

The Effects of Road Access on Disease Incidence in Rural India

Yeshwant Chillakuru

Department of Economics, The George Washington University

2115 G St. NW Suite 340, Washington, DC 20052

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Abstract

Using data from the Indian Human Development Survey, the effect of road expansion on disease incidence in rural India was estimated at the village-level. Having a paved road and proximity to a paved road for villages without a paved road had no impact on percent of villagers sick with any of the fourteen diseases surveyed. Roads had no impact on disease incidence for categories of communicable and non-communicable diseases or for any individual disease except cancer. Having a paved road, increased the percent of villagers with cancer by 0.064 percentage points. Results are robust with village and time-fixed effects.

Introduction

Improving transportation infrastructure is vital to India's long-term economic development. Paved roads are needed to facilitate trade between communities and improve access to markets, schools, and health facilities, especially in rural India, where most of the country's population lives. In 2000, India began the rural road expansion program known as Pradhan Mantri Gram Sadak Yojana (PMGSY), which aims to connect 170,000 villages with paved all-weather roads by 2020. As of 2010, 72,000 habitations have been connected by paved roads (World Bank, 2010). However, few studies have examined the efficacy of road improvement on health outcomes in India, and what literature exists is often plagued by weak methodology. The Ministry of Rural Development in India assessed PMGSY in 2004 and claimed an overwhelmingly positive impact of roads on health outcomes, stating improved travel times, higher levels of patient satisfaction, and increased hospital visits in several districts. However, the assessment was limited by a small sample size, no control groups, and failure to control for confounding variables, such as increased disease communication due to improved travel conditions causing more hospital visits.

The effect of road expansion on health outcomes has recently been researched, but the results, thus far, offer limited understanding of roads' impact. Bell and van Dillen (2014) examined health outcomes after road expansion under PMGSY in upland Orissa, India, with a cross-sectional analysis of 2010 survey data. The theoretical framework underlying their analysis stated that roads would not alter the disease environment (e.g. sanitation, strains of local bacteria/viruses) of the villages in the short-term but would improve treatment times and outcomes as patients travel to health centers and as ambulances reach patients more easily. They found that roads had no effect on morbidity rates, mortality rates, or treatment times. Bell and van Dillen's findings refute the positive impact touted by the Ministry of Rural Development, providing evidence that Indian rural health services are so inadequate that improved access may not improve health outcomes of villagers. However, their analysis was limited to the Orissa uplands and their data lacked a more robust, longitudinal analysis.

The effect of road access can lead to unexpected negative health outcomes. Contrary to intuition, Djemai (2011) has shown that HIV morbidity increases with road access in six sub-Saharan African countries. Djemai proposes a framework of two opposing forces:

1. Increased road access allows individuals to access markets to purchase condoms and receive HIV-related education, thus reducing the risk of HIV infection.
2. Increased road access allows for more communicability through both high-risk mobile groups and individuals having more sexual partners, thus increasing risk of HIV infection.

Djemai found that both effects independently occur and are significant, but the latter overpowers the former. By applying Djemai’s framework with the work done by Bell and van Dillen, rural roads expansion can effect health outcomes in India through the following mechanisms:

1. By improving access to treatment facilities, roads will improve overall health outcomes. However, if rural health care facilities lack effective treatments or contain non-sterile pathogenic environments, health outcomes may worsen.
2. By accelerating economic development and thus personal hygiene and sanitation, roads will improve overall health outcomes.
3. By increasing the likelihood of communication from high-risk mobility groups, roads will worsen health outcomes related to communicable disease, but will have no effect for non-communicable disease.

This paper uses panel data from the India Human Development Survey (IHDS) to demonstrate the relationship between road expansion and health outcomes, as defined by incidence of a major morbidity (i.e. long-term) disease in the past year, specifically the following 14 diseases: cataracts, tuberculosis, high blood pressure, heart disease, diabetes, leprosy, cancer, asthma, polio, paralysis, epilepsy, mental illness, STD/AIDS, and an other long-term disease. Using a linear regression model revealed that road expansion, whether by decreasing distance to nearest paved road or building a paved road in the village, significant had no impact on the incidence of any disease in rural India.

This paper is structured as follows. The next section, Data, will examine IHDS data, discussing it’s strengths and weakness. The Model section will introduce the two main equations that form the basis for the analysis. The Results section discusses the main findings when applying the models two the IHDS data. The Robustness Checks section attempts to identify and resolve any pitfalls in analysis.

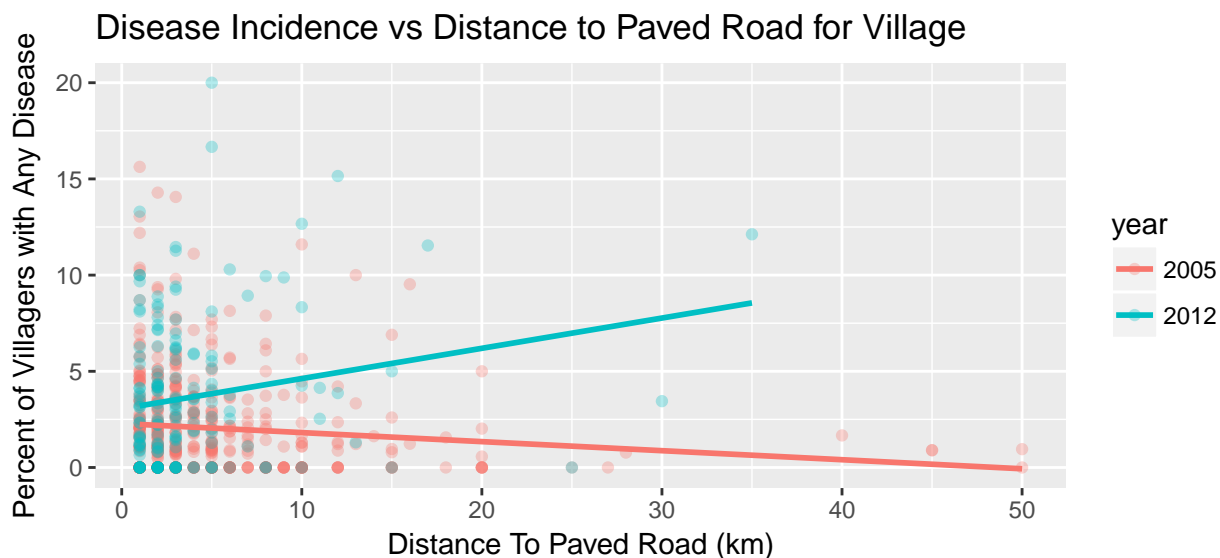
Data

IHDS is a nationally representative survey of 41,554 households in 1,503 villages and 971 urban neighborhoods in India. IHDS-I was conducted from 2004-2005, and IHDS-II was conducted from 2011-2012. The data of interest for this study was divided into several levels. Health outcomes, such as incidence of diabetes or polio, and individual-level controls, such as education and alcohol consumption, were stored in the individual-level dataset. Household-level controls, such as income and access to electricity, were stored household-level dataset. Road data, such as distance to road, and village-level controls were stored in the village-level dataset. The datasets were all encoded to be mapped together. Each village had an I.D. number.

Each household had an I.D. number that was mapped to the village I.D. number. Each individual had an I.D. number that was then mapped to the household and village I.D. numbers. Therefore, data was aggregated to the village level, which had the road data, and as a result, an individual village is the unit of observation. When aggregating data from the specific to the broad (i.e. individual/household to village), the mean was used if data was an interval or ratio variable. If the data was a categorical variable, dummy variables were created for each category and the means of the dummy variables were aggregated to the village level. After data cleaning, the 2005 data (IHDS-I) contained 1457 observations (i.e. unique villages), and the 2012 dataset (IHDS-II) contained 1345 observations. 1314 villages were the same in both 2005 and 2012.

From the survey data, the impact of PGMSY on rural India can be seen. In 2005, 66.71% of villages in the IHDS survey had paved roads, but in 2012, 86.9% had paved roads. Additionally, for villages without paved roads, the closest paved road was 4.93 km away on average in 2005, but only 3.86 km away on average in 2012. Disease morbidity increased from 2005 to 2012 for all diseases in the dataset, except STD/AIDS, which remained approximately the same (Table 1 and Table 2).

A plausible explanation for this may be improved diagnosis from medical campaigns. A simple analysis examining “Percentage of Village with Any Disease vs Distance to Road” reveals a negative relationship between distanceToPavedRoad and mbAnyDisease in 2005 but a positive relationship in 2012. The 2005 correlation opposes the prevailing notion that roads access would reduce disease incidence, but may be attributed to increased diagnosis.



Model

Two OLS regressions models with time and village-fixed effects will be used to analyze the impact of road expansion on incidence of disease:

$$diseaseIncidence_{it} = \beta RoadPaved_{it} + \delta_1 Household_{it} + \delta_2 Village_{it} + \delta_3 Medical_{it} + \gamma_{it} + \varepsilon_{it} \quad (1)$$

$$diseaseIncidence_{it} = \beta \ln(DistToPavedRoad)_{it} + \delta_1 Household_{it} + \delta_2 Village_{it} + \delta_3 Medical_{it} + \gamma_{it} + \varepsilon_{it} \quad (2)$$

diseaseIncidence is the percent of villagers in village i during year t (t is 2005 or 2012) that fall into one of three disease categories:

- Sick with at least one of the 14 disease categories collected in the IHDS (*diseaseIncidence* = *mbAnyDisease*)
- Sick with at least one of three communicable diseases, STD/AIDS, Polio, or Tuberculosis (*diseaseIncidence* = *mbComDisease*)
- Sick with at least one of the remaining non-communicable diseases (*diseaseIncidence* = *mbNonComDisease*)

Household_{it} represents village-level controls of household characteristics, such as income and electricity access, aggregated to the corresponding village of the household. *Village_{it}* represents controls for characteristics of the village, such as number of primary health centers in village or the number of immunization campaigns for polio conducted in the village in the past year. *Medical_{it}* represents village-level controls for where individuals in that village go for treatment, such as same village or different village, and for who individuals seek treatment, such private doctor or public doctor. γ_{it} represents village fixed effects, and ε_{it} is the error term.

The only difference between Models 1 and 2 is the primary independent variable of interest: *RoadPaved_{it}* vs $\ln(DistToPavedRoad)_{it}$. Equation (1) allows us to understand the impact of how introducing a paved road affects *diseaseIncidence_{it}*, while Equation (2) allows us to understand how becoming closer to a road for villages with no paved road can improve *diseaseIncidence_{it}*. *roadPaved_{it}* indicates if there is or is not a paved road in the village. $\ln(DistToPavedRoad)_{it}$ indicates the natural log distance to the nearest paved road for villages without a paved road. Model 2 is only applied to villages without a paved road to separate the effects of road being present or not versus improvement in distance to the road.

Simultaneous causality may present a problem in the current model. Individuals may move to areas

where roads are built to improve economic opportunities. This may increase risk of communicability, similar to Djemai’s study, where high-risk mobile groups increased HIV risk in areas closer to roads. To isolate the impact of increased communicability on disease incidence, I performed separate regressions for communicable vs non-communicable diseases. For example, if road access is bringing high-risk groups, who partake in risky sexual behavior, STD/HIV incidence would increase, while non-communicable diseases, like mental illness would not be effected.

Another issue with simultaneous causality is that villages with higher incomes and larger populations could be more likely to receive roads. Therefore, road placement may not be random. The PMGSY program is run at the national, and not state or district, level, and is less prone to influence of local village-level politics.

The time and village-fixed effects allowed to account for several potential areas of omitted variable bias. Differences between villages in healthcare technology and access and sanitation infrastructure may arise non-randomly as villages near urban areas may benefit from spillover effects and earlier development. However, this is adjusted for by village-fixed effects. Similarly, healthcare technology and sanitation infrastructure may improve from 2005 to 2012 in villages, but again this are accounted for in time-fixed effects.

Results

General Disease Incidence and Roads

Table 3: Regressions 1, 2, 3 present the results for Equation (1) for percentage of villagers with at least one of the 14 major morbidity diseases ($diseaseIncidence_{it} = mbAnyDisease_{it}$). A positive correlation initially exists at the 10% significance level (Table 3: Regression 2) between having a paved road and when controlling for $Household_{it}$ variables (income: average income of village, illiterate: percentage of villagers that can read or write, smokeTobacco: percentage of villagers that smoke, electricity: percentage of villagers with electricity, ownToilet: percentage of villagers own a toilet, seenDoctor: percentage of villagers who have seen a doctor in the past 5 years for a non-major morbidity disease). In Table 3: Regression 2, villages with a paved road have a 0.442 percentage points increase in the percent of their population sick with on the 14 diseases. However, the weak level of significance (10%) and combined results of Table 3: Regression 3 support concluding that introduction of a paved road has no significant impact on ‘mbAnyDisease. Table 3: Regression 3 includes $Medical_{it}$ controls where individuals sought treatment when sick with the disease (Treat.SameVil: percentage of villagers that sought treatment in the same village, Treat.OthrVil: percentage

of villagers that sought treatment in a different village, *Treat.OthrTwn*: percentage of villagers that sought treatment in a larger town, *Treat.DstrctTwn*: percentage of villagers that sought treatment in the large district town). When controlling for treatment location, the effect of having a paved road in the village and all $Household_{it}$ and $Village_{it}$ controls become insignificant.

Table 3: Regressions 4, 5, 6 presents data for Equation (2) for incidence of any disease ($diseaseIncidence_{it} = mbAnyDisease_{it}$). For villages without a paved road, increasing distance to the paved road has significant relationship with disease incidence, regardless of controls. Even among our controls, the only ones significant were the location where individuals sought out treatment. These non-significant finds are suprising, but important nonetheless because they fly in contradiction to the results of Djemai (2011) and the claims of Ministry of Rural Development in India. Analysis on disease categories and individual diseases will help develop a more comprehensive understanding the interactions between disease incidence and road expansion.

Communicable Disease Incidence and Roads

Communicable and non-communicable disease act through different channels, and Djemai (2011) and Tatem et al. (2006) have shown that roads and transportation infrastructure expansion strongly contribute to the spread of communicable disease. Table 4 details the analysis of Equations (1) and (2), on incidence of communicable diseases ($diseaseIncidence_{it} = mbComDisease_{it}$), which are defined here as STD/AIDS, polio, or tuberculosis. Opposite to expectations, roads in both Equations (1) and (2) have no net impact on communicable disease. However, the some treatment location variables were found to be significant in Table 4: Regression 6, just as occurred when $diseaseIncidence_{it} = mbAnyDisease_{it}$.

Non-Communicable Disease Incidence and Roads

Table 5 presents results from analysis of Equations (1) and (2), on incidence of non-communicable diseases ($diseaseIncidence_{it} = mbNonComDisease_{it}$). Similar to previous results thus far, road expansion appears to have no significant effect on incidence of non-communicable disease, while again the only significant controls are where individuals sought treatment (*Treat.OthrTwn* and *Treat.DstrctTwn*).

STD/AIDS Incidence and Roads

In order to make a direct comparison to Djemai’s results on the positive correlation between distance to paved road and HIV Incidence, I applied Equations (1) and (2) to STD/AIDS incidence. Table 6 details these results. Similar to Djemai, we control for education (literacy rate) and income, while also controlling for treatment location, immunization campaigns, and sanitary conditions (owning a toilet in home). The models in this paper lack controls for marriage, gender, HIV/knowledge, and age, primarily because our unit of observation is at the village level, while Djemai’s is at the individual level. Due to lack of GPS coordinate, I am unable to replicate Djemai’s instrumental variables methods using terrain ruggedness and gradient, but our analysis uses time-fixed and village-fixed effects, whereas Djemai could only use regional-fixed effects. Both analysis have the drawbacks and strengths, but the results in Tables 9 and 10 show that roads have no effect on STD/HIV incidence, in disagreement with Djemai’s results.

Robustness Checks

This analysis examined major groups of the diseases collected by the IHDS. However, when applying Equation (1) to each of the 14 individual disease, the analysis confirmed the relationship that roads have no significant impact on any of the individual health outcomes (Tables 7, 8, and 9), except for cancer, which was significant at the 5% level (Table 8: Regression 3). A positive relationship between presence of a paved road and incidence of cancer exists, where having a paved roads is correlated to a 0.064 percentage point increase in the percent of villagers with cancer.

A strange facet of the analysis is the significance of the treatment location, specifically whether an individual received treatment in the same village or elsewhere. Initially, this may be interpreted as individuals who are treated, whether in the same village or elsewhere, will have better health outcomes, compared to not being treated at all. To, the seenDoctor variable captures the percent of villagers who have been to a doctor in the past 5 years for a non-major morbidity disease. This variable would otherwise capture variations in seeing the doctor in villages across years, a potential effect of improved education and health awareness campaigns in rural India. Yet, the seenDoctor variable was not significant in nearly any regression result. Another plausible explanation for the significance of treatment location is that other villages may have better or more health facilities. However, a control variable for the number of Primary Health Centers (primaryHealthCntr) in each village in both 2005 and 2012. The Ministry of Health and Family Welfare of the Government of India (2016) launched the National Rural Health Mission in 2005 to improve healthcare in

rural India, which included expanding the number of Primary Health Centers, state owned health clinics. The significance of treatment location may be a statistically anomaly or the result of a psychological force where individuals who seek treatment more often are in general healthier because they are more conscious of their health. Little exists on the impact of road infrastructure on health outcomes in rural India, and even less exists on treatment location.

While road expansion has no effect on any type of disease incidence according to our analysis, it may impact the number of days incapacitated due to one or more of the 14 diseases. Equation (1) is expanded to examine average number of days villagers are incapacitated due to one or more of the disease (*mbDaysIncapacitated*), the following model:

$$mbDaysIncapacitated_{it} = \beta RoadPaved_{it} + \delta_1 Household_{it} + \delta_2 Village_{it} + \delta_3 Medical_{it} + \gamma_{it} + \varepsilon_{it} \quad (3)$$

Table 10 details the result of this analysis and supports the theory that roads have no net impact on any of the 14 major morbidity diseases collected by IHDS

One potential caveat in this analysis was the granularity of the unit of observation, the village. Road data was collected at the village level, so individual health data was aggregated using the mean to this level, which results in a loss of resolution in the data of individual variations. This means our model is unable to account for individual changes in behavior that may result in different health outcomes. This is an important drawback of the analysis because the mechanisms through which road expansion could alter health outcomes is through individuals. Individuals, not villages, make the decision to see physicians and travel to hospitals. Djemai (2011) was fortunate to have conducted his analysis at the individual level, and this difference in data resolution may account for the non-significant findings. However, my analysis did show significance in the univariate regressions between having a paved road and disease incidence.

Conclusion

Using data on individuals, households, and villages from the Indian Human Development Survey (IHDS), this paper analyzes the effect of road expansion on disease incidence in villages in rural India. This analysis examines how disease incidence both whether a village has a paved road or not and, if it has no paved road, whether the distance to paved road. Disease incidence is categorized by the percent of villagers in each village that have at least one of the 14 major morbidity (i.e. long-term) diseases collected by IHDS: cataracts, tuberculosis, high blood pressure, heart disease, diabetes, leprosy, cancer, asthma, polio, paralysis, epilepsy,

mental illness, STD/AIDS, and an other long-term disease. Using a OLS Regression Model with village and time-fixed effects and with villages as the unit of observation, the results suggest that road expansion has no significant impact on major morbidity incidence in villages in rural India.

These results contribute to the limited, but growing literature on rural infrastructure and health outcomes. Bell and van Dillen (2014) found no effect of paved roads on health outcomes in upland Orissa, India. While their paper limited to cross-sectional data from a relatively small sample of 1,292 villagers in 30 villages in a specific region of the country, this paper examined 1314 villages from throughout India in both 2005 and 2012 with village-level fixed effects. The null findings in this paper, however, support Bell and van Dillens claims using a more robust dataset and model. Djemai (2011) demonstrated a robust, positive relationship between HIV incidence and distance to paved roads in six African countries and attributed this effect to the increased movement of mobility groups with high HIV-risk overpowering the benefits of increased medical access and knowledge associated with road expansion. This analysis contradicted Djemai's findings as roads had no impact on STD/AIDS incidence or communicable diseases in general (IHDS combined STDs and AIDS into one survey question). This difference may be attributable to a difference in cultures (high-risk mobility groups may not have as large a presence in rural India) or differences in disease environments (HIV is not as prevalent in India).

These findings have important implications for Indian domestic rural policy and validity of internal reviews. The Ministry of Rural Development (2004) claimed an overwhelmingly positive impact of road expansion on rural health outcomes when conducting an assessment of PMGSY, the nation's rural road expansion program begun in 2004 and continuing to this day. The Ministry referenced survey data itself collected that showed improved travel times to health centers, higher levels of patients satisfaction, and increased hospital visits in several districts. The assessment was several limited by a small sample size, no control groups or variables, and any measure of tangible improvements in the direct health of individuals. This analysis shows that simply building infrastructure improving access is not enough to improve policy alone and internal reviews for assessing impact must be held to a higher standard of rigor. Additionally, these findings shed light on a more general topic of rural road infrastructure in developing countries and health outcomes. While road expansion is vital and important to the long-term economic and social development, it alone cannot induce improvements in population health. Road infrastructure is one component of an integrated plan, which includes health facility quality, physician access, mental health security, etc., to improving health outcomes.

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Tables

Table 1: 2005 Summary Statistics: Disease Incidence (Pct of village) 2005

Statistic	N	Mean	St. Dev.	Min	Max
mbCataract	1,457	0.510	1.108	0.000	12.500
mbTuberculosis	1,457	0.275	0.692	0.000	6.667
mbHighBP	1,457	1.141	3.377	0.000	100.000
mbHeartDisease	1,457	0.378	0.854	0.000	9.091
mbDiabetes	1,457	0.576	1.615	0.000	25.000
mbLeprosy	1,457	0.051	0.317	0.000	7.692
mbCancer	1,457	0.060	0.389	0.000	9.524
mbAsthma	1,457	0.615	1.174	0.000	13.158
mbPolio	1,457	0.116	0.403	0.000	4.286
mbParalysis	1,457	0.154	0.567	0.000	7.595
mbEpilepsy	1,457	0.116	0.435	0.000	5.263
mbMentalIllness	1,457	0.129	0.420	0.000	5.000
mbSTDorAIDS	1,457	0.055	0.373	0.000	6.154
mbOtherLongTerm	1,457	1.960	2.550	0.000	19.048
mbAnyDisease	1,457	1.960	2.550	0.000	19.048
mbComDisease	1,457	0.275	0.692	0.000	6.667
mbNonComDisease	1,457	0.129	0.420	0.000	5.000

Table 2: 2012 Summary Statistics: Disease Incidence (Pct of village) 2012

Statistic	N	Mean	St. Dev.	Min	Max
mbCataract	1,345	0.940	1.597	0.000	16.667
mbTuberculosis	1,345	0.286	0.698	0.000	8.696
mbHighBP	1,345	2.504	3.281	0.000	29.032
mbHeartDisease	1,345	0.651	1.255	0.000	11.538
mbDiabetes	1,345	1.197	2.474	0.000	25.806
mbLeprosy	1,345	0.058	0.365	0.000	6.250
mbCancer	1,345	0.057	0.338	0.000	6.250
mbAsthma	1,345	1.007	1.543	0.000	25.000
mbPolio	1,345	0.101	0.372	0.000	4.225
mbParalysis	1,345	0.379	1.390	0.000	20.339
mbEpilepsy	1,345	0.231	0.779	0.000	12.500
mbMentalIllness	1,345	0.328	0.872	0.000	14.286
mbSTDorAIDS	1,345	0.034	0.264	0.000	5.556
mbOtherLongTerm	1,345	3.901	3.859	0.000	32.000
mbAnyDisease	1,345	3.901	3.859	0.000	32.000
mbComDisease	1,345	0.286	0.698	0.000	8.696
mbNonComDisease	1,345	0.328	0.872	0.000	14.286

Table 3: Road Expansion and Incidence of Any Disease: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>					
	mbAnyDisease					
	(1)	(2)	(3)	(4)	(5)	(6)
roadPaved	1.486*** (0.247)	0.442* (0.255)	0.042 (0.183)			
income		0.00000* (0.00000)	−0.00000*** (0.00000)		−0.00001 (0.00001)	−0.00000 (0.00001)
illiterate		3.108** (1.396)	0.751 (0.947)		1.160 (4.125)	1.985 (2.658)
smokeTobacco		0.826*** (0.176)	−0.144 (0.124)		2.307*** (0.473)	0.347 (0.375)
ownToilet		0.014** (0.006)	0.006 (0.005)		0.018 (0.020)	−0.003 (0.011)
electricity		0.006 (0.005)	0.007* (0.003)		0.0002 (0.015)	0.003 (0.009)
seenDoctor		−0.847 (1.095)	−0.577 (0.782)		0.456 (2.339)	−1.451 (1.885)
ImmuniCamps			0.011 (0.013)			−0.005 (0.058)
PctPipedWater			−0.004 (0.003)			0.022** (0.009)
primaryHealthCntr			−0.494** (0.231)			−0.972 (1.512)
Treat.SameVil			0.494*** (0.042)			0.529*** (0.097)
Treat.OthrVil			0.543*** (0.041)			0.602*** (0.075)
Treat.OthrTwn			0.519*** (0.033)			0.481*** (0.078)
Treat.DstrctTwn			0.463*** (0.041)			0.376*** (0.073)
lnDistToPvdRd				−0.661* (0.385)	0.0003 (0.409)	0.240 (0.277)
Observations	2,800	2,742	2,590	658	642	602
R ²	0.025	0.145	0.636	0.016	0.290	0.753
Adjusted R ²	−1.081	−0.862	0.149	−4.174	−3.026	−0.598

Note:

Table 4: Road Expansion and Incidence of Communicable Disease: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>					
	mbComDisease					
	(1)	(2)	(3)	(4)	(5)	(6)
roadPaved	0.014 (0.041)	0.010 (0.048)	0.0005 (0.050)			
income		−0.00000 (0.00000)	−0.00000 (0.00000)		−0.00000 (0.00000)	−0.00000 (0.00000)
illiterate		−0.306 (0.285)	−0.453 (0.301)		0.360 (0.640)	0.041 (0.659)
smokeTobacco		−0.012 (0.030)	−0.048 (0.034)		0.153 (0.097)	0.137 (0.111)
ownToilet		0.002* (0.001)	0.001 (0.001)		−0.003 (0.004)	−0.003 (0.004)
electricity		0.0003 (0.001)	0.001 (0.001)		−0.003 (0.003)	−0.002 (0.003)
seenDoctor		−0.459* (0.276)	−0.477* (0.275)		−0.384 (0.491)	−0.123 (0.450)
ImmuniCamps			−0.007 (0.005)			0.021 (0.014)
PctPipedWater			−0.001 (0.001)			−0.004* (0.003)
primaryHealthCntr			−0.064 (0.082)			0.432 (0.312)
Treat.SameVil			0.009 (0.008)			−0.030 (0.030)
Treat.OthrVil			0.035*** (0.011)			0.047* (0.027)
Treat.OthrTwn			0.013 (0.008)			−0.002 (0.019)
Treat.DstrctTwn			0.046*** (0.015)			−0.001 (0.026)
lnDistToPvdRd				−0.062 (0.047)	−0.015 (0.061)	−0.057 (0.062)
Observations	2,800	2,742	2,590	658	642	602
R ²	0.0001	0.007	0.046	0.005	0.051	0.143
Adjusted R ²	−1.135	−1.163	−1.228	−4.232	−4.383	−4.537

Note:

Table 5: Road Expansion and Incidence of Non-Communicable Disease: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>					
	mbNonComDisease					
	(1)	(2)	(3)	(4)	(5)	(6)
roadPaved	0.131*** (0.041)	0.008 (0.048)	0.006 (0.052)			
income		0.00000 (0.00000)	0.00000 (0.00000)		0.00000 (0.00000)	−0.00000 (0.00000)
illiterate		0.230 (0.329)	0.414 (0.324)		−0.161 (0.585)	0.394 (0.385)
smokeTobacco		0.085** (0.034)	0.046 (0.033)		0.027 (0.074)	0.006 (0.079)
ownToilet		0.0002 (0.001)	−0.0003 (0.001)		0.002 (0.002)	0.002 (0.003)
electricity		0.001 (0.001)	0.001 (0.001)		0.0003 (0.001)	0.0003 (0.001)
seenDoctor		−0.320 (0.269)	−0.258 (0.277)		−0.398 (0.610)	−0.136 (0.524)
ImmuniCamps			−0.006 (0.004)			−0.018 (0.013)
PctPipedWater			0.001 (0.001)			0.0003 (0.004)
primaryHealthCntr			0.118 (0.079)			0.469 (0.485)
Treat.SameVil			0.013* (0.008)			0.017 (0.018)
Treat.OthrVil			0.016* (0.009)			0.001 (0.016)
Treat.OthrTwn			0.025** (0.010)			0.036 (0.023)
Treat.DstrctTwn			0.026*** (0.009)			0.017 (0.024)
lnDistToPvdRd				−0.052 (0.040)	−0.043 (0.041)	0.003 (0.072)
Observations	2,800	2,742	2,590	658	642	602
R ²	0.005	0.038	0.062	0.005	0.034	0.110
Adjusted R ²	−1.123	−1.095	−1.191	−4.232	−4.479	−4.749

Note:

Table 6: Road Expansion and Incidence of STD/AIDS: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>					
	mbSTDorAIDS					
	(1)	(2)	(3)	(4)	(5)	(6)
roadPaved	−0.029 (0.025)	−0.026 (0.027)	−0.034 (0.029)			
income		0.00000 (0.00000)	−0.00000 (0.00000)		−0.00000* (0.00000)	−0.00000 (0.00000)
illiterate		−0.190 (0.140)	−0.251 (0.157)		−0.784 (0.667)	−0.872* (0.448)
smokeTobacco		−0.004 (0.014)	−0.014 (0.014)		0.094* (0.057)	−0.054 (0.051)
ownToilet		0.00005 (0.001)	−0.0005 (0.001)		0.002 (0.003)	−0.001 (0.001)
electricity		0.0003 (0.0004)	0.0002 (0.0004)		0.001 (0.001)	0.001 (0.001)
seenDoctor		0.020 (0.107)	0.030 (0.120)		−0.064 (0.264)	−0.077 (0.261)
ImmuniCamps			0.001 (0.003)			−0.009 (0.008)
PctPipedWater			−0.0001 (0.001)			−0.005** (0.003)
primaryHealthCntr			−0.027 (0.042)			−0.558* (0.335)
Treat.SameVil			0.011*** (0.004)			0.022* (0.012)
Treat.OthrVil			0.015* (0.008)			0.061*** (0.021)
Treat.OthrTwn			0.002 (0.004)			0.026* (0.015)
Treat.DstretTwn			0.011** (0.004)			0.026 (0.018)
lnDistToPvdRd				−0.008 (0.040)	0.008 (0.042)	−0.001 (0.033)
Observations	2,800	2,742	2,590	658	642	602
R ²	0.001	0.004	0.033	0.0002	0.065	0.334
Adjusted R ²	−1.132	−1.169	−1.260	−4.255	−4.301	−3.304

Note:

Table 7: Road Paved and Disease Incidence: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>			
	df[, disease]			
	mbCataract	mbTuberculosis	mbHighBP	mbHeartDisease
	(1)	(2)	(3)	(4)
roadPaved	−0.007 (0.100)	0.065 (0.051)	0.211 (0.245)	−0.073 (0.081)
income	0.00000 (0.00000)	−0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)
illiterate	0.654 (0.509)	0.572** (0.263)	0.265 (1.250)	−0.367 (0.414)
smokeTobacco	0.060 (0.061)	−0.036 (0.032)	0.111 (0.150)	0.022 (0.050)
ownToilet	−0.0001 (0.002)	0.001 (0.001)	−0.001 (0.006)	0.004** (0.002)
electricity	−0.002 (0.002)	0.002 (0.001)	−0.008 (0.005)	−0.0002 (0.002)
seenDoctor	−0.018 (0.493)	0.202 (0.255)	−0.473 (1.213)	0.639 (0.402)
ImmuniCamps	−0.016 (0.010)	0.004 (0.005)	−0.053** (0.024)	−0.017** (0.008)
PctPipedWater	−0.003 (0.002)	0.003*** (0.001)	−0.005 (0.005)	−0.004*** (0.002)
primaryHealthCntr	0.047 (0.136)	0.007 (0.071)	0.260 (0.335)	−0.105 (0.111)
Treat.SameVil	0.020 (0.014)	−0.010 (0.007)	0.044 (0.033)	0.003 (0.011)
Treat.OthrVil	−0.030* (0.016)	−0.018** (0.008)	0.015 (0.038)	0.004 (0.013)
Treat.OthrTwn	−0.025* (0.013)	−0.015** (0.007)	0.039 (0.032)	0.012 (0.011)
Treat.DstrctTwn	−0.034** (0.017)	0.010 (0.009)	−0.018 (0.042)	−0.007 (0.014)
Observations	2,590	2,590	2,590	2,590
R ²	0.019	0.026	0.014	0.020
Adjusted R ²	−1.291	−1.277	−1.305	−1.290

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 8: Road Paved and Disease Incidence: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>				
	df[, disease]				
	mbDiabetes	mbLeprosy	mbCancer	mbAsthma	mbPolio
	(1)	(2)	(3)	(4)	(5)
roadPaved	−0.032 (0.145)	−0.024 (0.027)	0.064** (0.031)	−0.049 (0.112)	−0.041 (0.031)
income	0.00000 (0.00000)	−0.00000 (0.00000)	−0.00000 (0.00000)	−0.000 (0.00000)	−0.00000 (0.00000)
illiterate	−0.291 (0.740)	−0.065 (0.140)	0.007 (0.157)	0.439 (0.575)	0.070 (0.158)
smokeTobacco	−0.031 (0.089)	−0.007 (0.017)	−0.014 (0.019)	−0.058 (0.069)	0.050*** (0.019)
ownToilet	−0.0003 (0.003)	0.001 (0.001)	0.001* (0.001)	0.001 (0.003)	0.0002 (0.001)
electricity	0.0001 (0.003)	0.0003 (0.001)	0.00003 (0.001)	−0.003 (0.002)	−0.0001 (0.001)
seenDoctor	−0.312 (0.717)	−0.065 (0.136)	−0.268* (0.152)	0.048 (0.558)	0.288* (0.153)
ImmuniCamps	−0.001 (0.014)	−0.001 (0.003)	0.002 (0.003)	−0.005 (0.011)	0.009*** (0.003)
PctPipedWater	−0.001 (0.003)	0.0002 (0.001)	−0.0002 (0.001)	0.001 (0.002)	−0.0003 (0.001)
primaryHealthCntr	0.073 (0.198)	−0.042 (0.038)	0.107** (0.042)	0.188 (0.154)	−0.026 (0.042)
Treat.SameVil	0.031 (0.020)	0.001 (0.004)	−0.004 (0.004)	0.005 (0.015)	0.001 (0.004)
Treat.OthrVil	−0.001 (0.023)	−0.003 (0.004)	0.004 (0.005)	0.022 (0.018)	−0.003 (0.005)
Treat.OthrTwn	0.004 (0.019)	0.002 (0.004)	0.001 (0.004)	−0.014 (0.015)	−0.004 (0.004)
Treat.DstrctTwn	0.012 (0.025)	0.003 (0.005)	0.001 (0.005)	−0.027 (0.019)	−0.004 (0.005)
Observations	2,590	2,590	2,590	2,590	2,590
R ²	0.003	0.006	0.019	0.011	0.020
Adjusted R ²	−1.330	−1.322	−1.292	−1.311	−1.290

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 9: Road Paved and Disease Incidence: OLS with Village and Time-Fixed Effects

	<i>Dependent variable:</i>				
	df[, disease]				
	mbParalysis	mbEpilepsy	mbMentalIllness	mbSTDorAIDS	mbOtherLongTerm
	(1)	(2)	(3)	(4)	(5)
roadPaved	0.080 (0.080)	0.022 (0.054)	0.015 (0.058)	0.012 (0.027)	0.241 (0.232)
income	−0.00000 (0.00000)	0.00000** (0.00000)	−0.00000 (0.00000)	−0.00000 (0.00000)	0.00000 (0.00000)
illiterate	−0.196 (0.410)	−0.091 (0.278)	−0.083 (0.298)	0.026 (0.140)	0.330 (1.184)
smokeTobacco	0.040 (0.049)	−0.042 (0.033)	0.001 (0.036)	0.001 (0.017)	−0.065 (0.142)
ownToilet	−0.001 (0.002)	0.0004 (0.001)	0.002 (0.001)	−0.0002 (0.001)	0.006 (0.005)
electricity	−0.001 (0.002)	0.0005 (0.001)	0.001 (0.001)	−0.0001 (0.001)	0.006 (0.005)
seenDoctor	0.300 (0.398)	0.292 (0.269)	−0.068 (0.289)	−0.151 (0.135)	1.584 (1.149)
ImmuniCamps	0.001 (0.008)	−0.002 (0.005)	−0.005 (0.006)	0.003 (0.003)	0.020 (0.023)
PctPipedWater	−0.001 (0.002)	−0.001 (0.001)	−0.00002 (0.001)	−0.0003 (0.001)	−0.010** (0.004)
primaryHealthCntr	0.033 (0.110)	0.034 (0.074)	−0.056 (0.080)	−0.006 (0.037)	0.306 (0.318)
Treat.SameVil	−0.002 (0.011)	−0.006 (0.007)	0.002 (0.008)	0.004 (0.004)	0.040 (0.031)
Treat.OthrVil	−0.018 (0.013)	0.002 (0.009)	−0.015 (0.009)	−0.003 (0.004)	−0.016 (0.036)
Treat.OthrTwn	0.010 (0.011)	−0.007 (0.007)	−0.0002 (0.008)	0.003 (0.004)	−0.073** (0.031)
Treat.DstrctTwn	−0.005 (0.014)	0.002 (0.009)	−0.011 (0.010)	0.005 (0.005)	0.008 (0.039)
Observations	2,590	2,590	2,590	2,590	2,590
R ²	0.007	0.008	0.006	0.008	0.017
Adjusted R ²	−1.320	−1.318	−1.322	−1.317	−1.298

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 10: Road and Days Incapacitated Due To Illness: OLS with Village and Time-fixed Effects

	<i>Dependent variable:</i>					
	mbDaysIncapacitated					
	(1)	(2)	(3)	(4)	(5)	(6)
roadPaved	0.600 (0.382)	−0.050 (0.424)	−0.326 (0.394)	0.600 (0.382)	−0.050 (0.424)	−0.326 (0.394)
income		0.00001* (0.00000)	0.00000 (0.00000)		0.00001* (0.00000)	0.00000 (0.00000)
illiterate		−3.389* (2.038)	−5.909*** (1.930)		−3.389* (2.038)	−5.909*** (1.930)
smokeTobacco		0.242 (0.235)	−0.620** (0.247)		0.242 (0.235)	−0.620** (0.247)
ownToilet		0.001 (0.010)	−0.006 (0.011)		0.001 (0.010)	−0.006 (0.011)
electricity		0.014** (0.007)	0.013** (0.006)		0.014** (0.007)	0.013** (0.006)
seenDoctor		−2.953** (1.447)	−2.459* (1.327)		−2.953** (1.447)	−2.459* (1.327)
ImmuniCamps			0.034 (0.030)			0.034 (0.030)
PctPipedWater			−0.014* (0.007)			−0.014* (0.007)
primaryHealthCntr			−0.596 (0.498)			−0.596 (0.498)
Treat.SameVil			0.381*** (0.065)			0.381*** (0.065)
Treat.OthrVil			0.627*** (0.119)			0.627*** (0.119)
Treat.OthrTwn			0.405*** (0.064)			0.405*** (0.064)
Treat.DstrctTwn			0.492*** (0.083)			0.492*** (0.083)
Observations	2,800	2,742	2,590	2,800	2,742	2,590
R ²	0.002	0.022	0.214	0.002	0.022	0.214
Adjusted R ²	−1.131	−1.130	−0.838	−1.131	−1.130	−0.838

Note:

*p<0.1; **p<0.05; ***p<0.01

Appendix

Code on Github

All preliminary data cleaning code and exploratory data analysis can be viewed at <https://github.com/yesh747/RuralRoadsIndia>. Instruction on navigating these files can be found directly on the github.

Data cleaning, data analysis and paper itself was conducted using R Markdown in R Studio. Graphs were generated using ggplot2 package. Panel regressions were performed using the plm package. Tables and graphs were generated using the stargazer package. Data Manipulation was done using dplyr.

Data Analysis and Presentation Packages

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