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# Impact of road improvement project on household consumption: Evidence from Nepal

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## Abstract

This study examines the impact of road improvement project on the household consumption of food and non-food items from different sources such as self-produced and the market purchases. Using the household-level data pooled from the Annual Household Survey (2013-2016) and road network database, this study relies on the "difference-in-difference" method. The results suggest that the road improvement project was associated with a significant increase in the market-purchased household consumption. Market purchased food consumption and non-food consumption increased significantly by 21% and 31% following the implementation of the project. The impact is much more profound in rural households with the shift in their source of consumption from production to market purchase. These findings are consistent to robustness check using an unmatched sample and pre-trend analysis. We conclude that the improvement of road network improves consumption and thus the household welfare.

***Keywords:*** *Coarsened exact matching, Difference-in-difference, Household consumption, Market purchase, Nepal, Road improvement*

## 1. Introduction

Access to transportation is a fundamental component of economic development, especially in rural areas. The availability of access to all weathered roads[1] raises the living standards of people in rural areas by reducing the transportation costs incurred for travelling from villages to market areas, generating market activity, affecting input and output prices, and increasing agricultural productivity (Hine et al., 2016; Khandker et al., 2009).

[1] All weathered (also referred as fair-weathered) roads: the roads which is trafficable in all-weather condition and can be used whole year. Typically, this means a road that is constructed in such a way that excessive rain does not cause it to be flooded to such an extent that vehicles travelling over it likely become bogged.

The characteristics of developing countries like Nepal differ from those of the developed countries as the development of transportation in developing countries is still in the primary stage. Many places are yet to be connected even by earthen roads, and most of the existing rural roads are not all weathered roads (Pokharel and Acharya, 2015). Having described the various characteristics of developing countries in terms of speed of growth, population density, settlement pattern, capacity, and resource availability, Morichi and Acharya (2011) have argued for the need to have a unique practical strategy for sustainable investment in countries like Nepal. Nepal is yet to pay due attention to the policy research on transportation infrastructure investment. The decision making for the investment in transportation sector is complex, as it must consider multiple areas like travel time, road user behaviour cost, and social welfare (consumer surplus). While investment decisions in the transportation sector are based on the traditional cost benefit analysis[2] (CBA), the CBA approach is based on the direct user benefits and ignores the wider economic benefit. The wider economic impact, which includes agglomeration, returns to scale, thickening of labour markets and market power, and firms and household consumption cannot be captured by the CBA (Joint Transport Research Centre, 2008). Developing countries, where transportation development is still in the preliminary stage, can improve their project appraisal methodology by considering the wider economic benefits (Pokharel and Acharya, 2015).

The project for strengthening the National Rural Transport Program (SNRTP) was implemented by the Government of Nepal with the support from the World Bank. It was implemented with the aim of providing all weather road access to all local levels by gradually upgrading the district road core network (DRCN)[3] and providing continuous proper maintenance (DOLIDAR, 2013). The total assistance received for the project was USD 100 million, of which 72 million was in the form of grants and 28 million in the form of loans. The overall goal of this project was to promote economic growth, provide access to services, and create sustainable jobs in rural areas. The project covered 36 districts, whose total population was more than 14.6 million. The project aimed to reach 15.29 million beneficiaries, with there being an all-weather access to a network of roads stretching 1400 km. The physical targets of the project were the routine maintenance of 5500 km stretch of roads with the employment of 2708 RMGs[4] (Routine Maintenance Groups), periodic maintenance of rural roads, bridges, and crossing structures stretching 1500 km, and upgradation and rehabilitation of the district road core network stretching 1400 km. The project began in March 2014 and ended in January 2020. The major components of the project were output-based maintenance of rural roads and crossing structures, upgradation and rehabilitation of rural roads and crossing structures, beneficiary monitoring, and institutional strengthening and capacity building (DOLI, 2020). Following the implementation of the SNRTP project in the project-intervened areas, the World Bank found the population within the 2 hours of walking distance to an all-weathered road to increase by 12.35% in Terai (plain land) and by 11.81% in hilly areas. Similarly, the average distance to reach the all weathered roads using paved and gravelled roads reduced by 60% and 44% respectively. The time taken to reach the nearest socio-economic centre using paved and gravelled roads reduced by 24% and 15%, respectively. The decrease in average vehicle operating cost was 28% for paved roads and 17% for gravelled roads. This study found the mobility of people in shops and restaurants to have increased by 63% and 57%, respectively (World Bank, 2020). In addition, World Bank found the travel time taken to access health services for pregnant women to have decreased by 18%, and the average time taken to seek immunisation services for children to have decreased by 21%. The districts where the SNRTP project was implemented is shown in Figure 1.

[2] Cost benefit analysis: it is a systematic approach to determine the feasibility of investment and provide the basis for a company's investment by comparing the total expected cost of each option with its total expected benefits.
[3] DRCN is the network that allows all the village development committee (VDC) headquarters to be connected with the strategic road network and district headquarters.
[4] RMGs: routine maintenance group is a small group of people who are hired to carry out regular, routine, and emergency small maintenance works in the rural roads of Nepal.

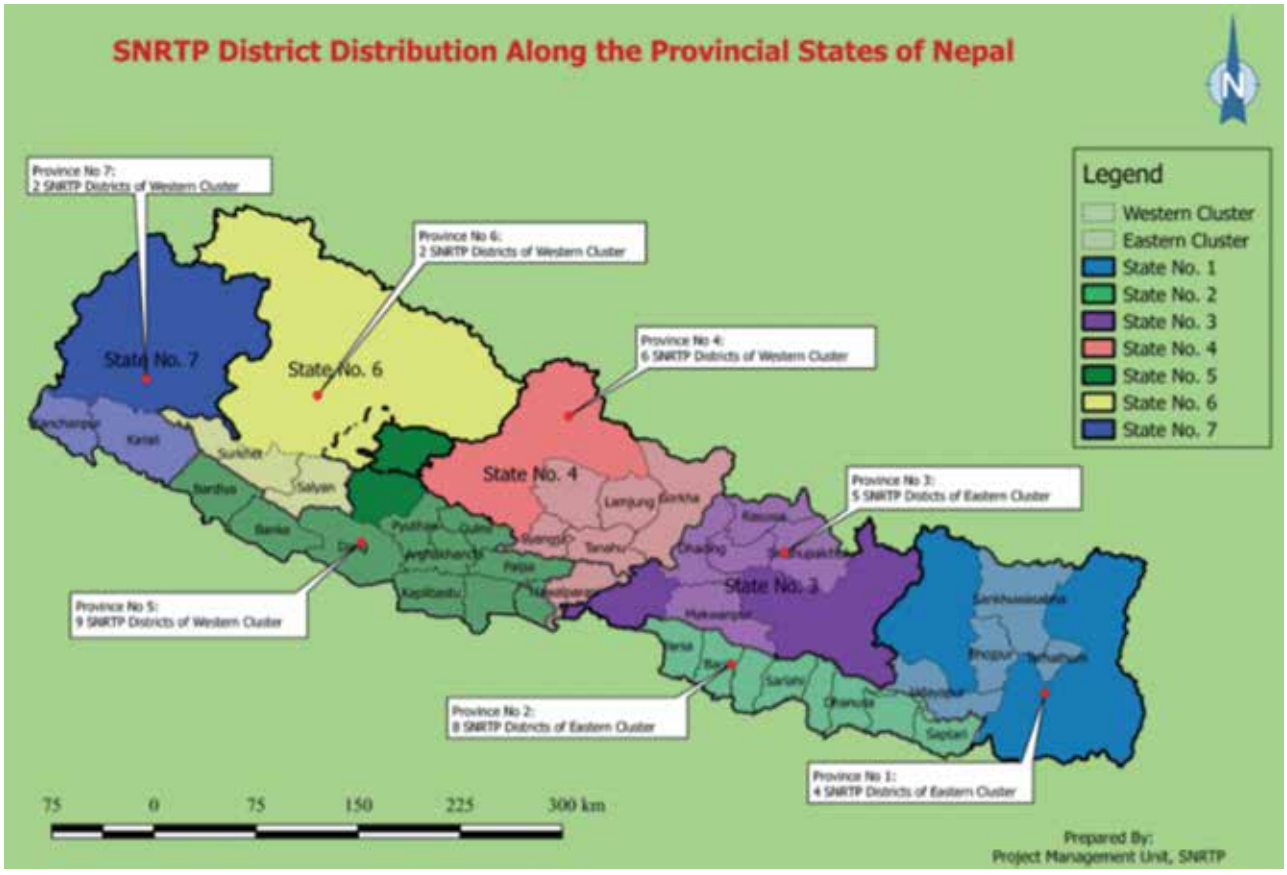


**Figure 1:** Districts implementing SNRTP projects

Household consumption is an essential component of aggregate demand. In most countries, household consumption represents a large proportion of the gross domestic product, comprising approximately 60%, making it an important variable for the economic analysis of aggregate demand (OECD 2009). Household consumption is the final purpose of any economic activity and the measure of consumption per person is often observed as a central measure of an economy's productive success. Moreover, household consumption is a key determinant of citizens' well-being at the global level (Bonsu and Muzindutsi, 2017).

Evidence shows that road maintenance projects have a positive impact on income, employment generation, and market development in the developing countries. While Khandker et al. (2009) and Wondemu and Weiss (2012) have found road development projects to have extensive development effects, others have noted that the magnitude of impact differs across the socio-demographic groups (Mu and van de Walle, 2011). Khandker et al. (2009) found the implementation of rural road development projects in Bangladesh to have caused the income poverty to decline to 5-7%, and found significant improvements when it came to adult labour supply and children going to school. The authors also found an increase in average household annual per capita consumption by 11% and an increase in men's agricultural wages significantly. These effects were found to be larger for the poorer households than for the wealthier households. Wondemu and Weiss (2012) found the average household income in Ethiopia to have increased by 63% following the improvement in the quality of rural roads. Mu and van de Walle (2011) found marginal returns on poverty and improvement in the market as a result of the improvement and upgradation of rural roads. Having analysed the linkage between rural road

development and household welfare, resilience, and economic conditions in Ethiopia using the difference-in-difference matching method, Nakamura et al. (2020) found Ethiopia's rural road development to be associated with a significant increase in household welfare or significantly smaller losses in household consumption during severe droughts. Furthermore, they found rural roads in very remote areas to be associated with farmers selling a larger share of their harvest and there being a higher chance of fertiliser use. The results of their study suggests that by connecting remote communities to markets and the main road network, rural roads have substantially supported the welfare and resilience of rural households in Ethiopia.

Bucheli et al. (2016) found evidence of reductions in household deprivation in Nepal due to the impact of rural road development which is primarily driven by the improvements in asset ownership and dwelling infrastructure. However, they failed to observe any significant effects on health and education indicators. Further, Shrestha (2020) identified the role of roads in improving agricultural livelihoods and examined the key market mechanisms through which improved connectivity translates into economic gains for agricultural households in Nepal. He found that 1% decrease in the distance to a road raises the market price of an agricultural plot from 0.1% to 0.25%, suggesting that a decrease in the distance to a road contributes to the commercialisation of agriculture and increases the use of fertilisers in agricultural production, thus, reducing the unit cost of fertilisers. Having used the difference-in-difference method to determine the impact of infrastructure on rural household income and inequality, Charlery, Qaim, and Smith-Hall (2016) found the newly constructed roads to have a significantly positive impact on the mean household income of USD 238 (28%). Furthermore, they found that the poorest household gained the most, making it a pro-poor intervention. A research carried out in China to determine the effect of access to domestic and international markets on the per capita consumption of households found improvement in the access to both domestic and international markets to have a positive effect on per capita consumption (Emran and Hou, 2013). The research further found the domestic market effect to be significantly larger in magnitude (Emran and Hou, 2013).

As a result, it is fair to say that the existing literature largely ignores the roles played by road improvements in household consumption. The existing literature does not incorporate the types of household consumption, namely food and non-food item consumption from different sources such as self-production or the market.

In this study, using the household survey data from Nepal, we have three specific objectives. Our first objective was to study the change in household consumption of self-produced food and non-food items and market purchased food and non-food items at household level due to improvement of road. Our second objective was to identify the impacts on consumption in rural and urban households. Similarly, our third objective was to find if household switches their consumption from self-produced source to market purchased source after the improvement of roads.

## 2. Materials and Methods

In this study, we outline a simple conceptual framework (Figure 2) that highlights the role of rural road development in determining household consumption. The development of rural roads to a better condition can impact households in two ways: a) increases household income generation and b) provides accessibility to the market. The increase in income generation is a result of economies of scale[5] in production and marketing, finer division of labour, adoption of new technology, and better labour market opportunities. Similarly, better accessibility to the market may be associated with low transportation costs, low travel times, and easy access to the market (Emran and Hou, 2013). Improvement of road conditions may result in the increase

[5] Economies of scale: cost advantages due to the increase in production and decrease in costs.

of household consumption and this increase in consumption could be more significant with regard to the consumption of food and non-food items purchased from the market.

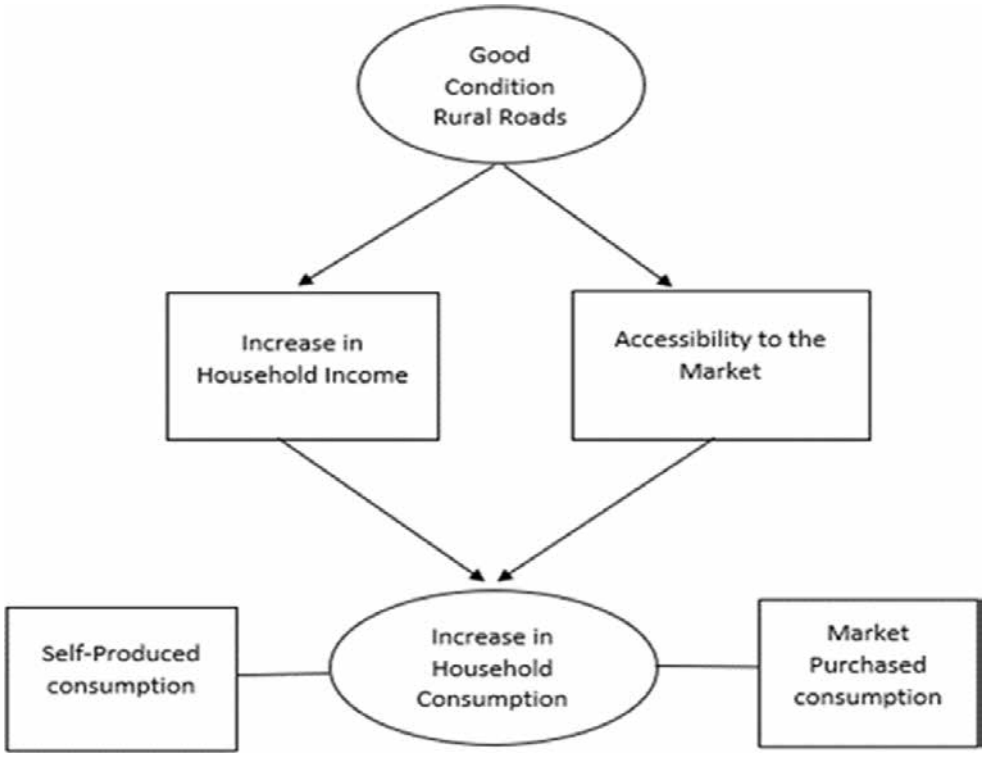


**Figure 2:** Conceptual framework of the study

## 2.1 Data

The household data used in this study were obtained from the National Living Standard Survey (NLSS) of 2010 and the Annual Household Survey (AHS) (2013-2016) by the Central Bureau of Statistics (CBS). While the National Living Standard survey is carried out once every ten years, the annual household surveys were carried out annually during the years 2012[6], 2013, 2014, 2015, and 2016. The survey collected household information such as demographic characteristics, consumption of food items and non-food items coming from their own production, and consumption of food items and non-food items purchased from the market to comprehensively reflect the status of household consumption, thus, providing a good database for the study. A detail description of methods adopted in the NLSS and AHS is reported elsewhere (CBS, 2011; CBS, 2017). This study used pooled data from the NLSS of 2010 and the AHS for the years 2013, 2014, 2015, and 2016.

## 2.2 Variables

The per capita household consumption expenditures for food items and non-food items were used as dependent variables in this study to measure the level of household consumption. Self-produced food and non-food consumption and market purchased food and non-food consumption were defined as the value obtained by dividing the aggregate household expenditure by the number of family members. The survey captured a detailed record of household consumption, including the expenditure for food, clothing, daily necessities,

[6] The study did not include data from the AHS 2012 due to data restriction for the public use.

housekeeping services, transportation, medical care, home maintenance, communication, entertainment, and education. Self-produced food items consist of food items such as cereals, rice, and maize, which are produced by the households themselves, and market purchased food items consist of food items such as noodles, beverages, and rice, which are purchased from the market. Similarly, self-produced non-food items consist of items such as utensils, firewood, house maintenance, and agricultural equipment, which are produced by the households themselves, and non-food items purchased from the market consist of items such as clothes, LP gas, kerosene, and equipment which are purchased from the market (CBS, 2017). The survey collected data for the self-produced food consumption and market-purchased food expenditure in the last seven days, the produced non-food consumption in the last month, and the market purchased non-food consumption in the last one year. Similarly, other independent variables such as gender of the owner of a household, urban or rural location of a household, district, geographical region, length of the District Road Core Network [7] (DRCN), length of the Strategic Road Network[8] (SRN), population density of the district, and road density[9] are also considered in this study. Treatment group are those households living in a district in which SNRTP project was implemented and control group are those households living in a district in which SNRTP project was not implemented. Descriptive statistics of the main variables are presented in Table 1.

**Table 1:** Descriptive statistics

| Variables | Treatment | | Control | | Mean Difference |
|---|---|---|---|---|---|
| | Obs. | Mean | Obs. | Mean | |
| Self-produced food consumption | 9015 | 313.78 (3.68) | 7305 | 294.52 (5.61) | 19.27*** |
| Market purchased food consumption | 9015 | 823.94 (7.45) | 7305 | 1087.19 (10.05) | -263.25*** |
| Self-produced non- food consumption | 9015 | 3035.89 (59.94) | 7305 | 2704.58 (70.08) | 331.31*** |
| Market purchased non- food consumption | 9015 | 41905.26 (1070.5) | 7305 | 55556.57 (1160.94) | 13651.31*** |
| Rural household | 9015 | 0.55 (0.005) | 7305 | 0.43 (0.006) | 0.12*** |
| Male household head | 9015 | 0.75 (0.005) | 7305 | 0.71 (0.005) | 0.033*** |
| Length of strategic roads (km) | 36 | 191.74 (12.21) | 39 | 142.86 (12.41) | 48.87*** |
| Length of district roads (km) | 36 | 392.86 (19.04) | 39 | 297.06 (32.2) | 95.87** |
| Road density (total road per area) | 36 | 0.67 (0.04) | 39 | 0.64 (0.11) | 0.043 |
| Population density | 36 | 278.94 (31.11) | 39 | 342.37 (128.39) | -63.43 |
| Region | 9015 | 0.55 (0.005) | 7305 | 0.43 (0.006) | 0.32*** |

[7] District Road Core Network (DRCN) is the network that allows all VDC headquarters to stay connected with the strategic road network and the district headquarters.
[8] Strategic Road Network (SRN) is the network that consists of the national highways that are connected all over the country.
[9] Road density is calculated by the dividing the total road network length within a district with the area of the district.

Note: Household consumption is expressed as the expenditure incurred by a household on food and non-food items, which are produced by the household or bought from the market. The unit of analysis is household. The value in parentheses denotes the standard error of mean. Transportation network and population data is expressed at the district level. Mean difference is the difference of means of the treatment variable and control variable. *, **, and *** in Table indicate the significance level of the mean difference of treatment and control variables at 10% level, 5% level, and 1% level, respectively.

### 2.3 Impact of road improvement on household consumption

The difference in difference (DID) method was used to estimate the impact of the road maintenance projects on household consumption. This method examine whether a particular intervention has an impact on our target population or on a specific target using an econometric approach. Moreover, it finds the significant difference in outcome across treatment and control groups, between pre-treatment and post treatment period (Chuen and Gregoria, 2014). The threat to the identification of the effect in our context is that the district selected for the implementation of the project may not have been random and may have been influenced by certain factors that determined the outcomes. For example, the government may have chosen districts that had already been well developed to complement its development with road construction. If this is the case, we might overestimate the effects of road construction on household consumptions. To deal with this endogeneity, first we control the district fixed effects that would capture the invariant characteristics that might determine the level of development. Furthermore, the dummy for whether the household is living in the mountain, hill and the Terai region[10] would address the invariant characteristics such as level of economic development across the regions. Second, we conduct an event-analysis to examine the validity of the parallel trend assumption. As we will explain in subsequent section (see Robustness Check), we did not find the evidence of pre-trend, which provides us with a confidence that our estimation results show causal effects.

To reduce the imbalance between the treatment and control district in the baseline characteristics, we used coarsened exact matching (CEM)[11]. We paired each treatment household with a control household with similar district characteristics so that the comparison between the treatment and control groups was not biased. Based on the review of the SNRTP strategies, we identified a set of potential factors that may have influenced the selection of SNRTP districts. These factors are the district-level connectivity and the economic characteristics[12] before the SNRTP implementation which include the number of roads, length of the blacktop road, length of gravelled roads, number of registered vehicles, road density, human poverty index (HPI), purchasing power parity, and geographical regions. We then used coarsening techniques to classify the district characteristics data into two or more categories. Table A1 in the appendix provides a detailed description of the district-level characteristics and the coarsening approach. The matching procedure generated the CEM weights for each district. The weight is specific to the stratum to which the districts are assigned, and represents the proportion of treatment and control present in the stratum. The unmatched districts weighed zero. This led to a reduction of 9015 treatment households and 7305 control households to 1710 treatment households and 1980 control households following the matching. We checked for multivariate

[10] Nepal is ecologically divided into three regions. The mountain, hill and the Terai region; analogous to the highland, midland and the plainland, respectively.

[11] CEM assigns each observation into one of a specified set of strata in which samples are exactly matched on a set of categorized variables. Matched samples are then assigned a weight specific to that the stratum and the representative of the proportion of all the samples are present in the stratum (Iacus, King, and Porro, 2011).

[12] Although the study used NLSS and AHS data to estimate the impact of SNRTP on household consumption, we considered district-level characteristics for the CEM since the likelihood of SNRTP implementation is based on the pre-existing district level attributes, rather than the household characteristics.

L1-statistics[13] in matched households and compared them with the L1-statistics in unmatched household to ensure the quality of matching. The multivariate imbalance between each variable decreased by more than 99% in the matched sample. Table A2 shows the L1-statistics before and after the execution of the CEM procedure. Figure 3 depicts flow chart diagram to arrive at the result.

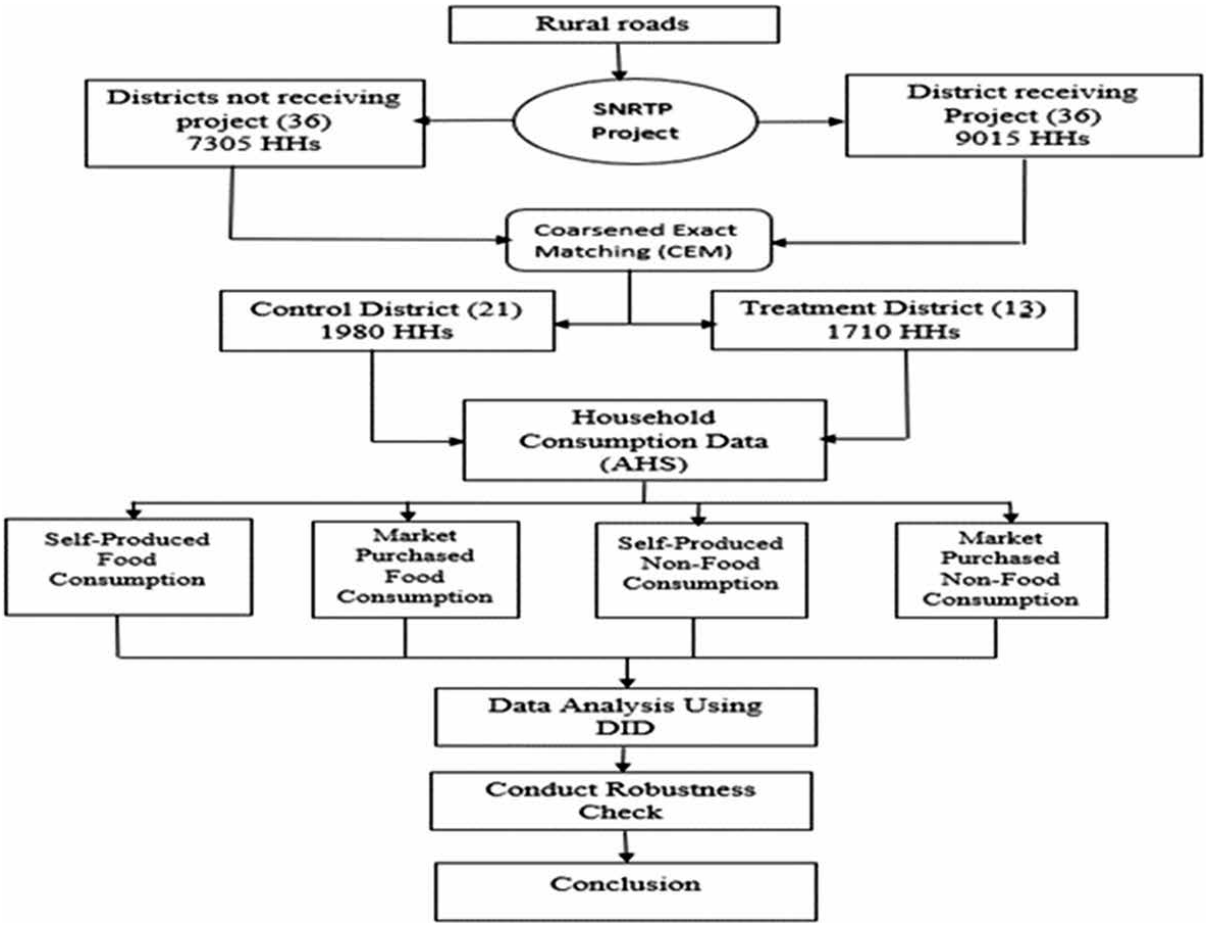


**Figure 3:** Flow chart diagram.

We then estimated the following standard DID model for the households in the matched sample.

$$Y_{ijt} = \alpha + \beta_1 Treatment + \beta_2 After + \beta_3 (After * Treatment) + \beta_4 X_{ijt} + \varepsilon_{it} \quad (1)$$

$Y_{ijt}$ is the vector of outcome, such as natural logarithm of per member's consumption of self-produced food items, consumption of food items purchased from the market, consumption of self-produced non-food items, and consumption of non-food items purchased from the market for household i in district j at year t. Treatment variable indicates those district in which SNRTP project were implemented, After variable indicates the year following the treatment, $X_{ijt}$ includes both time variant and time invariant household characteristics (listed in Table 1), $\varepsilon_{it}$ is an error term, and $\beta_3$ is the parameter that indicates the association between road development project and the outcome Y.

[13] The L1-statistic is a test of imbalance found in the CEM procedure. It takes a value between zero and one. The higher the L1 statistics, the less balanced are the treatment and control groups. Lower L1-statistics indicates the presence of treatment and controlled groups that are almost identical to each other.

### 2.4 Impact of road improvement on rural and urban household consumption

From a policy perspective, it is important to determine if the households in the rural areas have benefited from the road projects. Similarly, the comparative impact on rural and urban household is also important for the policy interventions. To explore such heterogeneity, we added one interaction term in Equation 1. Households are expressed using a dummy indicator (rural households = 1 and urban households rural = 0).

$$Y_{ijt} = \alpha + \beta_1 Treatment + \beta_2 After + \beta_3 Rural + \beta_4 (Treatment * Rural) + \beta_5 (After * Treatment) + \beta_6 (After * Rural) + \beta_7 (After * Treatment * Rural) + \beta_8 X_{ijt} + \varepsilon_{it} \quad (2)$$

$\beta_5$ indicates the degree of association between road development and the outcome variables for households in urban areas (rural = 0) and ($\beta_5 + \beta_7$) indicates the degree of association between road development and the outcome variable for households in rural areas (rural =1). Similarly, $\beta_7$ indicates the relative impact of projects on rural areas in comparison to the urban areas.

### 2.5 Shift of self-produced source to market purchased after road improvement

Using standard DID equation and adding interaction term rural in standard DID equation, we estimated if households are shifting their sources of consumption from self-produced to market purchased after the improvement of road. $\beta_3$ in Equation (1) gives the impact of treatment on self-produced food & non-food items and market purchased food & non-food items. Similarly, ($\beta_5 + \beta_7$) in equation (2) gives the impact of treatment on rural households in terms of self-produced food and non-food items and market purchased food & non-food items. Using Equations (1) and (2), if coefficient of self-produced source are negative and market purchased source are positive, we can conclude that there is shift in consumption from self-produced source to market purchased due to treatment effect of road improvement.

## 3. Results and Discussion

### 3.1 Impacts of road improvement on household consumption

The results show that road improvement projects are strongly and positively associated with household consumption in accordance with the DID estimates, especially the household consumption of food and non-food items purchased from the market. This shows that the consumption of food and non-food items purchased from the market increased significantly following the implementation of the project. However, the estimated results were not significant in the case of self-produced food items consumption and self-produced non-food items consumption. $\beta_3$, as estimated in Table 2, shows the impact of the road project on household consumption. As reported in column 2 of Table 2, the estimated results show that the consumption of food items purchased from the market increased by 21% following the implementation of the project, with the result being significant at 1% level of significance. Similarly, column 4 of Table 2 shows that the consumption of non-food items purchased from the market increased by 31% following the implementation of the project, with the result being significant at 1%.

**Table 2.** Estimating results for household consumption

| | **Log of Consumption for Self- Produced Food Items** | **Log of Consumption for Food Items Purchased from the Market** | **Log of Consumption for Self-produced Non-food Items** | **Log of Consumption for Non-food Items Purchased from the Market** |
|---|---|---|---|---|
| $\beta_1$: After | -0.62***<br>(0.07) | -0.07<br>(0.05) | 0 | -0.94<br>(0.06) |
| $\beta_2$: Treatment | -0.195<br>(0.14) | 0.12<br>(0.12) | 0.55***<br>(0.14) | 0.09<br>(0.13) |
| $\beta_3$: After * Treatment | 0.016<br>(0.09) | 0.21***<br>(0.06) | 0.048<br>(0.10) | 0.31***<br>(0.08) |
| Household characteristics | Yes | Yes | Yes | Yes |
| Road characteristics | Yes | Yes | Yes | Yes |
| District dummy, region dummy, year dummy | Yes | Yes | Yes | Yes |
| Observation | 3690 | 3690 | 3690 | 3690 |

*Notes: The unit of observation is the matched sample of households for the years 2013, 2014, 2015, and 2016. The DID model in Equation (1) was estimated using the natural logarithm of per equivalent household consumption of food and non-food items. The coefficient estimates for Treatment * After indicate the association between road projects and the outcome. Household characteristics (age, sex of the household owner, rural), road characteristics (length of SRN, local roads, road density), district dummies, region dummies, and year dummies were controlled. Robust standard errors are indicated in parentheses. *, ** and *** indicate the significance level of the estimated impact at 10% level, 5% level, and 1% level, respectively.*

### 3.2 Impact of road improvement on rural and urban household consumption

We also investigated the heterogeneity in the estimated association between the rural road development projects and household consumption changes in urban and rural areas. Estimates of Table 3 are determined from the DID estimates as shown in Equation (2). $\beta_5$ in row 2 of Table 3 provides an estimate of the impact of road development on household consumption in urban areas which are not statistically significant. The $\beta_7$ estimate brings out the difference between the consumption of rural and urban households. The results show that the difference in the consumption of rural and urban areas is highly substantial for the consumption of self-produced food items, consumption of self-produced non-food items, and consumption of non-food items purchased from the market. ($\beta_5$+ $\beta_7$) estimates the association between the road development projects and household consumption changes in rural households. The estimates in row 4 of Table 3 indicate a decrease in the consumption of self-produced food items and self-produced non-food items, while indicating an increase in the consumption of food items and non-food items purchased from the market. Self-produced consumption of food and non-food items decreased by 9% and 19% respectively and consumption of food and non-food items purchased from the market increased by 27% and 41%, respectively.

**Table 3.** Summary of the results based on the urban area and rural area

| | **Log of Consumption for Self-produced Food Items** | **Log of Consumption for Food Items Purchased from the Market** | **Log of Consumption for Self-Produced Non-food Items** | **Log of Consumption for Non-food Items Purchased from the Market** |
|---|---|---|---|---|
| **All households** | | | | |
| $\beta_3$: (After * Treatment) | 0.016<br>(0.09) | 0.21***<br>(0.06) | 0.048<br>(0.10) | 0.31***<br>(0.08) |
| **For rural households** | | | | |
| $\beta_5$: (After * Treatment) | 0.49<br>(0.26) | 0.16<br>(0.11) | 0.74<br>(0.85) | -0.22<br>(0.18) |
| $\beta_7$: (After * Treatment * Rural) | -0.58**<br>(0.27) | 0.11<br>(0.85) | -0.93***<br>(0.31) | 0.63***<br>(0.2) |
| $(\beta_5 + \beta_7)$ | -0.09<br>(0.08) | 0.27***<br>(0.07) | -0.19**<br>(0.10) | 0.41***<br>(0.09) |
| Household characteristics | Yes | Yes | Yes | Yes |
| Road characteristics | Yes | Yes | Yes | Yes |
| District dummy, region dummy, year dummy | Yes | Yes | Yes | Yes |

*Notes: The unit of observation is the matched sample of households for the years 2013, 2014, 2015, and 2016. The DID model in Equation (2) was estimated using the natural logarithm of per equivalent household consumption of food and non-food items. The coefficient estimates for $\beta_5$ indicate the association between road projects and outcomes in households located in urban areas. The coefficient estimates for $(\beta_5 + \beta_7)$ indicate the association between road projects and outcomes in households located in rural areas. Similarly, $\beta_7$ indicates the relative impact of projects in rural areas in comparison to the urban areas. Household characteristics, road characteristics, district dummies, region dummies, and year dummies were controlled. Robust standard errors are indicated in parentheses. *, ** and *** indicate the significance level of estimated impact at 10% level, 5% level, and 1% level, respectively.*

### 3.3 Shift of self-produced source to market purchased after road improvement

$\beta_3$ as estimated in Table 2 does not show negative value for self-produced food & non-food items. However, the coefficients are positive for market purchased food and non-food items. Thus, result shows that market purchased consumption items are increased but there is no evidence of households shifting their source of consumption in overall household. Similarly, using one interaction term in standard DID equation as shown in Equation (2), we estimated $(\beta_5 + \beta_7)$ and found the coefficient of self-produced food and non-food items and market purchased food and non-food items for rural households as shown in Table 3. The coefficient is negative for consumption of self-produced food and non-food items and positive for consumption of market purchased food and non-food items in rural households. Thus, result shows that in rural households, people are shifting their source of consumption from self-produced source to market purchased following the implementation of road project.

### 3.4 Robustness check

As a robustness check, the DID estimation was performed without matching the sample with the coarsened exact matching method using Equation (1). The estimated association between the road development project and household consumption does not change substantially as shown in Table A2 provided in the appendix section. The results show a decrease in the consumption of self-produced food and non-food items and an increase in the consumption of food items purchased from the market. However, the results show there to be no effect on the consumption of non-food items purchased from the market.

As DID estimates do not account for pre-trends, there is doubt whether the household consumption could change if the road project was implemented. We performed a pre-trend analysis in the matched sample as a robustness check, as shown in Equation (3). The NLSS data was used for the pre-trend analysis. Similarly, we used the data of the annual household surveys of 2013, 2014, 2015 and 2016. The road development project began in 2014. The consumption of self-produced non-food items was not estimated due to lack of data availability in the NLSS 2010.

$$Y_{ijt} = \alpha + \beta_1 Year2 + \beta_2 Year3 + \beta_3 Year4 + \beta_4 year5 + \beta_5 (Year2 * Treatment) + \beta_6 (Year3 * Treatment) + \beta_7 (Year4 * Treatment) + \beta_8 (Year5 * Treatment) + \beta_9 X_{ijt} + \varepsilon_{it} \quad (3)$$

$Y_{ijt}$ is a vector of outcomes, such as the natural logarithm of each member's consumption of self-produced food items, consumption of food items purchased from the market, and consumption of non-food items purchased from the market for household i in district j in year t. Treatment is an indicator of the district recipient status of the SNRTP project. $\beta_5$, $\beta_6$, $\beta_7$, and $\beta_8$ indicate the effect of treatment on the consumption of food and non-food items in comparison to 2010. $X_{it}$ includes the various time-variant and time-invariant household characteristics (listed in Table 1) and $\varepsilon_{it}$ is an error term.

The pre-trend estimation in Table 4 shows that $\beta_5$ is not significant for the consumption of self-produced food items, consumption of food items purchased from the market and consumption of non-food items purchased from the market in households which means that there was no pre-trend in 2012 before the implementation of the road development project. However, the coefficients $\beta_6$, $\beta_7$, and $\beta_8$ shown in Table 4 are significant which shows the existence of trend following the treatment year. While the trend is not clear for the consumption of self-produced food items, the consumption of food and non-food items purchased from the market has increased at a significant level. The graphs for the pre-trend analysis are shown in Figure A1 provided in the appendix section.

**Table 4:** Pre-trend estimation of household consumption.

| | **Log of Consumption for Self-produced Food Items** | **Log of Consumption for Food-items Purchased from the Market** | **Log of Consumption for Non-food Items Purchased from the Market** |
|---|---|---|---|
| $\beta_5$: (Year 2 * Treatment) | -0.03<br>(0.09) | -0.02<br>(0.07) | 0.03<br>(0.08) |
| $\beta_6$: (Year 3 * Treatment) | 0.12<br>(0.08) | 0.14**<br>(0.065) | 0.43***<br>(0.07) |
| $\beta_7$: (Year 4 * Treatment) | 0.21**<br>(0.08) | 0.27***<br>(0.069) | 0.37***<br>(0.08) |

| | Log of Consumption for Self-produced Food Items | Log of Consumption for Food-items Purchased from the Market | Log of Consumption for Non-food Items Purchased from the Market |
|---|---|---|---|
| $\beta_8$: (Year 5 * Treatment) | -0.14*<br>(0.08) | 0.18***<br>(0.06) | 0.18***<br>(0.067) |
| Household characteristics | Yes | Yes | Yes |
| Road characteristics | Yes | Yes | Yes |
| District dummy, region dummy, year dummy | Yes | Yes | Yes |
| Observation | 5380 | 5380 | 5380 |

Note: The unit of observation is the matched sample of households for the years 2010, 2013, 2014, 2015, and 2016. The pre-trend analysis model in Equation (3) was estimated using the natural logarithm of per equivalent household consumption of food and non-food items. The coefficient estimates for $\beta_5$, $\beta_6$, $\beta_7$, and $\beta_8$ indicate the effect of treatment on the consumption of food and non-food items in comparison to that in 2010. Household characteristics, road characteristics, district dummies, region dummies, and year dummies were controlled. Robust standard errors are indicated in parentheses. *, ** and *** indicate the significance level of estimated impact at 10% level, 5% level, and 1% level, respectively.

### 3.4 Discussion

The DID model's estimates suggest that the project helped increase the households' consumption of food and non-food items purchased from the market. While the consumption of food and non-food items purchased from the market increased significantly for rural households, there is no significant impact on urban households. The results suggest that the impact of the project is more prominent in rural households than in urban households. In rural households, while the consumption of self-produced items has decreased, the consumption of items purchased from the market has increased substantially. This evidence supports the notion that households in rural areas are shifting their source of consumption from self-production to the market. The research results are consistent with the study conducted by the World Bank (Implementation Completion Report, 2020), which found a substantial decrease in average time to reach the economic centre by 24% and an increase in trip of people to shops and restaurants by 63% and 57%, respectively.

## 4. Conclusions

Rather than relying only on the traditional cost-benefit approach while making investment decisions pertaining to infrastructure-related projects, policy makers need to be aware of the impact of projects on wider economic benefits. Consequently, to fully establish the impact of the road improvement project (SNRTP) on household welfare and to propose a policy direction, we conducted a regression analysis coupled with DID. This study assessed the relationship between the road development projects and household welfare by using consumption data as an indicator of welfare. Pooled data sets relating to consumption of self-produced and market-purchased food and non-food items at the household level and the road network data have made it possible for us to relate the impact of road development projects on household consumption. The road development project was implemented in 2014 with the aim of promoting economic growth, providing access to services, and creating sustainable jobs in rural areas. Our assumption was that this project helped increase the accessibility to the market, mainly in rural areas, and created job opportunities directly and

indirectly, thus, increasing household income which should have increased household consumption, especially consumption of items purchased from the market. Moreover, we assumed that the households would switch the source of consumption from self-production to purchase from the market due to better road conditions.

The results suggest that the project increased the households' consumption of food and non-food items purchased from the market. Market purchased food consumption increased by 21% and market purchased non-food consumption increased by 31%. While the consumption of food and non-food items purchased from the market increased significantly for rural households, there is no significant impact on urban households. The results suggest that the impact of the project is more prominent in rural households than in urban households. In rural households, while the consumption of self-produced items has decreased, the consumption of items purchased from the market has increased substantially. In rural households, the self-produced non-food consumption is decreased by 19%, market purchased food consumption in increased by 27% and market purchased non-food consumption is increased by 41%. This result supports the concept that households in rural areas are shifting their source of consumption from self-production to the market. This research will help the government and stakeholders working on rural sector to make policies and priorities on rural investment.

However, our study has several limitations. Efforts have been made to remove endogeneity in estimating the impact of rural road projects on household consumption. However, DID with coarsened exact matching (CEM) cannot perfectly eliminate the bias of unobserved factors, which may have affected the outcomes. Lehne et al. (2018) have reported that political capital, such as communities with a strong relationship with politicians, might impact the chance of receiving a road project. Similarly, there could be other projects, assistances, grants, and subsidies that were not considered in this study; these could have impacted the consumption of households, thus, opening the room for endogeneity bias. The limitations of this study are due to the lack of data on household characteristics and the factors affecting household consumption which include an increase in household income and an increase in accessibility to the market. Further research studies that could compute the impact of the road improvement projects on accessibility and increment in income are needed to verify the validity of our results.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendices

**Table A1:** Grouping of the district prior characteristics for CEM matching.

| District Prior Characteristics | Coarsen Grouping | Bins |
|---|---|---|
| No of rural roads in 2012 | 6 groups | 100/200/300/400/500 > 500 |
| Length of Black topped rural roads in 2012 (km) | 4 groups | 200/300/400 > 400 |
| Length of gravelled rural roads in 2012 (km) | 3 groups | 500/1000 > 1000 |
| Human Poverty Index in 2011 | 2 groups | <25/> 25 |
| No of Vehicle in 2011 | 4 groups | 50000/100000/150000 > 150 K |
| Rural Road Density in 2012 | 6 groups | 50/100/150/200/250 > 250 |
| Purchasing Power Parity (PPP) in 2011 | 2 groups | <1000/>1000 Mountain/Hilly/Plain |

*Note: we manually coarsened the continuous covariates into several groups as indicated in the table. The reason for manual coarsening was to maintain the maximum sample size in each coarsened class and to reduce the imbalance between the treatment group and control group.*

**Table A2:** Univariate imbalance before and after matching.

Multivariate L1 distance (before matching) = 1

Multivariate L1 distance (after matching) = 2.77 * 10-27

| Variables | Univariate Imbalance | |
|---|---|---|
| | **Before Matching** | **After Matching** |
| No of rural roads | 0.31 | 0 |
| Length of blacktopped rural roads | 0.08 | 0 |
| Length of gravelled rural roads | 0.194 | 0 |
| Human poverty index | 0.25 | 0 |
| Road density | 0.31 | 0 |
| No of vehicles | 0.31 | 0 |
| PPP (purchasing power parity) | 0.22 | 0 |
| Region | 0.333 | 0 |

Note: The unit of analysis is district. The matched sample was created by the coarsened exact matching (CEM) method. After matching the sample, the multivariate L1 distance moved from one to zero.

**Table A3:** Did results for household consumption for matched and non-matched sample.

| | **Non-matched Sample** | | | | **Matched Sample** | | | |
|---|---|---|---|---|---|---|---|---|
| | **(I)** | **(II)** | **(III)** | **(IV)** | **(I)** | **(II)** | **(III)** | **(IV)** |
| $\beta_1$: After | -0.34*** (0.044) | 0 | 0.17*** (0.04) | -0.82*** (0.03) | -0.62*** (0.07) | -0.07 (0.05) | 0 | -0.94 (0.06) |
| $\beta_2$: Treatment | 0.015 (0.015) | -0.2*** (0.05) | 0.53*** (0.11) | -0.75*** (0.09) | -0.195 (0.14) | 0.12 (0.12) | 0.55*** (0.14) | 0.09 (0.13) |
| $\beta_3$: After * Treatment | -0.11** (0.06) | 0.002 (0.03) | -0.04 (0.05) | 0 (0.03) | 0.016 (0.09) | 0.21*** (0.06) | 0.048 (0.10) | 0.31*** (0.08) |
| Household characteristics | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Road characteristics | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| District dummy, region dummy, year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observation | 16320 | 16320 | 16320 | 16320 | 3690 | 3690 | 3690 | 3690 |

*Note: (I) Log of Consumption for Self-produced Food Items, (II) Log of Consumption for Market Purchased Food Items, (III) Log of Consumption for Self-produced Non-food Items, and (IV) Log of Consumption for Market Purchased Non-food Items. The units of observation are the matched and unmatched samples of households for the years 2013, 2014, 2015, and 2016. The DID model in equation (1) was estimated using the natural logarithm of per equivalent household consumption of food and non-food items. The coefficient estimates for Treatment * After indicates the association between road projects and the outcome. Household characteristics (age, sex of the household owner, rural), road characteristics (length of SRN, local road, road density), district dummies, region dummies, and year dummies were controlled. Robust standard errors are indicated in parentheses. *, **, and *** indicate the significance level of the estimated impact at 10% level, 5% level, and 1% level, respectively.*