Aggarwal, 2018; Asher and Novosad, 2016).

We use street lighting, bus stops, and the share of adults in the age group of 18-60 years from a household who are employed as the three indicators that measure the direct impact of road infrastructure. We use this information and examine if an all-weather pucca road is positively associated with these outcome variables. We compile this information in Table 11.

<Table 11>

Column 1, 2 and 3 of Table 11 confirms that building an all-road pucca road in a village has a positive and significant impact on villages getting streetlights as part of a public programme, higher likelihood of having a bus service in the village itself and a higher share of working adults within the household. These findings corroborate the direct effects of building road infrastructure in rural India.

These economic benefits have larger indirect effects that favor a higher quality of life which consequently reduces criminal activities. Hence, we examine if building pucca roads impacts income on resident households (Column 4 of Table 11) and find that households dwelling in villages with pucca roads have higher income. Since inequality and relative deprivation are central to crime's social disorganization theory, we also examine the impact of pucca roads on two measures based on land ownership. We use the squared difference of share of land owned by the general and the marginalized caste category (Column 5)¹⁷. We construct a similar measure for religion (Column 6). Results from columns 5 and 6 confirm that pucca roads have a negative impact on these measures.

These results confirm the broader findings of Aggarwal (2018), Asher and Novosad (2016) and Adukia et al. (2020). Better road infrastructure leads to easier connectivity and access to economic opportunities that were previously unavailable to them. This is reflected as a rise in the employment of adults in the working-age population of households. Finally, households become better off as depicted with a rise in income levels. In fact, our findings indicate that roads are related to a decline in inequality in villages as reflected through a reduction in inequality in landholding, one of the most valuable assets in the rural context. These channels broadly confirm that reduction in criminal activity due to road infrastructure in rural areas is due to the direct effect of better street lighting and the indirect effect of reduced barriers to better opportunities.

6.4 Some extensions

6.4.1 Role of institutions

Crime is related to the quality of institutions ranging from the ability of police in preventing and deterring crime and the efficacy of courts in dealing with timely verdicts of cases (Mastrobuoni, 2020). Given the high spatial variation across various states in India in the quality of courts and police, we use related measures for examining the role of institutions on the impact of road infrastructure on crime. We use pendency (share of pending to total cases in the high court), conviction (share of convicted to convicted and acquitted individuals in the high court) and prison (total number of prisons per million population of the state). We divide

¹⁷ This measure is based on the concept of variance that gives higher weight to observations further away from mean.

states into low and high categories using the group average and re-estimate the models for the two subsamples. Results have been compiled in Figure 1¹⁸.

<Figure 1>

Figure 1 indicates that the negative impact of pucca roads on criminal activities is limited to states that have higher pendency, lower conviction and lower prison rates. In contrast, the effects are insignificant in the other two subsamples. Figure 1 presents an interesting pattern of how states with low quality institutions may invest resources on road infrastructure that leads to villages being better connected. In summary, road infrastructure acts as a tool for states lagging behind in institutions to catch up with states with better quality of institutions to reduce crime.

6.4.2. Role of inequality and employment programs

Inequality and income uncertainty are key variables that affect both infrastructure provisioning and crime. We divide our sample into two categories based on the average level of inequality at the state level. Additionally, the Government of India provides an employment guarantee scheme, named Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), to tackle the uncertainty of income in rural areas by providing 100 days of employment per year to job seekers at a fixed daily wage rate. We use a similar approach of splitting our sample into two groups according to the average employment generated under MGNREGS in respective states. We present our results in Figure 2.

<Figure 2>

Figure 2 shows that the negative impact of pucca roads on crime is limited to households dwelling in more unequal states and in the group of states that provide higher MGNREGS employment. These results confirm that road infrastructure is critical in combating crimes in highly unequal regions. Further, since the majority of the work under MGNREGS is related to building roads, it involves participation by local residents by getting employed in these projects. With employment opportunities directly related to building the road network, local residents face lower crimes. These extensions highlight the critical role of a well-connected road system in the rural areas of India.

¹⁸ We use crime index 1

7. Conclusion

We attempt to examine the effect of building road infrastructure on crime in rural India. We use data from the two rounds of IHDS, a nationally representative household-level survey, conducted in 2004-05 and 2011-12. Using instrumental variable estimation models, we estimate that road infrastructure has a negative impact on crime in rural India. We tease out this result by examining the underlying channels that drive it. We find that since building road infrastructure is directly related to increased provisioning of street lights and the presence of public bus services, it has an immediate impact on crime deterrence. We also find that with increased access and lower transaction costs, there are economic benefits such as better employment opportunities, increased asset holding and lower inequalities. These improve the quality of life and hence a shift away from participation in illegal activities. These effects are more pronounced if states are at a disadvantageous position in terms of institutional quality and inequality among masses.

Our results highlight the importance of building a solid infrastructure base in developing economies. In addition to improving employment opportunities, road infrastructure generates positive spillover in the form of reduced crime. This has significant policy implications in designing and implementing policies that focus on investing resources in these projects despite long gestation periods. There are few limitations of the current study. In the absence of village identifiers in the IHDS survey, PMGSY implementation and crime mapping remains unexplored. Additionally, the current paper has focused on the effect of road infrastructure on criminal activities in the rural sector. The impact of road infrastructure on the incidence of crime in urban areas is open for further research.

Despite these limitations, the current paper underscores an essential issue from a policy perspective. The ongoing COVID-19 pandemic has deepened the existing inequality of income, gender and caste in India (Deaton, 2021; Deshpande, 2021; World Bank, 2020). In such situations, the role of the government in scaling up investment in infrastructure projects like road becomes pivotal to ensure that the pandemic-induced rise in inequality is short-lived. In the rural sector, where infrastructure quality continues to be poor, building all-weather pucca roads can carry the twin benefit of improved economic opportunities due to easy access and reduced criminal activities.

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Annexure I

A possible alternate to an instrumental variable estimation methodology is using a difference in difference estimation where in we use the two rounds of IHDS survey to get the effect of roads in the second wave. However, using a difference in difference estimation design by exploiting the presence of an all-weather road between the two rounds of the survey may have some convoluted issues. In a difference in difference estimation design, if treatment (presence of all-weather roads in the village) is not randomized, crime outcomes will be affected both by the treatment and the effect of non-random assignment¹⁹.

We test this by examining the difference in crime incidence for the group of households that have access to better roads compared to their counterpart. Specifically, using district identifiers from our IHDS data we divide our villages into two groups- districts with better connected villages and districts with worse connected villages. We do so by grouping districts into higher and lower than the average proportion of villages with all-weather roads. Next, we use district level data on reported crime from the NCRB for the period 2001-2004 and test whether the average number of crime in the two groups of districts follow a parallel path or not. We present the trends in Figure 3.

<Figure 3>

Figure 3 confirms that the average crime levels between the two groups of districts follow a trend that varies overtime violating the parallel path assumption. This may be due to a variety of reasons. In certain occasions in India, villagers demand better roads or build roads themselves. For instance, individuals such as Dasrath Manjhi and Ramchandra Das who hail from different villages in Bihar have built or demanded the state government to build an all weather road to their village²⁰. In Uttarakhand, three hundred dwellers from a cluster of villages, built their own pucca road connecting the villages to the wider network of roads²¹. Similar effort was observed from residents of Sundaran villages in West Bengal²², Devbhilai

¹⁹ Source: <https://community.lawschool.cornell.edu/wp-content/uploads/2020/12/RubinfeldDifferenceinDifferencesCELS2007-2.pdf>

²⁰ Manjhi in 2005 and Das in 2010 were determined to connect their village to the outside world and when the state government was not acting keenly, they built roads themselves. Source: <https://www.downtoearth.org.in/coverage/one-man-22-years-a-road-973>

²¹ Men and women from these ten villages worked for ten whole days averaging eight to nine hours per day and built a road using basic tools such as chisels and hammers. Source: <https://www.thebetterindia.com/37252/uttarakhand-villagers-construct-road/>

²² Villagers built roads using voluntary labor from the dwellers in Sundarban, West Bengal. Source: <https://www.ndtv.com/india-news/in-bengals-sundarbans-a-road-built-with-voluntary-labour-757001>

village in Madhya Pradesh²³ and Sirsa village in Haryana²⁴. Farmers from Malegaon district in Maharashtra, had started an online petition in 2006 for construction of a concrete road as an effective tool for public support²⁵. Akhilesh Yadav, former chief minister of Uttar Pradesh, a northern state in India, had also built a pucca road in his own ancestral village, Saifai whereas the neighbouring villages felt left out²⁶. These selected excerpts underscore the significance of pressure and motivation of residents in the rural areas for demanding or building roads in their villages. The emphasis of people's participation and pressure is further underlined in the case of Chhattisgarh village where the residents opposed the idea of building roads to connect their village since the construction programme and the roads would provide easy access to security and Maoist forces leading to more frequent conflicts and violence²⁷.

These excerpts reveal that the provisioning of all-weather roads in an Indian village may be driven by its selection in public schemes or even by the pressure and motivation of the residents. Hence, in considering the existence of pucca roads as treatment may not be completely exogenous (leading to violation of the parallel trends assumption as observed in Figure 1). Further, for a difference-in-difference estimation, we will have to restrict our sample to only those villages that did not have access to all-weather roads in the first round and then trace them in the second wave. However, according to IHDS-I, 65% of the villages had access to a pucca road in 2004-05. By dropping these households, we would be left with a very small sample. Secondly, this approach would help us examine the impact of 'new' roads only, i.e., roads built between the two waves of IHDS survey. Hence, using an instrumental variable estimation methodology that can control for unobservable factors such as motivation and pressure from residents without loss of datapoints will be a more appropriate approach.

²³ On their pleas being repeatedly ignored by the government officials, 50 villagers, mostly elderly women, built their own roads connecting their village to the nearest town. Source: <https://www.dailymail.co.uk/indiahome/indianews/article-2796328/devbhilai-villagers-build-road-babus-ignored-pleas.html>

²⁴ Villagers from Sirsa built a road without any government support. Source: <https://www.rushlane.com/villagers-in-sirsa-build-a-road-bridge-12155463.html>

²⁵ Pagare, a farmer in Budruk village of Malegaon district has been demanding a pucca road for his village through an online petition that ran for ten years. Source: <https://www.deccanchronicle.com/nation/current-affairs/090616/farmer-starts-online-petition-demanding-concrete-road.html>

²⁶ Source: <https://indianexpress.com/article/india/india-others/neighbours-envy-3/>

²⁷ Source: <https://scroll.in/article/770891/why-some-chhattisgarh-villagers-dont-want-the-government-to-build-roads-in-their-areas>

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Figure 1- Influence of institutional factors on the main effect

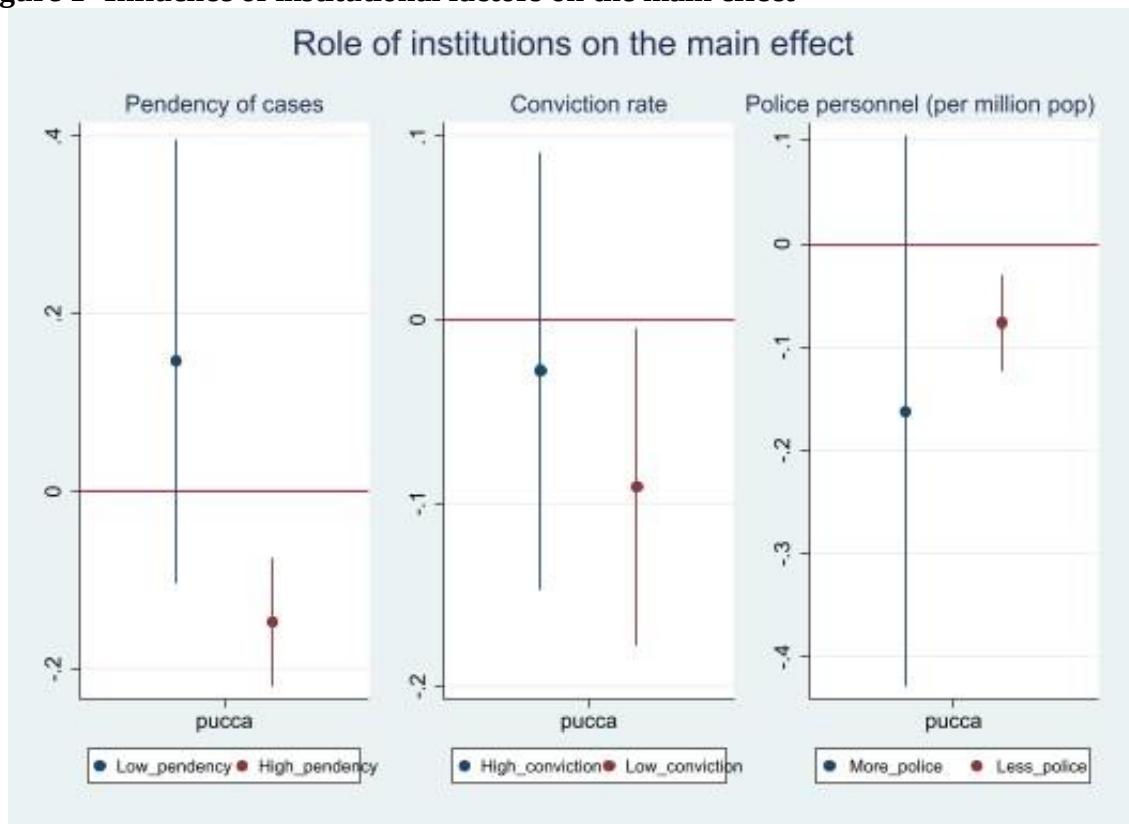


Figure 2- Influence of casual employment and inequality on the main effect

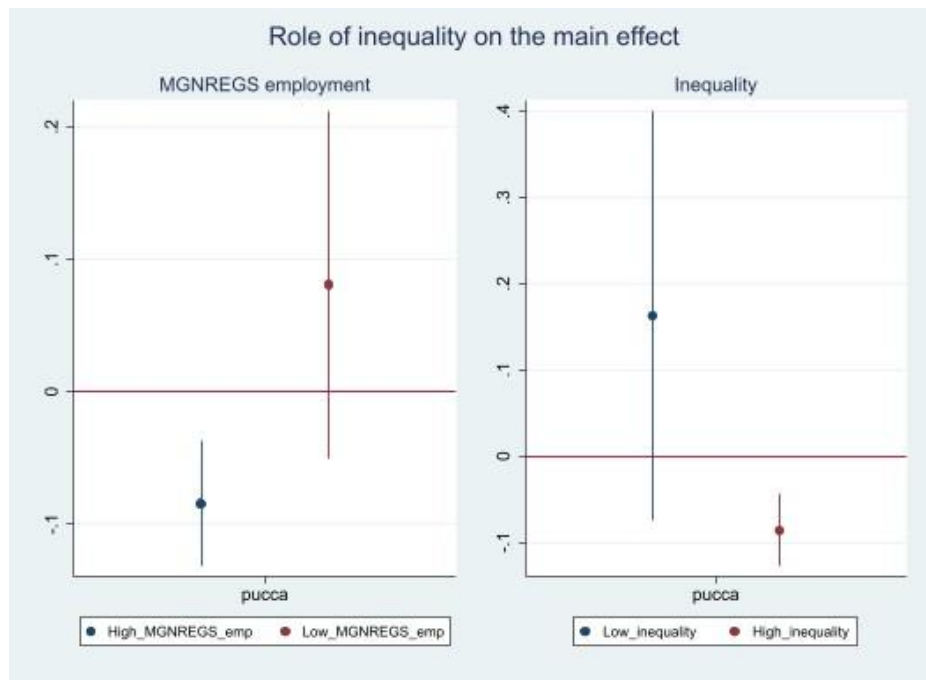
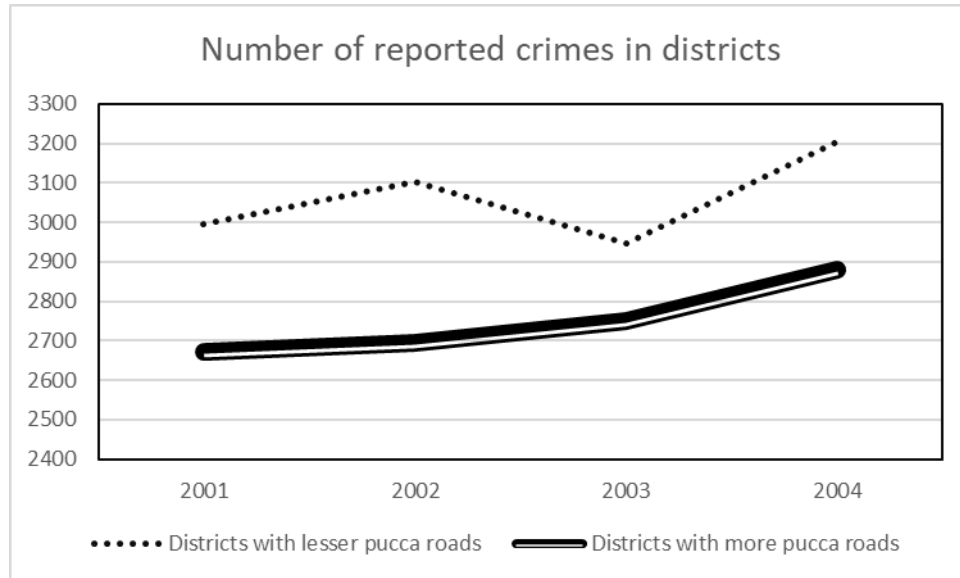


Figure 3- Average crime incidence followed by the two groups of districts in 2001-2004



List of Tables

Table 1- Summary statistics of variables

Variable	Measure	Obs	Mean	Std. Dev.	Min	Max
<i>Crime incidence</i>						
Theft	Dummy variable for anything stolen in the last 12 months	54449	0.03	0.19	0	1
Attack	Dummy variable for getting attacked or threatened in the last 12 months	54449	0.02	0.15	0	1
Harassment	Dummy variable for unmarried women getting harassed in the last 12 months	54525	0.15	0.35	0	1
Breaking into home	Dummy variable for someone breaking into home in the last 12 months	54449	0.02	0.09	0	1
Pr(crime)	Dummy variable that takes a unit value if any crime is committed	54525	0.18	0.39	0	1
Principle component 1	First component from principle component analysis with an eigen value 2	54525	0.01	0.51	-0.19	4.38
Principle component 2	Second component from principle component analysis with an eigen value 0.8	54525	-0.00	0.60	-1.64	1.47
Crime index 2	Simple average of all the four criminal activities mentioned above	54389	0.05	0.13	0	1
<i>Village level infrastructure and composition measures</i>						
<u>Direct road measures</u>						
Pucca road	Dummy variable for an all-weather pucca road in the village	54525	0.75	0.43	0	1
<u>Other infrastructure measures</u>						
Presence of police station	Ln(1+Distance from the police station)	54505	2.25	0.62	0	4.15
Street light	Dummy variable for villages that have a public program that spends on it	54491	0.38	0.51	0	1
Bus stop	Ln(1+ distance of a bus stop from the village)	54525	1.14	0.61	0	3.73
Presence of female leaders	Dummy variable for females at the local panchayat level	27024	0.29	0.45	0	1
<u>Village composition measures</u>						
Caste based land ownership diff	Difference in share of land ownership between general caste and others	54525	0.10	0.38	0	1
Religion based land ownership diff	Difference in share of land ownership between majority religion and others	54525	0.51	0.48	0	1
Wage diff between two seasons	(Wage difference between the kharif and rabi season for men)/average wage	52380	1.55	0.59	-0.08	6
Migrants from outside the village	How many people came to work during the last year? (1- less than 20, 2- more than 20)	54525	0.80	0.94	0	2
<i>Confidence in institutions</i>						
Police	Dummy variable for confidence in courts	54192	0.70	0.43	0	1

Panchayat	Dummy variable for confidence in panchayat	54029	0.80	0.39	0	1
Courts	Dummy variable for confidence in courts	52955	0.80	0.30	0	1
<i>Household level factors</i>						
Household income	Share of the assets owned by the hhd to the tot number of assets mentioned	54525	0.31	0.14	0	1
Employment ratio	Share of adults in the household that are work > 240 hrs in a year	53496	0.67	0.30	0	1
Household size	Log (total number of individuals in the household)	54525	5.18	2.55	1	38

Table 2- Mean difference according to road infrastructure in the village

Variables	Pucca roads	No pucca roads	Difference
<i><u>Types of criminal activity</u></i>			
Theft	0.036	0.045	-0.008***
Attack	0.023	0.030	-0.007***
Harassment	0.145	0.150	-0.004*
Breaking into home	0.009	0.010	0.001
Pr(crime)	0.188	0.188	0.000
Principle component 1	-0.003	0.010	-0.014***
Principle component 2	-0.010	0.003	-0.014***
Crime index	0.023	0.028	-0.005***
<i><u>Other facilities and economic outcomes</u></i>			
Street lights	0.437	0.236	0.201***
Bus stop distance	1.043	1.471	-0.428***
Employment ratio	0.759	0.684	0.074***
Household income	0.327	0.279	0.048***

Table 3- Pattern of water availability within household compound

Village categories	Public piped drinking water	No public piped drinking water
<i><u>Households with water</u></i>		
Within compound	51.38 %	53.48 %
Outside compound	48.62 %	46.52 %
<i><u>Households with toilet facility</u></i>		
Within compound	21.01 %	19.42 %
Outside compound	78.99 %	80.58 %
<i><u>Households with LPG and cleaner fuels</u></i>		
Yes	35.74 %	52.62 %
No	64.26 %	47.38 %

Table 4- Effects of road infrastructure on crime in India

Dep variable		Prob (crime)		PC 1		PC 2		Average crime	
Models		I(a)	I(b)	2(a)	2(b)	3(a)	3(b)	4(a)	4(b)
<u>Road infrastructure</u>									
Pucca road		-0.635** (0.310)	-0.829** (0.392)	-0.164* (0.096)	-0.236* (0.127)	-0.146** (0.071)	-0.206** (0.094)	-0.053** (0.024)	-0.143** (0.069)
<u>Confidence in institutions</u>									
Confidence in police		-0.103*** (0.017)	-0.100*** (0.017)	-0.034*** (0.006)	-0.034*** (0.006)	-0.025*** (0.004)	-0.025*** (0.004)	-0.009*** (0.001)	-0.009*** (0.002)
Confidence in panchayat		-0.097*** (0.019)	-0.095*** (0.019)	-0.038*** (0.007)	-0.038*** (0.007)	-0.028*** (0.005)	-0.028*** (0.005)	-0.009*** (0.002)	-0.009*** (0.002)
Confidence in courts		-0.049** (0.023)	-0.043* (0.023)	-0.026*** (0.009)	-0.026*** (0.009)	-0.019*** (0.006)	-0.019*** (0.007)	-0.007*** (0.002)	-0.007*** (0.002)
<u>Village characteristics</u>									
Presence of police station		-0.007*** (0.002)	-0.008*** (0.002)	-0.002*** (0.001)	-0.002*** (0.001)	-0.002*** (0.000)	-0.002*** (0.001)	-0.001*** (0.000)	-0.001*** (0.000)
Caste based land ownership diff			0.108*** (0.037)		0.021* (0.011)		0.023*** (0.008)		0.008*** (0.003)
Religion based land ownership diff			0.143*** (0.034)		0.031*** (0.011)		0.031*** (0.008)		0.011*** (0.003)
Wage diff between two seasons			0.059*** (0.016)		0.007 (0.005)		0.009** (0.004)		0.004** (0.002)
Migrants from outside the village			0.055*** (0.014)		0.014*** (0.005)		0.011*** (0.004)		0.006*** (0.002)
<u>Household level characteristics</u>									
Income		0.141* (0.084)	0.117 (0.094)	0.028 (0.027)	0.026 (0.031)	0.022 (0.020)	0.021 (0.023)	0.009 (0.007)	0.018 (0.013)
Household size		0.004 (0.003)	0.004 (0.003)	-0.002 (0.001)	-0.002 (0.002)	-0.002* (0.001)	-0.002* (0.001)	0.000 (0.000)	-0.001 (0.000)
<u>Other controls</u>									
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Caste FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant		-0.370* (0.200)	-0.353 (0.220)	0.123** (0.061)	0.148** (0.066)	0.263*** (0.038)	0.143*** (0.051)	0.105*** (0.016)	0.106*** (0.018)
Observations		50727	49,142	51,422	49,298	51,422	49,298	51,422	49,298

Note: All the models summarize the results from the second stage of instrumental variable estimation. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5- Estimates of the instruments obtained from the first stage regressions

	Model 1(b)	Model 2(b)	Model 3(b)	Model 4(b)
<i><u>Instruments</u></i>				
Proportion of households with piped water	0.046*** (0.004)	0.046*** (0.004)	0.046*** (0.004)	0.023*** (0.004)
Other exogenous variables	Yes	Yes	Yes	Yes
Religion FE	Yes	Yes	Yes	Yes
Caste FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
No. of observations	49142	49298	49298	49298
<i><u>Tests of instrument validity</u></i>				
<i>F test of excluded instrument</i>				
Sanderson Windmeijer test	106.07 (0.000)	109.84 (0.000)	109.84 (0.000)	29.22 (0.00)
<i>Under-identification test</i>				
Anderson Canon. Corr. LM statistic	5.19 (0.022)	4.53 (0.032)	4.45 (0.035)	4.96 (0.02)
<i>Weak- identification test</i>				
Cragg-Donald wald statistic	106.07	106.03	106.03	28.19
10% maximum IV value	16.38	16.38	16.38	16.38
Note: The top panel of this table presents estimates of the instrument from the first stage of Models 1(b), 2(b), 3(b) and 4(b) from Table 3. Standard errors are reported within parentheses. *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. The bottom panel presents the tests of instrument validity and relevance. The values indicate the test statistic and p-values are reported in parentheses.				

Table 6- Effect of road infrastructure on various types of criminal activity

	Theft	Attack	Harassment	Harassment II	Breaking into home
<u>Road infrastructure</u>					
Pucca road	-1.795*** (0.565)	-0.088 (1.397)	-1.367** (0.694)	-1.917*** (0.664)	1.187 (1.867)
Other controls	Yes	Yes	Yes	Yes	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes
Caste FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes
Presence of SHG	-	-	No	Yes	-
Observations	45252	39274	49987	48974	35999

Note: This table presents the regression results for determinants of various types of criminal activities. Each of the models use *ivprobit* since the dependent variables are dichotomous. Harassment II controls for the presence of self help group in the village. The values indicate the coefficients of each of the covariates. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7- Robustness tests- Alternate estimations

Dependent variable	Pr (crime)	PC 1	PC 2	Crime index
<i>Panel 1- Plausibly exogenous model</i>				
$\hat{\gamma}$	-0.010*** (0.001)	-0.010** (0.004)	-0.012*** (0.004)	-0.003*** (0.001)
All controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	49142	49298	49298	49298
<i>γ values (95% of estimated values)</i>				
Minimum γ value	-0.010	-0.010	-0.012	-0.003
Maximum γ value	0	0	0	0
<i>Pucca road</i>				
Lower bound for Pucca road	-2.380	-3.176	-3.176	-0.815
Upper bound for Pucca road	-0.870	-1.279	-1.220	-0.314
<i>Panel 2- Lewbel's model</i>				
Pucca road	-0.019*** (0.005)	-0.015** (0.007)	-0.012** (0.007)	-0.021*** (0.007)
All controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	49142	49298	49298	49298
<i>Panel 3- OLS estimation on matched villages</i>				
Pucca road	-0.064*** (0.020)	-0.016*** (0.006)	-0.015*** (0.004)	-0.005*** (0.001)
All controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	38250	38300	38300	38300
Note: All covariates and dummy variables are included in the models. For Panel I, <i>Plausexog</i> command has been used in STATA 16 with the Union of Confidence Interval (UCI) approach. For Panel II, we use <i>Sspecialreg</i> command in STATA 16 with income as the special regressor.				

Table 8- Effect of road infrastructure on crime using reported crime data

	#Reported crime	Reported crime measure I	Reported crime measure II
<u>Road infrastructure</u>			
Pucca road	-0.073*** (0.005)	-2.707*** (0.044)	-0.841*** (0.306)
Other controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
District FE	Yes	Yes	Yes
Observations	540	540	531

Note: This table presents the regression results of the impact of road infrastructure on crime using reported crime data available at the district level. Model I uses a poisson specification and the rest use instrumental variable regression methodology. The values indicate the coefficients of each of the covariates. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9- Association of road infrastructure after controlling for PMGSY

Panel I				
Aggregate crime measures	Pr (crime)	PC 1	PC 2	Crime index
Population (>1000) * Post dummy	-0.342*** (0.042)	-0.049** (0.012)	-0.055** (0.011)	-0.019*** (0.003)
Pucca road	-0.110*** (0.039)	-0.024** (0.010)	-0.022** (0.088)	-0.007*** (0.003)
All controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	51100	51252	51252	51252
Panel II				
Crime components	Theft	Attack	Harassment	Breaking into home
Population (>1000) * Post dummy	-0.085* (0.053)	0.046 (0.064)	-0.365*** (0.056)	-0.020 (0.068)
Pucca road	-0.098** (0.039)	-0.029 (0.051)	-0.100** (0.045)	0.061 (0.056)
All controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	47417	41254	50991	38363

Note: This table presents the association of road infrastructure after controlling for the effect of PMGSY using a difference in difference estimation methodology. The values indicate the coefficients of each of the covariates. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10- Impact of road infrastructure after controlling for female panchayat leaders

Panel I				
Aggregate crime measures	Pr (crime)	PC 1	PC 2	Crime index
Pucca road	-2.079*** (0.459)	-0.557** (0.284)	-0.512** (0.223)	-0.182** (0.077)
All controls	Yes	Yes	Yes	Yes
Female leader dummy	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	25963	26393	26393	26393
Panel II				
Crime components	Theft	Attack	Harassment	Breaking into home
Pucca road	-1.909** (0.801)	-0.046 (0.900)	-1.915*** (0.606)	0.439 (0.930)
All controls	Yes	Yes	Yes	Yes
Female leader dummy	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	21526	17385	25303	14612

Note: This table presents the association of road infrastructure after controlling for the effect of PMGSY using a difference in difference estimation methodology. The values indicate the coefficients of each of the covariates. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 11- Potential channels of how road infrastructure reduces criminal activities

	Direct effect			Indirect effect		
	Street light	Bus stop presence	Employment status	Household income	Land ownership diff- caste	Land ownership diff- religion
<i>Road infrastructure</i>						
Pucca road	1.780*** (0.155)	1.727*** (0.131)	0.308* (0.164)	0.043** (0.022)	-1.178*** (0.258)	-1.021*** (0.237)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes
Caste FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48658	48691	47767	48,661	48,658	48,658
R-squared	0.70	0.49	0.10	0.11	0.17	0.60

Note: This table presents the regression results for the effect of road infrastructure on presence of street lights, bus stop within the village, employment status, household income and difference in land ownership in the village at the caste and religion level. We use *ivreg2* to obtain the results. The values indicate the coefficients of each of the covariates. Robust standard errors are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1