Journal of Development Effectiveness

ISSN: 1943-9342 (Print) 1943-9407 (Online) Journal homepage: https://www.tandfonline.com/loi/rjde20

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To cite this article: Lindy C. Charlery, Matin Qaim & Carsten Smith-Hall (2016) Impact of infrastructure on rural household income and inequality in Nepal, Journal of Development Effectiveness, 8:2, 266-286, DOI: 10.1080/19439342.2015.1079794

To link to this article: https://doi.org/10.1080/19439342.2015.1079794

Published online: 20 Aug 2015.

Journal of Development Effectiveness, 2016
Vol. 8, No. 2, 266–286, http://dx.doi.org/10.1080/19439342.2015.1079794

Impact of infrastructure on rural household income and inequality in Nepal

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Weak public infrastructure may contribute to poverty and inequality. Studies have found that roads are a key factor affecting rural incomes in developing countries. Yet, there is relatively scant evidence of the economic impacts of rural roads at the individual household level. This study contributes to the literature by empirically analysing the effects of rural road construction on household income and income inequality in Nepal. Using a quasi-experimental design, a difference-in-difference approach is developed and employed to analyse household (n = 177) data before and after road construction. We find that the new road had a significantly positive impact on mean household income of USD 235 (28%). Contrary to expectations, we do not find an increase in income inequality. Compared to the counterfactual site, it appears that the road has rather contributed to decreasing income inequality. The poorest households gained most from the road construction, making it a pro-poor development intervention.

Keywords: difference-in-difference; impact evaluation; rural roads; income; Nepal

1. Introduction

Weak public infrastructure, such as lack of roads and electricity, contribute to poverty and inequality, especially in less-accessible rural communities in developing countries (Calderón and Chong 2004). Improving the understanding of the relationships between public infrastructure, poverty reduction and equitable benefit distribution remains important to policymakers and donor agencies aiming to maximise returns to scarce resources (Dillon, Sharma, and Zhang 2011; Jacoby 2000; Porter 1995, 1997, 2002; van de Walle 2002; Warr 2008, 2010). While rural infrastructure development is widely believed to bring about rural livelihood improvements, there are relatively few studies based on in-depth panel data sets with survey periods before and after the intervention.

Infrastructural development refers to the provision, enhancement and/or maintenance of infrastructure facilities aimed at improving living and working conditions of the population and allowing the free introduction and adoption of innovations. Infrastructural facilities can be grouped into three slightly overlapping categories: physical (water, rural electrification, roads, storage and processing facilities), social (health and educational facilities, community centres and security services) and institutional (markets, credit and financial institutions, agricultural research facilities and centres of innovation) (Kahn 1979, in Olayiwola and Adeleye 2005). The focus here is specifically on physical infrastructure, in the form of low grade (unpaved, earth surface) rural road construction in Nepal.

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Do rural roads contribute to lift people out of poverty? Rural road (here understood as road segments located in a rural policy area; Montgomery County Planning Department 2009) construction and maintenance increase the connectivity between rural communities and urban or semi-urban centres, and appear to promote transformations from subsistence to more commercial and multifunctional use of remote lands (Thongmanivong and Fujita 2006). Both high grade (high-quality motorways normally joining larger cities) and rural (regional) road construction foster economic and social development through region-wide economic spillovers and general equilibrium effects. Nonetheless, due to the remoteness and disconnected nature of less-developed regions, rural roads are likely to have greater economy-wide and locally specific impacts. In a study on regional road development in China, Fan and Chan-Kang (2008) found rural roads to have more than four times higher benefit/cost ratios for national GDP, and that they raised more people out of poverty, than high-grade roads. Khandker, Bakht, and Koolwal (2009) reported that rural road projects contributed to the reduction of moderate and extreme poverty in Bangladesh. However, our understanding of the local impacts of rural roads is limited (van de Walle 2009); in particular, there is a dearth of empirical studies focusing on household-level impacts in developing countries.

Here we present an empirical study of the household-level impact of rural road construction in Nepal. There is extensive rural road construction as all district headquarters are becoming connected to the national road network. Many of the new rural roads are dry-weather tertiary roads with earth surfaces, not useable by ordinary vehicles outside the dry season. Local-level consequences of new rural roads include both negative environmental spillovers – such as increased landslides (Sudmeier-Rieux et al. 2012) and deforestation (Bhattarai, Conway, and Yousef 2009) – and positive economic impacts – such as increased access to markets and health facilities, leading to more rural mobility and poverty reduction (Dillon, Sharma, and Zhang 2011). These studies do not, however, provide information on the impacts of low grade rural road construction at the microlevel. While Biggs and Watmough (2011) found that rural roads were among the most important factors affecting rural livelihoods in Nepal, their study fell short in providing any form of quantification as to *how important a factor it is*. Issues related to household income dynamics and income inequality remain unaddressed. The current study provides an empirical evaluation of the household-level economic impacts of a newly constructed tertiary rural road in Nepal.

White (2009) and Deaton (2010) stress the importance of answering *why* certain interventions work, along with answering *what* works. This study is more focused on *what* works, without reducing the importance of answering *why*. Following recommendations in the recent literature on impact evaluation (Hansen, Andersen, and White 2011; van de Walle 2009; White 2009), the *difference-in-difference* (DD) econometric approach is employed to assess the impacts of a rural road on household income. Special attention was given to the careful selection of a counterfactual that allows comparison with the factual[1] for isolating and accurately assessing the impacts of the road intervention. The statistical treatment–effects analysis of income levels is supported by a descriptive decomposition analysis of income inequality to assess the impact of the road on the income distribution dynamics of locally affected villages.

Our primary outcome measure for this impact evaluation study is household income (total and disaggregated). Income was chosen for three reasons: first, the data set available includes high-quality income data. Second, we believe that one of the biggest changes the new road brings is increased access to markets, which in turn is likely to significantly affect household income. Third, income is a widely used measure of well-being, which also allows us to assess the impacts of the new road on poverty and social equity in the affected villages.

Our first research question is: *what is the impact of rural road construction on household income in the affected villages?* The hypothesis is that households' total income in the treatment village experienced a significant increase as a result of the new road construction. Due to the diverse nature of the rural households' income portfolio in the study area (Rayamajhi, Smith-Hall, and Helles 2012), total household income is decomposed into its major sources to observe how each source is affected. The second research question is: *how does infrastructural development in the form of a rural road impact social (income) inequality in the affected villages?* We assess how income inequality has changed. We also assess whether particular income sources become more or less contributing to total income inequality. The hypothesis is that the new road increases income inequality. While access to markets provides avenues for households to increase their income – from services and trade of farm and environmental products – the new opportunities are possibly more accessed by those sections of the population that possess the resources needed for initial investment purposes. We recorded no special interventions to help poorer households tap into opportunities. The third and final research question is: *how are different wealth groups affected by the new road?* To answer this question, the population was subdivided into terciles (poorest, intermediate and least poor) and we estimated the treatment effects on each tercile. A greater change in income for the poorest group would indicate pro-poor attributes of the road and vice versa.

We make use of an in-depth environmentally augmented total household income data set to provide a more complete picture of how road construction affects households in a rural environment-reliant community of Nepal. Angelsen et al. (2014) highlight the importance of including environmental income in data sets used in assessing rural livelihoods. To our knowledge, this is the first case where such a data set is used in a road impact evaluation. Other impact studies typically do not include environmental income. The use of such a data set in the form of a quasi-experiment[2] provides a sound scientific basis for evaluating the impacts of rural road construction on household-level incomes in areas similar to the rural Nepalese communities under study.

2. Methods

2.1. *Geographical context*

The approach employed in this study utilises data from two points in time, before (2006) and after (2012) construction of the Beni–Jomsom-Sadak road (2008). Data were gathered from Lete – the site affected by the road intervention (also referred to as the treatment site or the factual) – and from Lulang – the counterfactual site without road connection for both periods. The data are compared between villages, across time, to control for time-varying factors – other than the road construction – that may influence the chosen outcome variables. This section describes the study villages, the road intervention, the data collected and the analytical approaches used to answer the research questions.

2.1.1. Treatment site. Lete Village Development Committee (VDC) is located about 2000 m.a.s.l. in Mustang District (around 28°34′–28°41′ N and 83°33′–83°44′ E, Figure 1). Before the new road, access was by 6 hours trek downstream the Kaligandaki River from the district headquarters of Jomsom, or 18 hours trek upstream from the adjacent Myagdi District headquarters, Beni. Today, Lete can be accessed by a

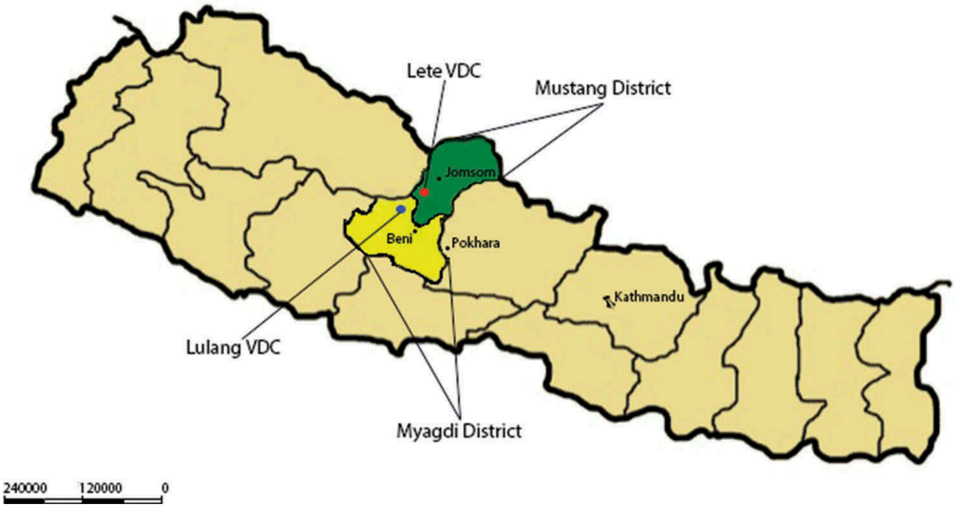

Figure 1. Location map of study area; Nepal.

Table 1. Description of treatment and counterfactual sites.

Indicators	Lete VDC (treatment site)	Lulang VDC (counterfactual site)
Sub-villages	Ghasa, Lete, Dhampu	Lamsung, Lulang, Khoriya
Number of households	174	236
Population	1117	1262
Sampled households	98	103
Ethnic groups	Thakali, Magar, Dalit	Bishowkarma, Magar, Dalit
Livestock	Goat, sheep, cattle, buffalo	Goat, sheep, cattle, buffalo
Vegetation	Conifer, mix, broadleaf	Conifer, mix, broadleaf
Main livelihood strategies	Tourism, agriculture, trade	Agriculture, trade, tourism
Schools	Primary (2), lower secondary (1), higher secondary (1), technical (1)	Primary (2), lower secondary (1), higher secondary (1)
Trekking route	Yes	Yes
Distance to Beni	~40 km	~60 km

Source: Larsen et al. (2014).

4–5 hour bus ride along the Beni–Jomsom-Sadak road or a 4-hour bus ride from Jomsom. Until the completion of the new road, mules and horses were the primary modes of transport for goods to and from the villages. Table 1 provides a summary description of Lete VDC and the counterfactual site, Lulang VDC.

2.1.2. Counterfactual. The most important difference between the counterfactual and treatment villages is that the former remains remote, with no motor-able road joining to town centres. The counterfactual is thus not affected by the specific treatment being assessed, but otherwise the two sites are considered to follow similar trends. The treatment–counterfactual method helps to identify which changes in the treatment villages can be attributed to the new road as opposed to other concurrent changes, including the end of the Nepal civil war and the changing levels of trade across the Chinese (Tibetan) border. Two major differences exist between the counterfactual and treatment villages: (1) in the level of mean annual total household income; and (2) in the level of income generated from business. However, similarities in other characteristics and the guiding prerequisite that Lulang has up till now not been affected directly by a road intervention provide a reasonable basis for the treatment–effect analysis in this impact evaluation study.

Lulang VDC lies at approximately 2250 m.a.s.l. in Myagdi District in western Nepal. Lulang is about 30 km or 8 hours walk from the nearest dry-weather road in the town centre of Darbang, which in turn is 3 hours by bus from the district headquarters of Beni. Transportation to and from the villages is by foot and the use of horses and mules for carrying products. The construction of a dry weather road from Darbang to Takum (4 hours from Lulang) began in 2012. The villagers of Lulang expressed their expectation that this road will in time be extended to their village. The continued construction of new rural roads in both Mustang and Myagdi supports the assumption that both districts have similar growth potentials, which is important for the parallel trends assumption with the DD approach (see below). We exploit the fact that progress in road construction does not happen simultaneously, so that Lulang VDC was not yet affected directly by a road at the time of data collection.

2.1.3. Beni–Jomsom-Sadak road. Construction of the Beni–Jomsom-Sadak road (which includes the Jomsom to Lete section) was undertaken by the Nepal Army. Following the end of the civil war in 2006, the Beni–Jomsom road section was completed by the end of 2008 (Conservation 2008). This dry-weather road runs through Lete VDC providing vehicular access to markets, hospitals, schools and other major facilities in the more developed centres of Beni and Jomsom. Rural road development in the study districts is an ongoing process, as efforts are made to better connect the remote rural communities to the town centres and to the national road network, simultaneously promoting a more market-oriented economy. The fact that rural road construction has also started in Myagdi district is a reason to believe that treatment and counterfactual sites are similar in terms of their growth potential to make the comparison meaningful.

2.1.4. Major income sources in study sites. Income diversification is the norm for rural households in most developing countries, including in the study area (Nielsen et al. 2013). Households diversify their income portfolio for reasons of general risk management, seasonality in employment opportunities and differences in skills among household members (Nielsen et al. 2013). Seven main sources of income are identified among the households in this study. *Agricultural crop income* includes all farm income from crop production. This is a dominant source of income in most studies on rural livelihoods but not in the study areas of Lete and Lulang (Rayamajhi, Smith-Hall, and Helles 2012). *Livestock income* includes income from farm animals or their products and services. *Wage income* includes income from wage work, whether on or off farm. *Business income* includes income from private businesses, other than farms, owned and managed by the household. *Environmental income* is income generated from the extraction of forest and other environmental products (from fallows, grasslands and other noncultivated lands). *Remittance income* is received from family members living and working away. *Other income* is any income not included above (for example income from pensions).

Household income from each source is calculated as the total value of cash, goods and services less the cost of all inputs except labour provided by household members. All goods produced or collected by the household and used for household subsistence (home consumption) are valued and counted as part of household income (Wunder, Luckert, and Smith-Hall 2011). The income values for the follow-up year, 2012, are all deflated to 2006 values using the country average CPI index for Nepal (no local price index is available). Following Angelsen et al. (2014), all values are in adult equivalent units (aeu) to allow for interhousehold comparisons.

2.2. Data and data collection

The data from the treatment villages were collected from randomly selected households[3] (see Larsen et al. 2014 for a detailed description of the sampling process) on a quarterly basis throughout 2006 and 2012, following the poverty environment network (PEN) approach (Angelsen et al. 2011; Rayamajhi, Smith-Hall, and Helles 2012), while data from the counterfactual site were collected in early 2013, based on recall for 2012 and 2006, using identical data collection instruments. White (2009) advocates the use of recall data, with caution, as the best option when the counterfactual was not identified together with the treatment villages. However, many studies highlight the biases in using recall data, especially over longer periods (Jagger et al. 2012; Lund, Shackleton, and Luckert 2011). To improve the accuracy of the counterfactual site recall data, especially in the case of 2006, we implemented a methodology similar to Krishna's *stages-of-progress* approach (Krishna 2004; Kristjanson et al. 2007). Respondents were reminded of major event(s) in 2006, for example the end of the civil war, to help jog their memory. The 2006 questionnaire was implemented only after the 2012 questionnaire was completed, most of the times on a separate visit to the household. In the randomly selected households, the household head was interviewed face to face. The questionnaire covered economic activities and income sources of all household members. Data were checked while in the field and households were revisited to clarify inaccurate or unclear answers.

It can be argued that household assets and other larger consumables are more likely or easier to be recalled by the respondents than income or expenditure data. However, the latter was chosen as the indicator variable in this study for two main reasons: (1) it was the most complete variable accounted for in the PEN questionnaire instrument used for data collection; and (2) focussing on the collection of income data from the counterfactual VDC allowed for the development of a data set better comparable with the data already collected from the treatment VDC. Additionally, with the aim of disaggregating total income into its main components, it is not possible to use assets and larger consumables as a proxy, since they cannot be accurately divided to represent the individual income components of household total income. Yet, we use asset variables in an additional test to support the robustness of the results with the income data.

In addition to the interviews at the household level, group interviews were conducted in the study villages to collect contextual and qualitative data to aid in understanding the quantitative data collected in the survey. Key informant interviews were conducted with village officials and leaders of forest user groups.

A total of 98 households were initially surveyed in Lete in 2006. Of these, 74 households were surveyed again in 2012, resulting in a relatively small sample size. Ideally, a larger sample would provide more statistically precise estimates. However, given that Lete only has a total of 174 households, the sample covers more than 40 per cent of all households and can thus be considered representative of all village households. We decided not to include data from other villages in the region, as these are located at varying distances away from the road, which would have made it impossible to consider road construction as a binary treatment variable. The reduction of 98 to 74 households between the first and second round of data collection implies a 24 per cent attrition rate. While many impact studies with panel data ignore the problem of attrition bias, we tested whether attrition was random or not. We found that attrition was significantly correlated with our main outcome variable of total household income (Appendix 1A and 1B). It was also significantly correlated with two of the seven major income sources analysed in the study – *business income* and *other income*. To correct for any attrition bias, we followed Quisumbing and Baulch (2013) calculating and using inverse probability weights, that is the ratio of the predicted probabilities of the attrition probits, first excluding the variables that are significantly associated with attrition then including them. In Lulang, 103 households were surveyed in one single round, so that attrition was not an issue.

2.3. *Data analysis*

2.3.1. Econometric analysis: DD model. The DD approach allows the subtraction of effects from any other unobserved factors which may also influence the outcome variables being assessed. Keeping with the required *parallel trends assumption* any other changes which occur are assumed to occur in both the treatment and counterfactual sites and to have similar effects in both sites (in other words, in the absence of the treatment, the observed DD estimator is 0). Hence, subtracting the outcome variable difference of the counterfactual site from that of the treatment site will yield the desired treatment effects (Lee 2005). If the parallel trends assumption does not hold, then this limits the effectiveness of the DD approach, as any observed effects can be due to changes other than the treatment being assessed. We explained earlier that the treatment and counterfactual villages chosen for this study have similar growth potentials, except for the fact that Lete already has road access while Lulang has not. Hence, we argue that the parallel trends assumption is realistic. We also use propensity score matching (PSM) to increase the reliability of comparisons between households in the treatment and counterfactual groups. Nonetheless, some caution in interpreting the exact numerical results is certainly warranted.

Following Meyer (1995) the underlying model of the outcome variable is

$$y_{it}^{j} = \alpha + \alpha_1 d_t + \alpha^1 d^j + \beta d_t^j + \epsilon_{it}^{j} \tag{1}$$

where y is the outcome variable of interest for unit i (household; $i = 1, \ldots, N_t$) in group j (counterfactual = 0 or treatment = 1) in period t (2006 = 0 or 2012 = 1). d_t, d^j and d_t^j are dummy variables where $d_t = 1$ if $t = 1$ and 0 otherwise, $d^j = 1$ if $j = 1$ and 0 otherwise; $d_t^j = 1$ for the treated group after receiving the treatment. β is the true causal effect of the treatment on the outcome for the treated group. The key identifying assumption is that β would be 0 in the absence of the treatment, or $E[\epsilon_{it}^{j}|d_t^j] = 0$. Ultimately, an unbiased estimate of β can be obtained by the DD method[4] as

$$\hat{\beta}_{\text{dd}} = \Delta\bar{y}_0^1 - \Delta\bar{y}_0^0 = \bar{y}_1^1 - \bar{y}_0^1 - \left(\bar{y}_1^0 - \bar{y}_0^0\right) \tag{2}$$

where a bar indicates an average over i, the subscript denotes the time period and the superscript denotes the group. See Meyer (1995) for an in-depth explanation of the use of DD in quasi-experiments in economics. There may be a time-invariant difference in overall means between the groups $j = 0$ and $j = 1$, but this aspect is captured by α^1.

Similar to the method used in Mu and van de Walle (2007) and Bruhn and McKenzie (2013), to allow for the possibility of time-variant selection bias due to initial observables, we use PSM to match the compared households in the DD estimation. In order to compute robust estimates, households in the treatment villages were matched with households in the counterfactual villages using weighted PSM, implemented using a probit model. This also helps ensure that the parallel trends assumption required for DD estimation is fulfilled (Lemmon and Roberts 2010). This method was recommended by van de Walle (2009) and used in a number of related evaluation studies, including Khandker, Bakht, and Koolwal (2009) and Rand (2011). The results of the probit regression showing the balancing of pretreatment initial characteristics (with the propensity scores calculated at the baseline) are presented in Appendix 2. The set of control variables include various household-specific characteristics described in Appendix 3. Six variables appear significant – namely household head born in village, the number of adult males, total value of implements, area of cropland, distance from village centre and whether the household had experienced a severe shock – indicating that there are some differences between the treatment and counterfactual groups, which are reduced for through the matching process. Perfectly matched groups of treatment and counterfactual households were not possible due to the limited sample size; perfect matching would have resulted in the dropout out of too many households affecting the representativeness of the sample.

The empirical analyses using DD estimation was first carried out with total household income as the dependent variable. To check the robustness of the model results, total income was replaced with the total asset value and results were compared in terms of sign and significance level. The value of total assets was calculated as the sum of household implements (value) and bank savings and jewellery (value) less household debt.[5] We also estimated the impact of road construction on each of the seven major income sources, for the entire sample. The treatment effect was then also estimated by total income terciles based on 2006 income levels to inform on how impacts varied between the better-off (upper tercile) and worst-off (lower terciles) households.

A complete set of covariates providing information on household characteristics in the treatment and counterfactual villages is presented in Appendix 3. These independent variables were used in the PSM probit model. Variables 1–5 provide information on the household head, who is in most cases the main income earner. Variables 6–10 provide information on household composition, where children and elders are dependents and adult males and females are income earners. Variables 11–16 provide information on physical asset holdings. These are a measure of the structural well-being of the household. Variables 17 and 18 provide information on the position of the household in terms of distance from the village centre and forest where resources are gathered from. Variable 19 provides information on whether the household experienced a shock in the survey years which may have affected the household income.

2.3.2. Gini and income inequity decomposition. Total income inequality was calculated with the Gini index in each observation period. Furthermore, to investigate how the various household income sources contributed to income inequality, we decomposed total inequality, measured by the coefficient of variation (CV), between the individual sources of income i (de Janvry and Sadoulet 2001; Shorrocks 1980). Following Pyatt, Chen, and Fei (1980), the percentage decomposition of total inequality takes the form of

$$\sum_i w_i r_i (CV_i/CV) = 1 \tag{3}$$

where $w_i = \mu_i/\mu$ is the weight of income source i, with μ_i the mean income from source i and μ the mean total income; $r_i = \text{corr}(y_i, y)$ is the correlation between income y_i from source i and total income y; and CV_i is the CV of income source i.

Sources of income with a relative concentration coefficient r_iCV_i/CV greater than 1 contribute to increasing total income inequality, while those with a relative concentration smaller than 1 reduce total income inequality (de Janvry and Sadoulet 2001).

3. Results and discussion

3.1. *Household annual income*

Mean household income by income source and by study site is presented in Table 2. Total household income is lower in 2012 than in 2006 in both the counterfactual and treatment villages. Other data, not presented in this study, show the same pattern in other villages across Nepal. Assessing the reasons for this drop is beyond the scope of this paper; a possible explanation could be the impact of the global economic crisis.

3.2. *Road impacts on household income*

The DD estimator with weighted PSM was used to measure the impacts of the new road on total household income and each of the seven major income sources in Lete. Results are shown in Table 3. The impact on total income is positive and significant (p = 0.056). As explained earlier, the 2006 incomes of households in Lulang are based on recall data, which may be associated with inaccuracy. As a robustness check, we also carried out the estimates using asset values instead of income as the outcome variable. Assets ownership tends to be less volatile so that the recall data are likely more precise. Results of the DD

Table 2. Mean household income (aeu, USD) per source per site per period.

	Lulang VDC (n = 103)		Lete VDC (n = 74)	
Income sources	2006	2012	2006	2012
Agricultural crop income	28 (22)	20 (17)	40 (57)	24 (65)
Livestock income	147 (152)	95 (85)	117 (209)	54 (79)
Wage income	19 (37)	16 (41)	19 (34)	25 (48)
Business income	8 (37)	7 (27)	463 (819)	302 (557)
Environmental income	208 (159)	213 (243)	166 (154)	149 (178)
Remittances	61 (130)	34 (89)	20 (67)	90 (266)
Other income	23 (69)	8 (33)	82 (121)	246 (495)
Total income	494 (304)	396 (342)	906 (850)	888 (810)

Notes: Average 2012 conversion rates: USD 1 = 85 Nepali rupees. Standard deviation in parentheses.

Table 3. DD estimation results (PSM probit regression in Appendix 2) for the impact of rural road construction on household incomes in Lete, Mustang District, Nepal.

Mean of outcome variables (USD)	Baseline (BL) – 2006 Counter	Treated	Diff(BL)	Follow-up (FU) – 2012 Counter	Treated	Diff(FU)	DIFF-IN-DIFF
Treatment villages (Lete), n = 74; counterfactual villages (Lulang), n = 103							
Total income	441.43	905.98	464.55	170.46	888.12	717.67	253.12
Standard error	66.39	65.48	93.25	66.39	65.48	93.25	131.88
Z	6.65	13.84	4.98	2.57	13.56	7.7	1.92
$P > z$	0	0	0.000***	0.011	0	0.000***	0.056*
Environmental income	229.08	165.92	−63.16	90.23	148.76	58.52	121.68
Standard error	14.24	14.14	20.06	14.24	14.14	20.06	28.37
Z	16.09	11.74	−3.15	6.34	10.52	2.92	4.29
$P > z$	0	0	0.002***	0	0	0.004***	0.000***
Crop income	25.23	40.34	15.11	23.72	24.01	0.29	−14.82
Standard error	4.81	4.78	6.78	4.81	4.78	6.78	9.58
Z	5.25	8.45	2.23	4.93	5.03	0.04	−1.55
$P > z$	0	0	0.026**	0	0	0.966	0.123
Livestock income	97.54	116.76	19.22	22.85	53.70	30.86	11.64
Standard error	12.89	12.80	18.17	12.89	12.80	18.17	25.69
Z	7.57	9.12	1.06	1.77	4.19	1.7	0.45
$P > z$	0	0	0.291	0.077	0	0.090*	0.651
Remittances	32.40	20.08	−12.32	1.85	89.52	87.66	99.98
Standard error	15.83	15.72	22.31	15.83	15.72	22.31	31.54
Z	2.05	1.28	−0.55	0.12	5.7	3.93	3.17
$P > z$	0.041	0.202	0.581	0.907	0	0.000***	0.002***
Business income	0.21	462.51	462.31	0.54	301.90	301.36	−160.95
Standard error	55.59	54.83	78.08	55.59	54.83	78.08	110.43
Z	0	8.43	5.92	0.01	5.51	3.86	−1.46
$P > z$	0.997	0	0.000***	0.992	0	0.000***	0.146
Wage income	75.11	18.56	−56.55	51.65	24.53	−27.11	29.44
Standard error	4.19	4.16	5.90	4.19	4.16	5.90	8.35
Z	17.94	4.46	−9.58	12.34	5.9	−4.59	3.53
$P > z$	0	0	0.000***	0	0	0.000***	0.000***
Other income	0.54	81.80	81.27	0.82	245.71	244.88	163.62
Standard error	28.61	28.22	40.18	28.61	28.22	40.18	56.83
Z	0.02	2.9	2.02	0.03	8.71	6.09	2.88
$P > z$	0.985	0.004	0.044**	0.977	0	0.000***	0.004***

Notes: Means and standard errors are estimated by linear regression. Significance levels: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

analysis with asset values are shown in Appendix 4; they confirm a positive impact of the road construction at a high level of significance ($p = 0.009$). We therefore conclude that the results are quite robust.

On average, the new road in Lete has increased household income by 28 per cent (USD 253). Possible causal explanations are reduced transportation costs and transportation time. Lower transportation costs contribute to higher profits and more frequent market transactions, whereas time savings allow the re-allocation of family labour to other remunerative activities. This finding is in line with expectations. As rural households in Lete generally exhibit a diverse income portfolio (Rayamajhi, Smith-Hall, and Helles 2012), Table 3 also estimates the impacts of the road by income source.

Table 3 shows that the impact of the road differs across major income sources. The impacts are significantly positive on four (all $p < 0.01$) of the seven income sources: the DD results imply that the new road has increased household environmental income by USD 122, remittances by USD 100, wage income by USD 29 and other income by USD 164. Information from village focus group meetings and key informant interviews indicated, in the case of environmental income, that more products are now traded in markets outside the villages at higher prices and/or that extracted amounts have increased for some products. The main environmental product extracted in both periods is fuel wood (as also found by Rayamajhi, Smith-Hall, and Helles 2012) which, in addition to subsistence use, is also traded in the market. Other marketed environmental products include timber, bamboo products, medicinal plants, mushrooms and sea-buckthorn fruits. Prices and net margins are reportedly higher when products are sold in Jomsom or Beni instead of locally to middlemen as was common practice before the construction of the road. The road impact on income from remittances may be due to increased access to banking services in the town centres of Jomsom, Beni and beyond. Transportation costs have been reduced and security on the road is said to have improved. The significant positive impacts on wage income and other income appear to be a direct result of villagers commuting more frequently to the more developed town centres to provide wage labour and to participate in other income-generating activities. The demand for wage work as porters, unskilled construction workers and other unskilled nonfarm labourers is greater in the town centres, which attracts villagers who can now make the journey easier and faster. The biggest road impact was on *other income*, which was not clearly described in the data set. Some villagers admitted that engaging in illegal activities was now easier and more profitable due to the new road; this apparently included better access to timber markets in town centres.

The road also had a positive but insignificant impact on livestock income. Livestock herders drive their herds to the town centres for sale during festival seasons, yet the road does not seem to be of major importance for this economic activity. Interestingly, crop income and business income may have been affected negatively by the road construction, although these effects are not statistically significant. Negative effects on certain income sources may be explained by the re-allocation of family labour and other household resources. For instance, villagers reported that the new opportunities in the town centres decreased some of their labour use in crop faming. In the case of business income, a drop might be due to a decline in the number of tourists staying overnight in the village: most business income in Lete is from lodges for trekkers, who now often use buses and may only stay in the village for a short stopover.

3.3. Income inequality estimates

Total income inequality in each period was calculated using the Gini coefficient of total income in the two sites. Income inequality in Lete is greater than in Lulang, in both periods, showing a slight and insignificant decrease of 0.003 from 2006 to 2012. In Lulang, income inequality increased by 0.066 which is significant at the 10 per cent level (Table 4). The difference in trends between the sites could be a result of the new road, that is new economic opportunities leading to less inequality.

Table 4. Gini index in 2006 and 2012 for Lete and Lulang, Nepal.

Index	Estimate	Standard error	t	$P > t$	95% Confidence interval
Lete (n = 74)					
GINI_2006	0.446	0.030	14.806	0	0.386 – 0.506
GINI_2012	0.443	0.032	13.932	0	0.380 – 0.506
Difference	−0.003	0.047	−0.056	0.956	−0.096 – 0.091
Lulang (n = 103)					
GINI_2006	0.295	0.027	11.076	0	0.242 – 0.348
GINI_2012	0.362	0.039	9.311	0	0.285 – 0.439
Difference	0.066	0.038	1.722	0.088*	−0.010 – 0.143

Note: Significance level: *$p < 0.1$.

This is investigated in more detail in Table 5 presenting the contribution of each income source to overall inequality in Lete in the two periods. Business income was the only contributor to income inequality in 2006 (relative concentration coefficient of 1.769). In 2012, business income continued to contribute to income inequality, albeit to a lower degree, along with income from remittances and other income. In Table 3, we saw that income from remittances and other income were significantly affected by the road, while the road had no significant impact on business income. Only a small percentage of households received income from remittances (Table 5) and hence its significant increase made it a contributor to inequality. Other income was the income source most significantly impacted by the new road; since one third of the population do not realise other income, this could result in an increased income gap and hence contribution to income inequality.

At first glance it seems fair to expect that with more income sources now contributing to income inequality, there should be an overall rise in income inequality in Lete with completion of the road. However, as already noted, this was not the case. The main reason is that two income sources that were positively and significantly affected by the road – environmental and wage income – both continue to play an inequality-reducing role, with relative concentration coefficients well below 1. Environmental income is known to be of higher importance to poorer households in the region (Rayamajhi, Smith-Hall, and Helles 2012). Furthermore, the wage income participation rate went up from 36 per cent in 2006 to 45 per cent in 2012, thus strengthening the inequality-reducing effect. These findings support the conclusion, contrasting with our hypothesis, that the new road has had an overall positive impact on income distribution in Lete, preventing inequality from rising as it did in Lulang, the counterfactual village.

3.4. *Who benefits most?*

Earlier we saw that the road played a significant role in increasing total household income without increasing income inequality. Later we describe the impacts of the new road on wealth groups using income terciles (Table 6), with the poorest households in the first tercile.

Significantly positive impacts of road construction on total household income were found for the poorest (109% or USD 313) and intermediate (72% or USD 459) households, while the effect for the least-poor households was negative but insignificant.

Table 5. Contribution of major income sources to total income inequality in Lete in 2006 and 2012.

	Abbreviation	Crop income	Livestock income	Wage income	Business income	Environment income	Remittance income	Other income	Total income
2006 – Lete (n = 74)									
Mean income	M_i	40.34	116.76	18.56	462.51	165.92	20.08	81.80	905.98
Weight of income source	w_i	0.045	0.129	0.02	0.511	0.183	0.022	0.09	1
Coefficient of variation	CV_i	1.422	1.793	1.857	1.771	0.928	3.361	1.474	0.938
Correlation (y_i, y)	r_i	0.239	0.231	−0.259	0.937	0.129	−0.043	0.104	
Relative variation	CV_i/CV	1.515	1.911	1.980	1.887	0.989	3.583	1.571	1
Relative concentration coefficient	$\boldsymbol{c_i = r_i} \times CV_i/CV$	0.362	0.441	−0.513	1.769	0.128	−0.154	0.163	
Decomposition of CV	$w_i \times c_i$	0.016	0.057	−0.011	0.903	0.023	−0.003	0.015	1
Per cent of households with positive income from source		100	95	36	74	100	17	68	100
2012 – Lete (n = 74)									
Mean income	M_i	24.01	53.70	24.53	301.90	148.76	89.52	245.71	888.12
Weight of income source	w_i	0.027	0.06	0.028	0.34	0.167	0.101	0.277	1
Coefficient of variation	CV_i	2.699	1.471	1.961	1.846	1.199	2.976	2.015	0.912
Correlation (y_i, y)	r_i	0.171	0.085	−0.065	0.700	0.113	0.401	0.561	
Relative variation	CV_i/CV	2.960	1.614	2.150	2.024	1.315	3.264	2.210	1
Relative concentration coefficient	$\boldsymbol{c_i = r_i} \times CV_i/CV$	0.506	0.137	−0.140	1.417	0.149	1.309	1.241	
Decomposition of CV	$w_i \times c_i$	0.014	0.008	−0.004	0.482	0.025	0.132	0.343	1
Per cent of households with positive income from source		97	91	45	61	99	28	66	100

Table 6. DD estimation of the impact of new road on wealth groups (income terciles) in Lete, Mustang District, Nepal.

	Baseline (BL) – 2006			Follow-up (FU) – 2012			
Mean of outcome variables (USD)	Counter	Treated	Diff (BL)	Counter	Treated	Diff (FU)	DIFF-IN-DIFF
Poorest households							
Total income	306.30	288.44	−17.86	291.34	586.87	295.54	313.39
Standard error	91.26	51.63	104.85	91.26	51.63	104.85	148.28
Z	3.36	5.59	−0.17	3.19	11.37	2.82	2.11
$P > z$	0.001	0	0.865	0.002	0	0.007***	0.039**
Intermediate households							
Total income	445.66	635.40	189.73	217.12	865.73	648.61	458.88
Standard error	80.92	77.61	112.12	80.92	77.61	112.12	158.56
Z	5.51	8.19	1.69	2.68	11.15	5.78	2.89
$P > z$	0	0	0.094*	0.008	0	0.000***	0.005***
Least-poor households							
Total income	868.69	1831.10	962.41	438.14	1225.25	787.11	−175.30
Standard error	525.39	185.75	557.26	525.39	185.75	557.26	788.08
Z	1.65	9.86	1.73	0.83	6.6	1.41	−0.22
$P > z$	0.104	0	0.090*	0.408	0	0.164	0.825

Notes: Means and standard errors are estimated by linear regression. Significance levels: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Hence, the new road seems to have a large pro-poor impact in Lete, supporting the earlier results on income inequality. Other studies in Nepal (Biggs and Watmough 2011; Dillon, Sharma, and Zhang 2011), Bangladesh (Khandker, Bakht, and Koolwal 2009) and China (Fan and Chan-Kang 2008) also found that rural roads play an important role in reducing poverty and improving income among the poorest population segments in rural areas.

4. Conclusions

The available quantitative evidence of the impacts of rural dry-weather roads on household income and income inequality is scant. Using a DD econometric approach, we contribute empirical evidence of the impacts of the Beni–Jomsom-Sadak road on rural household income and income inequality in the Lete VDC of Mustang District in western Nepal.

Comparing household-level data in treatment and counterfactual villages, we found that the road had a positive impact on total annual household income in a magnitude of 28 per cent (USD 253). Further disaggregation revealed that the new road significantly increased environmental income, remittances, wage income and other income. The estimated effects for crop and business income were negative, but insignificant.

The new road contributed to lower income inequality. While remittances and other income tend to increase inequality, these effects are more than offset by the positive impacts on environmental and wage incomes, which are both inequality reducing. This finding was supported by the disaggregation of income effects by income terciles: the two lowest income terciles have benefited over-proportionally from the road construction, whereas the effect for the least-poor households was insignificant.

A few limitations of our approach should be stressed. First, the sample is relatively small and drawn from only two villages. Second, the comparison of treatment and counterfactual villages assumes that economic developments in both villages would have been similar without the road. We have chosen the counterfactual site such that this assumption likely holds and have also used a PSM approach to make the comparison more reliable. Nonetheless, we acknowledge that some uncertainty remains. Third, past income data in the counterfactual village were collected through a household recall, which may be associated with inaccuracies. We carried out a robustness check by using asset instead of income data, which confirmed the results. Fourth, impacts of a road may evolve over time. The second round of data collection took place 4 years after the road construction, so that longer-term effects on economic development may not be fully captured. Against the background of these limitations, the exact numerical results should not be over-interpreted. However, given that the empirical results are quite robust and according to theoretical expectations, we cautiously conclude that the road construction has contributed to pro-poor economic growth in this region of West Nepal. Further infrastructure development should be promoted.

Acknowledgements

This paper has benefited from the work of the ComForM project and the co-operation of members of the Lete and Lulang VDCs, Nepal. The authors also acknowledge the comments and insight provided by Henning Tarp Jensen and other colleagues at the Global Development section at the Department of Food and Resource Economics, University of Copenhagen.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Funding for the study was provided by the Erasmus Mundus Consortium, FONASO.

Notes

1. The factual refers to the village being affected by the intervention (here road construction), while the counterfactual is a comparable village that is not affected.
2. A natural experiment or quasi-experiment occurs when some exogenous events – often a change in government policy or implementation of development projects – change the environment in which individuals, households or villages operate (Wooldridge 2009).
3. Households were randomly selected through a computer-generated random table, produced from an updated census list sourced from the VDC office.
4. The difference-in-difference model can be calculated directly in Stata using the diff command. Ideally, due to the small sample size the results could be clustered to adjust the standard errors. Villa (2012) provides a complete guide for calculating the difference-in-difference model in Stata using the diff command.
5. We only refer to financial capital assets (as opposed to human or social capital). The value of land owned by the household was not included in the calculation of assets value as it was not possible to accurately assess the value of the household land holdings due to the absence of land markets in the area.

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Appendix 1A. Probit model on 2006 data, showing which variables are significantly affected by attrition between 2006 and 2012 (Lete, *n* = 98 in 2006)

Dependent variable attrition_06_12	Coefficients	Robust standard error	*P* > *z*
Independent variables			
Total household income in 2006	5.65E-06	1.84E-06	0.002***
Head_year_born_06	−0.0068109	0.0170493	0.690
head_female_06	−0.155769	0.4711425	0.741
Head_educ_06	0.07977	0.0507354	0.116
Max_HH_educ_06	−0.1409309	0.0551017	0.011**
Age_HH_06	−0.0000927	0.0117372	0.994
Head_born_village_06	−0.3623397	0.3076386	0.239
Head_belong_Biggest_caste_06	0.4113067	0.3385306	0.224
Head_marital_status_06	0.1983291	0.1024303	0.053*
num_of_children_06	−0.213751	0.1041456	0.040**
num_of_male_adults_06	0.1176524	0.1432153	0.411
num_of_female_adults_06	−0.1301461	0.1865615	0.485
num_of_elders_06	0.1440159	0.2453861	0.557
Total_imp_value_aeu_06	−3.07E-07	8.16E-06	0.970
Large_livstk_end_val_aeu_06	−2.03E-07	1.69E-06	0.904
Small_livstk_end_val_aeu_06	6.78E-07	5.44E-07	0.212
V_small_livstk_end_val_aeu_06	0.0000108	0.0000221	0.624
Beehives_end_val_aeu_06	0.0004044	0.0004241	0.340
Crop_land_sqm_06_aeu	0.0000335	0.0001776	0.851
Total_land_owned_sqm_06_aeu	−0.000216	0.0001125	0.055*
Bank_saving_aeu_06	5.58E-07	2.02E-06	0.782
Jewellery_aeu_06	8.13E-07	1.30E-06	0.531
debt_aeu_06	2.79E-06	2.40E-06	0.246
Dist_village_center_mins_06	−0.0016895	0.0024352	0.488
Tot_cons_2006_AEU	−0.0000236	8.95E-06	0.008***
Kunjo_06	−0.2354749	0.2476827	0.342
_cons	13.93957	33.61893	0.678

Note: Significance levels: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Appendix 1B. Probit model on 2006 data, showing which income source variables are significantly affected by attrition between 2006 and 2012 (Lete, n = 98 in 2006)

Dependent variable attrition_06_12	Coefficients	Robust standard error	$P > z$
Independent variables			
Total environmental income	−5.84E-07	7.59E-06	0.939
Total crop income	−4.6E-05	3.24E-05	0.153
Total livestock income	−1.85E-06	3.73E-06	0.619
Remittances	2.57E-07	8.22E-06	0.975
Total other income	2.39E-05	1.05E-05	0.023**
Total business income	9.27E-06	2.83E-06	0.001***
Total wage income	4.26E-05	2.88E-05	0.139
Head_year_born_06	−0.01008	0.018328	0.582
head_female_06	−0.2643	0.514422	0.607
Head_educ_06	0.067842	0.050852	0.182
Max_HH_educ_06	−0.14233	0.055806	0.011**
Age_HH_06	−0.00294	0.01257	0.815
Head_born_village_06	−0.26512	0.305641	0.386
Head_belong_Biggest_caste_06	0.550524	0.359255	0.125
Head_marital_status_06	0.214095	0.119551	0.073*
num_of_children_06	−0.25294	0.112125	0.024**
num_of_male_adults_06	0.133856	0.144357	0.354
num_of_female_adults_06	−0.10547	0.184416	0.567
num_of_elders_06	−0.02786	0.249878	0.911
Total_imp_value_aeu_06	−9.34E-06	1.04E-05	0.370
Large_livstk_end_val_aeu_06	2.22E-07	1.69E-06	0.895
Small_livstk_end_val_aeu_06	1.51E-06	6.57E-07	0.021**
V_small_livstk_end_val_aeu_06	2.67E-05	2.32E-05	0.250
Beehives_end_val_aeu_06	0.000479	0.000455	0.293
Crop_land_sqm_06_aeu	−0.00028	0.000113	0.013**
Other_land_06_aeu	−0.00014	0.000095	0.142
Bank_saving_aeu_06	6.82E-07	2.04E-06	0.738
Jewellery_aeu_06	−9.66E-08	1.28E-06	0.940
debt_aeu_06	3.12E-06	2.52E-06	0.216
Dist_village_center_mins_06	−0.00022	0.002523	0.932
Tot_cons_2006_AEU	−2.5E-05	8.86E-06	0.004***
Kunjo_06	0.147194	0.279216	0.598
_cons	20.29956	36.12448	0.574

Note: Significance levels: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Appendix 2. Balancing of pretreatment initial characteristics (probit regression with propensity scores estimated at baseline)

	Village_Lete (n = 177)		
Regressors	Coefficients	Robust standard error	$P > z$
Household head age	0.03022	0.0194	0.119
Household head female	0.25679	0.4399	0.559
Household head education	0.00045	0.1110	0.997
Household head born in village	−2.32593	0.5300	0.000***
Household head marital status	−0.51601	0.3937	0.190
Number of children	−0.04120	0.1220	0.736
Number of adult males	1.03101	0.2609	0.000***
Number of adult females	−0.40672	0.2544	0.110
Number of elders	0.54620	0.4691	0.244
Total value of implements	0.00014	0.0001	0.007***
Area of cropland	7.48E-04	0.0002	0.002***
Area of other land	2.60E-04	0.0002	0.221
Bank savings	1.28E-07	0.0000	0.990
Jewellery value	9.00E-06	0.0000	0.324
Household total debt	1.19E-06	0.0000	0.836
Distance from village centre (minutes)	0.01376	0.0058	0.017**
Household experienced severe shock	1.95616	0.4705	0.000***
Distance from forest (minutes)	0.00141	0.0044	0.751
Constant	−2.76137	1.3176	0.036
Pseudo R^2	0.883		

Note: Significance levels: ***$p < 0.01$; **$p < 0.05$.

Appendix 3. Means of variables used in the empirical analyses

	Lete (n = 74)		Lulang (n = 103)	
Independent variables	2006	2012	2006	2012
(1) Household head age	54.22 (12.40)	57.46 (12.11)	41.32 (15.84)	47.32 (15.84)
(2) Household head female (dv)	0.19 (0.39)	0.19 (0.39)	0.11 (0.31)	0.11 (0.31)
(3) Household head education	3.09 (4.41)	3.27 (4.62)	1.86 (2.68)	1.86 (2.68)
(4) Household head born in village (dv)	0.59 (0.50)	0.62 (0.49)	0.96 (0.19)	0.96 (0.19)
(5) Household head marital status (dv)	0.77 (0.42)	0.77 (0.42)	0.91 (0.28)	0.91 (0.28)
(6) Number of children	1.53 (1.28)	0.93 (1.0)	2.88 (1.75)	2.20 (1.53)
(7) Number of adult males	1.68 (1.11)	1.66 (1.36)	1.26 (0.73)	1.52 (0.98)
(8) Number of adult females	1.58 (0.91)	1.58 (1.01)	1.29 (0.74)	1.58 (0.86)
(9) Number of elders	0.36 (0.65)	0.45 (0.72)	0.12 (0.32)	0.24 (0.49)
(10) Total value of implements (aeu) (USD)	153 (271)	159 (172)	9 (17)	18 (20)
(11) Area of cropland (aeu) (m^2)	1858 (1983)	938 (1358)	732 (668)	718 (599)
(12) Area of other land (aeu) (m^2)	584 (1771)	458 (1337)	250 (405)	217 (526)
(13) Land rented (aeu) (m^2)	510 (777)	178 (380)	93 (502)	157 (703)
(14) Bank savings (aeu) (USD)	428 (1191)	489 (877)	69 (340)	99 (568)
(15) Jewellery value (aeu) (USD)	544 (1042)	423 (712)	70 (168)	102 (181)
(16) Household total debt (aeu) (USD)	376 (828)	139 (186)	166 (516)	297 (569)
(17) Distance from village centre (minutes)	47.54 (53.00)	47.54 (41.71)	30.96 (18.05)	30.96 (18.05)
(18) Distance from forest (minutes)	58.07 (36.62)	58.07 (8.64)	93.96 (52.84)	93.82 (51.88)
(19) Household experienced severe shock (dv)	0.69 (0.47)	0.08 (0.27)	0.04 (0.19)	0.10 (0.30)

Notes: aeu, adult equivalent units; dv, dummy variable (0,1). Standard deviation in parentheses.

Appendix 4. DD estimation of road impacts on household's total assets value

Mean of outcome variables (USD)	Baseline (BL) – 2006			Follow-up (FU) – 2012			DIFF-IN-DIFF
	Counter	Treated	Diff(BL)	Counter	Treated	Diff(FU)	
Treatment villages (Lete), n = 74; counterfactual villages (Lulang), n = 103							
Total assets value	375.098	748.298	373.199	−105.269	932.797	1038.065	664.866
Standard error	127.926	125.306	179.071	127.926	125.306	179.071	253.245
Z	2.93	5.97	2.08	−0.82	7.44	5.8	2.63
$P > z$	0.004	0	0.038**	0.411	0	0.000***	0.009***

Notes: Means and standard errors are estimated by linear regression. Significance levels: ***p < 0.01; **p < 0.05.