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From Walking to Driving: Economic Impact of Mountain Roads

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December 2024

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Keywords: Road, transport, firm, informal sector, gender

JEL classification: D22, O17, O18, R42

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From Walking to Driving: Economic Impact of Mountain Roads[†]

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Abstract
Road construction requires substantial investment in mountainous countries, and measuring the economic impact of road infrastructure is key to sound policy making. This paper evaluates the impact of Sindhuli Road on new business establishments in Nepal—new paved roads built on previously mountain trails with elevations between 200 and 1500 meters and traversing 160 kilometers. I use a unique Nepalese dataset that surveys all nonfarm establishments in the formal and informal sectors. To reduce selection bias, I adopt the propensity-score weighted regression method combined with the covariate-balancing propensity-score estimator. The results show that opening the road increased the number of new firms in local treatment wards by 108%, employment by 132%, and sales by 232%. The impacts were heterogeneous across construction sections, industries, and genders. To infer transportation cost savings in a modal shift from porter to vehicle, I surveyed porter transport prices along mountain trekking routes and show a striking difference in transport prices between porter and vehicle.

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1. Introduction

Roads are an essential foundation for daily lives through the transportation of goods and people, and investment in road infrastructure is key to industrial development and economic growth. In mountainous areas, footpaths are used for human movement and goods transportation by porters and pack animals. Constructing paved roads in mountainous areas can induce a modal shift from primitive transportation to vehicle transportation such as passenger cars, buses, and trucks. New paved roads can reduce transportation costs dramatically and produce large economic gains along mountain roads. Meanwhile, road construction requires substantial investment in mountainous countries and causes deforestation and ecological destruction (Damania et al., 2018). Measuring the economic impact of road infrastructure is a crucial input for sound policy making.[1] However, there is little formal evidence on the economic benefits of mountain roads.

In this paper, I seek to evaluate the economic impact of Sindhuli Road in Nepal: new paved roads that were built on previously mountain trails with elevations between 200 and 1500 meters and traversing 160 kilometers. The construction project was supported by Japan's Official Development Assistance (ODA), with a grant limit of about 26 billion yen.[2] Figure 1 shows a map of Sindhuli Road with municipality-level administrative boundaries.[3] Chronologically, its specific routes were determined in 1986 to connect Bardibas and Nepalthok with passing points in Sindhuli Bazar, Sindhuli Gadhi, and Khurkot. Dhulikhel was subsequently chosen as a destination point on the Kathmandu side. Construction work was completed in March 2015, and the entire route formally opened in July 2015. Because the road was built along a traditional trade route between Nepal and India for pedestrians, porters, and pack animals, the new opening of Sindhuli Road is associated with a modal shift from walking to driving along the mountain footpath from a long-term perspective.

---Figure 1 here---

To assess the economic impact of Sindhuli Road, I examine whether the new opening of the road promotes new businesses along the road after March 2015: the new entry of business establishments starting from April 2015 to June 2018. In this respect, I estimate the short-run impact of road completion. A threat to identifying causal effects is that the placement of new mountain roads is not random. Because the first road plan was proposed in 1962 and the specific routes were fixed in 1986, the geographic location of the road should be plausibly exogenous from the current determinants of new business establishments between 2015 and 2018. However,

[1] The average elevation is significantly high in mountainous countries: for instance, 3,279 meters for Bhutan, 3,266 meters for Nepal, 3,187 meters for Tajikistan.

[2] For the impact of ODA for roads on the location of firms, see Tanaka and Tsubota (2013).

[3] Appendix Table 1 lists municipalities along Sindhuli Road. The unit of regions for analysis is defined at the ward level under municipalities. Upper administrative boundaries include districts and provinces in Nepal.

treatment regions along the road may systematically differ from control regions in their economic and social characteristics. If treatment regions experienced higher industrial growth in the pre-opening period, comparing treatment and control regions may over-estimate the economic impact on new establishments because unobserved regional trends may correlate with the treatment variable. Thus, unbalanced characteristics between treatment and control regions may cause selection bias in estimation.

To reduce selection bias, I adopt the propensity-score-weighted (PSW) regression method by Hirano et al. (2003). Propensity scores are estimated from a first-stage logit regression, and the estimated propensity scores are used to construct weights for the observations in a regression model. By assigning a larger weight to control regions with a higher propensity score, the PSW regression helps reduce selection bias. For this task, I adopt the covariate-balancing propensity-score (CBPS) estimator by Imai and Ratkovic (2014). The advantage of the CBPS estimator is that the propensity score is estimated such that the resulting covariate balance between treatment and control groups is optimized along with the optimization of a likelihood function for a propensity-score model. By selecting parameter values to maximize the resulting covariate balance, the CBPS estimator mitigates the influence of potential misspecification of a parametric propensity-score model.

Outcome variables for new establishments are measured by the Nepalese Economic Census 2018 (NEC). The NEC data are unique in that they collect economic information on all nonfarm establishments and enterprises over the entire territory of Nepal. The census enumeration was conducted between April 14 and June 14 in 2018 through the Internet, face-to-face interviews, and direct mailing to major enterprises. The survey asks individual establishments about registration with any government agency, and the answer to this question is used to define the formal (registered) and informal (unregistered) sectors. The NEC reports a total of 923,356 establishments with 3.2 million persons engaged, with 462,605 formal and 460,422 informal establishments in my sample. Because the informal sector is pervasive in developing economies such as Nepal, the NEC allows me to estimate precisely the impact of roads on both formal and informal sectors.

The estimation results show that opening Sindhuli Road increased the number of new firms in local treatment wards by 108%, employment by 132%, and sales by 232%. Robust to alternative outcome variables, the results show the positive impact of the road on new establishments in both formal and informal sectors. These results are robust to alternative definitions of outcome variables and alternative control groups in the sample. Additionally, the results show the heterogeneous impacts of the road across construction sections, with the most significant impacts on the southern regions of Sindhuli Road. Meanwhile, there is some evidence on a hollowing-out effect in the middle part of the road. In terms of industrial heterogeneity, the positive impact of the road is pronounced in accommodation and food services, consistent with the casual observation that an increase in traffic flows produces a strong demand for local accommodation and food services. Finally, the results show that the aggregate impact of the road is stronger for new establishments by female managers than by male managers and larger for female employment in new establishments than male employment. Thus, females benefit strongly from the new mountain roads.

My findings highlight the substantial impacts of Sindhuli Road on new businesses and suggest a sizable decline in transportation costs as a key source of the large impacts. A plausible explanation is that new paved roads in mountain regions led to a modal shift from porters and pack animals to vehicle transportation such as passenger cars, buses, and trucks along the mountain footpath, thereby substantially reducing transportation costs and time for local business activities. To infer the size of local transportation cost savings from the modal shift, I collected information on transport prices by porter and pack animal along mountain trekking routes in Nepal and demonstrate a striking difference in the transport prices between porter and transportation by vehicle. For instance, porter transport prices for a transport distance of 100 kilometers are predicted to be 8.3 times higher than for a truck, with price differences increasing with distance.

This paper contributes to the literature on the economic impact of road infrastructure in developing economies.[4] First, a growing literature examines the economic impact of rural roads on households and other socioeconomic outcomes (Khandker et al., 2009; Mu and van de Walle, 2011; Stifel et al., 2016; Nakamura et al., 2020; Shimamura et al., 2023; Wiegand et al., 2023; Kebede, 2024). Other related studies estimate the economic and social impact of road networks and their upgrading (Faber, 2014; Shiferaw et al., 2015; Gibbons et al., 2019; Banerjee et al., 2020; Bird and Straub, 2020; Dumas and Jάtiva, 2024; Djemaï et al. 2024; Gertler et al., 2024). In the context of India, prior works such as Datta (2012), Ghani et al. (2013), and Ghani et al. (2016) investigate the economic impact of the Golden Quadrilateral highway project, whereas Asher and Novosad (2020) estimate the impact of new rural roads built by the Village Road Program. Meanwhile. In the context of Nepal, previous studies such as Jacoby (2000), Charlery et al. (2016), and Shrestha (2020) estimate the economic benefits of roads on households. In sum, the existing literature has assessed road infrastructure by focusing on road upgrading and connectivity improvements in rural, trunk, and highway roads. To my knowledge, there is little assessment on new paved roads built on previously mountain trails, which can produce large economic gains in regions with high transportation costs as compared with road construction in regions with well-developed road networks. This paper provides the first formal evidence on the

[4] For a literature review on the economic impact of transport infrastructure, see Berg et al. (2017) and Raitzer et al. (2019).

economic impact of large-scale mountain roads.

Second, this paper contributes to the literature by demonstrating the economic impact of mountain roads on both formal and informal sectors. Road infrastructure reduces transport costs for production, and a large number of informal firms in developing economies may benefit from road improvements (Lewis, 1954; La Porta and Shleifer, 2014). However, there is limited study to examine the road impacts on both sectors (Ghani et al., 2013; Fiorini and Sanfilippo, 2022): prior findings suggest that road improvements have little effect on informal manufacturing firms and job creation. In this respect, this paper shows formal evidence that road infrastructure promotes an entry of informal firms across manufacturing and service industries. Additionally, the related literature highlights a reduction in transport costs as a key consequence of road improvements but has paid little attention on the economic magnitude of transportation cost savings. This paper compares the predicted difference in transport prices by porter and truck in Nepal and suggests that a modal shift of transportation from porter to truck in Sindhuli Road would largely reduce local transportation costs, consistent with large positive impacts on new business establishments.

The rest of this paper is organized as follows. Section 2 describes the background for the construction of Sindhuli Road. Section 3 discusses an empirical strategy to identify the causal effect of road completion on new business establishments. Section 4 describes data sources on outcome variables and regional data in Nepal. Section 5 shows the estimation results and robustness checks, followed by the results on heterogeneous effects by region, industry, and gender. Section 6 presents supporting evidence for the role of transport costs in understanding the large impact of Sindhuli Road. Finally, Section 7 concludes.

2. Background of Sindhuli Road

This section describes the background of Sindhuli Road by drawing on the work by Kamei (2016). From a chronological perspective, the first plan for Sindhuli Road is found in the report on the Kathmandu-Janakapur Road Plan for 1962 by the Regional Transportation Organization in Nepal. While the construction plan was not implemented for decades, the Japan International Cooperation Agency (JICA) started an aid project for agricultural development around Sindhuli Bazar, a starting point of Sindhuli Road in the south of Nepal. As a lack of paved roads in the mountainous areas prevented the transportation of agricultural goods to other markets, JICA provided heavy machinery to construct roads in this region for 1981.

In 1983, the Infrastructure Development Institute Japan proposed a construction project of Sindhuli Road as an aid project from Japan to Nepal. In 1985, the Government of Nepal requested the Japanese government to conduct a feasibility survey for road construction, which was conducted in 1986 by JICA to determine specific road routes: at the time of the survey, it had been decided to connect Bardibas and Nepalthok with passing points in Sindhuli Bazar, Sindhuli Gadhi, and Khurkot. The route along these regions is a traditional trade route between Nepal and India: a footpath for pedestrians, porters, and pack animals. Subsequently, Dhulikhel was chosen as a destination point on the Kathmandu side. Based on the survey, a construction plan was proposed for four sections: Section 1 between Bardibas and Sindhuli Bazar; Section 2 between Sindhuli Bazar and Khurkot; Section 3 between Khurkot and Nepalthok, and Section 4 between Nepalthok and Dhulikhel. Table 1 summarizes the construction period and distance for each section. The completion periods differ by section, with construction work in the final section completed in March 2015 and the entire Sindhuli Road formally opened in July 2015.

---Table 1 here---

Sindhuli Road is a new paved road built on previously mountain trails with elevations between 200 and 1500 meters and traversing 160 kilometers. The project was supported by Japan's ODA with a grant limit of about 26 billion yen. The construction required 5.8 million person-days of construction workers, the cutting of 2.4 million cubic meters of soil, and the filling of 1.4 million cubic meters of soil. The construction area is vulnerable not only to large-scale landslides and flooding due to heavy rainfall during the rainy season, but also to active orogenic movement in the mountainous terrain and soil erosion by human activities. For this reason, the project required substantial engineering work to reduce the risk and damage from natural disasters. Additionally, the civil war between the government and the Maoists caused workers' strikes during the construction project and required protective measures for rebel guerrillas.

Anecdotal evidence for economic impacts on local livelihoods is reported in Kamei (2016, pp. 180-183). First, traffic flows increased substantially along Sindhuli Road due to improved road access. Between April 2012 and April 2015, local areas experienced an increase of population, an improvement of housing materials, and an expansion of local commercial buildings such as restaurants, small businesses, and retail shops. Branch roads from Sindhuli Road to neighboring villages were expanded subsequently. Additionally, household surveys suggest that household income and agricultural production in the region increased along with a decline in poverty rates. These findings provide a motivation for formally assessing Sindhuli Road on local development.

It should be noted that other aid projects were implemented to support regional development near Sindhuli Road. For instance, JICA implemented a project to improve local transportation: bridges were constructed at river-crossing points because flooding during the rainy season often closes rural roads. Another project supported agricultural development in the region by providing agricultural technology and market information on agricultural goods to local farmers. Additionally, the Switzerland and Asian Development Bank supported road construction in the Ramechhap district, the north of Khurkot, during the construction period. After a new bridge was completed in July 2014 to connect the Ramechhap district and Sindhuli Road in Khurkot, traffic flows from Khurkot to Dhulikhel increased. An implication for this study is that my evaluation of Sindhuli Road may account partly for the impacts of other aid projects near Sindhuli Road.

3. Empirical Strategy

This paper estimates the causal effect of mountain roads on local economic development by exploiting the new opening of Sindhuli Road in Nepal. Outcome variables are measured by newly established firms after the completion of road construction in March 2015.[5] Specifically, I estimate the impact of Sindhuli Road on new firms by specifying a model for region i:

$$Y_i = \alpha + \beta Road_i + \boldsymbol{X'}_i\boldsymbol{\gamma} + f_{d(i)} + \varepsilon_i \quad (1)$$

where Y_i is an outcome variable in region i as measured by the number, employment, and sales of establishments that were newly established after construction work on Sindhuli Road was completed in March 2015: new firms were established from April 2015 to June 2018. Employment and sales for new firms are measured at the enumeration time of the Economic Census 2018. $Road_i$ is a dummy variable that takes on unity for local treatment regions along Sindhuli Road, and zero otherwise.[6] $\boldsymbol{X}_i$ is a vector of region-level characteristics that are exogenous from the variable $Road_i$ and can affect the size of new local businesses across regions. While control variables must be predetermined before the opening of Sindhuli Road in March 2015, regional characteristics before 2015 may be partially affected by the construction of Sindhuli Road because construction work in the first section started in 1996. Subsequently, the construction project could have an impact on regional economies such as the population, industrial activities, and other time-varying regional characteristics before March 2015. The inclusion of these regional characteristics as control variables may lead to under- or over-estimate the economic impact of Sindhuli Road because the new construction of mountain roads can also affect local economic environments for new businesses. In this respect, I include only exogenous geographic characteristics such as the area and elevation as control variables. $f_{d(i)}$ is a district-level fixed effect to control for unobserved district-level impacts on new business establishments. Finally, ε_i is an error term.

The coefficient of interest is β for estimating the causal impact of regional exposure to the new opening of Sindhuli Road, which is measured by the difference in new business establishments after March 2015 between treatment and control regions. Because new firms are

[5] For the role of road transport infrastructure in manufacturing location, see Holl (2004).

[6] The economic impact of road infrastructure is estimated based on market access in prior work such as Gibbons et al. (2019), Fiorini and Sanfilippo (2022), and Jedwab and Storeygard (2022). A new approach to estimating the causal impact of market access is developed in Borusyak and Hull (2023); this approach is applied to evaluate the effect of large bridges over the sea in Japan (Konishi and Ono, 2024).

measured in April 2018, I estimate the short-run impact of new mountain roads on local economic development.[7] This specification raises two limitations for estimating the economic impact of mountain roads. First, my analysis does not account for a possible expansion of existing businesses that had been established before March 2015. This suggests that if new mountain roads promote the performance of existing firms, my estimate may underestimate the positive effect of new roads on local businesses. Second, as shown in Table 1, the road construction was completed in some sections before the full opening of Sindhuli Road in March 2015. While new paved roads could benefit local wards in these sections, my specification does not capture the accumulated economic impact of partial road completion. This issue also suggests that my estimate may underestimate the positive effect of new roads on local businesses.[8] I explore this issue in section 5.4.

While my specification controls for potential confounding factors that are captured by geographic characteristics and unobserved factors at the district level, a key identification issue is that the placement of new mountain roads is not random. In this respect, the first plan was proposed in 1962 and specific road routes were fixed in 1986, suggesting that unobserved shocks to local economic activity after 2015 should not induce strongly new investment in Sindhuli Road. My estimates would not be strongly affected by such a reverse causality bias. However, there remain confounding factors in my specification. Specifically, local regions along Sindhuli Road may systematically differ from other regions in economic and social characteristics. For instance, the local treatment regions were previously connected by footpaths, and high transportation costs would constraint economic development in these regions. If the treatment regions exhibit a systematically lower rate of industrial growth in the pre-opening period, a comparison between treatment and control regions can lead to under-estimate the impact of Sindhuli Road because unobserved regional characteristics may correlate with the treatment variable. Thus, unbalanced covariates between treatment and control groups may cause selection bias in estimating the causal impact of Sindhuli Road.

To reduce selection bias, I adopt the PSW regression method by Hirano et al. (2003). Propensity scores are estimated from a first-stage logit regression, and the estimated propensity scores are used to construct weights for the observations in a benchmark model. By assigning a larger weight to control regions with a higher propensity score, the PSW regression helps to reduce selection bias. Specifically, I estimate the first-stage logit model for region i:

$$Pr(T_i = 1) = f(\boldsymbol{Z'}_i\boldsymbol{\delta} + e_i) \quad (2)$$

[7] Prior work such as Ghani et al. (2016) examines the long-term impact of road infrastructure on manufacturing activity in India.

[8] While firm-level panel data during construction periods can shed light on this issue, only cross-section data are available for this study.

where T_i takes on unity if region *i* is exposed directly to the new opening of Sindhuli Road after March 2015, and zero otherwise. $\boldsymbol{Z}_i$ is a vector of pre-treatment covariates at the region-level, including industrial agglomeration, a share of formal firms, a share of foreign firms, a change in built-up area, the built-up area, a change in cropland area, the cropland area, log of ward-level population size, and the number of newly established firms in each year for 2005-2014.[9] Because propensity scores are estimated to reduce confounding factors, I include as many covariates as possible in terms of data availability and their possible influences on firm entry. Meanwhile, I do not include variables related only to the exposure to road completion (e.g., distance from the road) because they do not address confounding factors and can decrease precision (Brookhart et al., 2006; Garrido et al., 2014). All these covariates are based on the data before 2014, and Appendix Table 2 presents the definition and summary statistics of these variables.

A propensity score in equation (2) is estimated by using the CBPS estimator by Imai and Ratkovic (2014). The advantage of the CBPS estimator is that the propensity score is estimated such that the resulting covariate balance between treatment and control groups is optimized along with the optimization of a likelihood function for a propensity-score model. By selecting parameter values to maximize the resulting covariate balance, the CBPS estimator mitigates the effect of the potential misspecification of a parametric propensity-score model.

A propensity score from the estimated model indicates a likelihood that a region is exposed to the new opening of Sindhuli Road given its observed covariate values, $\boldsymbol{Z}_i$. Intuitively, I seek to reduce confounding factors from the treatment effect by making the treatment and control groups comparable in terms of the covariates included in the logit model. If some control regions have a high (low) probability of receiving the treatment but do not receive the treatment, they have a larger (smaller) weight in regression. Specifically, let $\hat{p}$ be the estimated propensity score of region *i*. The weight, ω_i, for PWS regression is given by:

$$\omega_i = \begin{cases} 1 & if\ i \in T \\ \frac{\hat{p}}{1-\hat{p}} & if\ i \in C \end{cases} \tag{3}$$

where a unit weight is assigned to the treatment region $i \in T$. A weight, $\hat{p}/(1-\hat{p})$, is assigned to the control region $i \in C$, suggesting that a larger weight is assigned to the control regions with a higher propensity score because these regions are more similar to the treatment regions in terms of the observed covariates. Using the weights for each observation in the estimation of equation (1), I estimate the average treatment effect on the treated.

It is in order to discuss some issues in my estimation. First, as compared to other matching estimators, the PWS regression is flexible in accounting for heterogeneous treatment effects in a regression framework. This is a crucial advantage for this study because each section in Sindhuli

[9] For determinants of firm entry, see Klapper et al. (2006), Bruno et al. (2013), and Dong (2020).

Road opened in different periods and the final opening may affect each section differently. These heterogeneous effects can be examined in the PWS regression. Second, the PSW helps to make the treatment assignment independent of observable covariates because selection bias is mitigated in terms of the observed covariates, $\boldsymbol{Z}_i$. However, I cannot rule out selection bias arising from other unobserved factors that make treatment and control regions unbalanced and affect new business establishments after 2015.

The propensity-score method has the stable unit treatment value assumption in that the outcome in one region should be unaffected by the treatment status in other regions. In my context, there may be positive spatial spillovers between the treatment regions and their neighboring control regions for the subsequent expansion of branch roads along Sindhuli Road. If the construction of Sindhuli Road could affect the outcome in the neighboring control regions, it is difficult to estimate the causal impact of Sindhuli Road. Meanwhile, it is also challenging to address this issue because spatial spillovers are not observable. To mitigate the influence of interference across the treatment and control regions, I assume that the spatial spillovers are localized in neighboring ward-level regions. Thus, the sample used in estimation excludes control wards in the same municipality that has the treatment wards.[10]

4. Data Description

4.1. New Business Establishments

A quantitative assessment of roads needs economic data on a wide range of industries, and firm-level panel data are used in the related literature (e.g., Li and Li, 2013; Shiferaw et al., 2015; Holl, 2016; Gibbons et al., 2019; Branco et al., 2023). Although firm-level panel data are not available in Nepal, I use a new comprehensive dataset on establishment activities.[11]

Nepalese Economic Census 2018. The main dataset on outcome variables comes from the Nepalese Economic Census 2018 (NEC) by the Central Bureau of Statistics (CBS) under the National Planning Commission of Nepal. The census project was mainly funded by Japan's ODA and implemented by the CBS. The NEC aims to collect economic information on all nonfarm establishments and enterprises over the entire territory of Nepal. The establishment is defined as an economic unit that engages in economic activity at a single physical location under a single legal entity. The administrative geographic units include 6,734 wards in 753 local units (municipalities) under 77 districts of 7 provinces.[12] The census enumeration was conducted

[10] 91 wards are dropped from the sample.

[11] Industrial statistics were collected in the National Census of Manufacturing Establishments and the Survey of Small Manufacturing Establishments in the past. However, these surveys cover only registered establishments in manufacturing industries.

[12] Local units include 6 metropolitan cities (maha-nagarpalika), 11 sub-metropolitan cities (upa-maha

between April 14 and June 14 in 2018 to survey all the establishments and enterprises, including street business establishments that operate at a fixed location but can move.[13] The survey method was based on the Internet, face-to-face interviews, and direct mailing from CBS to major enterprises. The NEC reports a total of 923,356 establishments with 3.2 million people engaged. The survey asks individual establishments about registration with any government agency, and the answer to this question is used to define the formal (registered) and informal (unregistered) sectors. In my sample, there are 462,605 formal and 460,422 informal establishments. Thus, the NEC provides a unique dataset to measure entire economic activities in Nepal with precision.

Microdata in the NEC are used to construct data on newly established firms before and after the opening of Sindhuli Road. Specifically, newly established firms are defined as establishments that started business from April 2015 to June 2018. Based on this definition, the total number of new firms is 419,967 and the total number of persons engaged in these firms is 995,147. These firms are aggregated over wards to define a regional measure of new business establishments. Given the substantial size of the informal sector in Nepal, I construct the outcome variables for all, registered, and unregistered firms, respectively. Table 2 presents the summary statistics of outcome variables for the 54 treatment and other control regions. All outcome variables show a larger mean value for treatment than control regions, suggesting that the treatment wards along Sindhuli Road experienced larger new businesses.

---Table 2 here---

4.2. Other Regional Data

A unit of analysis is defined at the ward-level administrative boundaries for 2018 in Nepal. Geographic information on ward boundaries is provided by the Ministry of Federal Affairs and Local Development in Nepal. Geographic information is used to compute the area of each ward and the geographic distance between wards. Data on population come from the National Population and Housing Census 2011 by the Central Bureau of Statistics, Nepal. Since the population size is measured at the municipality level, I calculate ward-level population size by dividing municipality-level population by the area share of wards in the corresponding municipality.

The average elevation at the ward level is calculated by using the high-resolution digital topographic database of the Earth in the Shuttle Radar Topography Mission, which is an international project by the National Geospatial-Intelligence Agency and the National

nagarpalika), 276 municipalities (nagarpalika), and 460 rural municipalities (gaunpalika).

[13] The survey does not cover the establishments classified into (1) agriculture, forestry, and fishing, (2) public administration and defense, (3) activities of households as employers, (4) activities of extraterritorial organization and bodies, and (5) mobile establishments such as a bike taxi and a street peddler.

Aeronautics and Space Administration. Cropland and built-up areas are computed by using the land cover data of Nepal by the National Land Cover Monitoring System for Nepal. Land cover maps on an annual basis are generated by using remote sensing data in Landsat and a cloud-based machine learning architecture in the Google Earth Engine platform. The type of land cover is classified into waterbody, glacier, snow, forest, riverbed, built-up area, cropland, bare soil, bare rock, grassland, and other wooded land. By matching each grid with the ward-level geographic boundaries, I compute cropland and built-up area in each ward.

5. Estimation Results

5.1. Baseline Results

Table 3 shows the PSW results of equation (1), with the column headers indicating a dependent variable used in estimation. I report standard errors clustered by municipality.[14] In column (1), the dependent variable is the log of the number of newly established firms. The coefficient of Sindhuli Road is significant and positive, suggesting that the opening of Sindhuli Road increased the number of new firms in local treatment wards by 108%.[15] In columns (2) and (3), the coefficients are significant and positive for the number of new formal and informal firms, respectively. The coefficient is similar in magnitude between formal and informal firms, suggesting that Sindhuli Road promoted new business establishments in both formal and informal sectors. These results are in contrast with the prior evidence: Ghani et al. (2013) find that highway roads in India had limited effects on the informal sector as compared to the formal sector, and Gertler et al. (2024) find that road maintenance induces employment from the informal to the formal sector in Indonesia. Compared with prior work, my analysis is based on a comprehensive survey of formal and informal establishments in Nepal, which allows for the precise estimation of road impacts on informal firms.

---Table 3 here---

In columns (4), (5), and (6), the dependent variable is the log of the total number of workers for all, formal, and informal firms, respectively. In column (4), the coefficient is significant and positive, suggesting that Sindhuli Road increased employment for new firms in the local treatment wards by 132%. In columns (5) and (6), the coefficients are significant and positive for both formal and informal employment, with a larger impact on formal employment than on informal employment. In columns (7), (8), and (9), the dependent variable is the log of average monthly sales for all, formal, and informal firms, respectively. Column (7) shows that the coefficient is significant and positive, implying that Sindhuli Road increased the sales for new firms in the local treatment wards by 232%. The coefficients are significant and positive for both formal and

[14] The main results are quantitatively similar for clustering by district.
[15] The marginal effect is computed from $100 \cdot (exp(0.73) - 1)$.

informal sales, with a larger impact on formal sales than on informal sales. Taken together, the new opening of Sindhuli Road contributed significantly to the stronger growth of new firms in the local treatment wards.

Table 4 shows several robustness checks of the main results. First, I define dependent variables in level to mitigate a possible influence of sample selection bias; logging the outcome variable removes some wards with zero values.[16] The results in Panel A show that the coefficient of Sindhuli Road is significant and positive for all the dependent variables in columns (1) to (9). Thus, the main results are robust to the specification for outcome variables in level. Second, possible spatial spillovers across regions can violate the non-interference assumption, as discussed in section 3. To further address this issue, I exclude a group of control wards within 15 kilometers from Dhulikhel, Khurkot, or Bardibas. Panel B shows that the results are unchanged. I also set the threshold distance for 30 kilometers in Panel C and find the similar results. The estimated coefficients in these results are generally larger in size, consistent with the interpretation that positive spillovers can be stronger in neighboring regions and including these regions in a control group may underestimate the average treatment effect on the treated regions. Additionally, spatial spillovers may be more pronounced around neighboring regions at the end of Sindhuli Road. In this respect, I exclude neighboring districts to Dhulikhel, the north end: Kathmandu, Bhaktapur, and Lalitpur. Panel D shows that the results remain unchanged. Finally, I exclude neighboring districts to Bardibas, the south end: Siraha and Sarlahi. Panel E shows that the results are unchanged. Taken together, the main results are robust to alternative control groups in the sample.

---Table 4 here---

5.2. Heterogeneous Impacts by Region and Industry

While the previous analysis has focused on the aggregate impact of Sindhuli Road, the results may mask heterogeneous treatment effects, suggesting that the impacts may be heterogeneous across construction sections. This question is crucial because the construction periods differ by section, as summarized in Table 1. To investigate this issue, I decompose the dummy variable of Sindhuli Road into four sections: the treatment dummy variables take on unity for corresponding wards in each section and zero otherwise.

Table 5 shows the PSW results of equation (1) with the treatment variables for each section. The coefficient of Sindhuli Road is significant and positive for all outcomes in the local wards between Bardibas and Sindhuli Bazar. It is also significant and positive in the local wards between Sindhuli Bazar and Khurkot for most outcomes. The opening of Sindhuli Road contributed

[16] For an issue of log transformation, see Chen and Roth (2023).

significantly to the growth of new business establishments along the local wards in these sections. Meanwhile, the coefficient of Sindhuli Road is significant and positive only for some outcomes such as informal employment in the local wards between Nepalthok and Dhulikhel, suggesting that this section may benefit weakly from Sindhuli Road. By contrast, the coefficient of Sindhuli Road is significant and negative in the local wards between Khurkot and Nepalthok. Because this section is likely to be a stopover point in the middle of Sindhuli Road, the result may suggest a hollowing-out effect in that new transportation infrastructure in mountain areas leads to the reallocation of economic activity in economically hub regions such as Bardibas and Sindhuli Bazar. Taken together, the impacts of Sindhuli Road on new businesses are significantly heterogeneous across the construction sections, with the most significant impacts on the South regions of Sindhuli Road.

---Table 5 here---

A related question is whether Sindhuli Road produces heterogeneous impacts across industries. In this respect, I estimate equation (1) separately for each industry at the 1 digit-level. On examination, the number of observations for newly established firms is significantly small for various industries, and I focus on industries including manufacturing, wholesale and retail, accommodation and food services, and other services. The results of Table 6 show for these industries show that the coefficient of Sindhuli Road is generally significant and positive for alternative outcomes in each industry. Because unreported estimation shows little effects for other industries, the positive aggregate impact of Sindhuli Road should be mainly driven by newly established firms in these industries. Among these industries, the coefficient of Sindhuli Road is relatively larger for alternative outcomes in accommodation and food services.[17] For instance, Sindhuli Road increased the number of new firms for the industry by 180%. This finding is sensible in that new paved roads in mountain areas should promote traffic flows substantially and generate a strong demand for accommodation and food services in the local wards.

---Table 6 here---

5.3. Heterogeneous Impacts by Gender

By reviewing a growing literature on the economic impact of transportation infrastructure, Raitzer et al. (2019) suggest the limited evidence on businesses and gender equality.[18] To fill this

[17] Gibbons et al. (2019) find the positive impact of road infrastructure on firms in producer services for the U.K., whereas Ghani et al. (2016) show the positive road effect on industries that are intensive in the use of land and building.

[18] For instance, Khandker et al. (2009) examine the impact of rural roads on male and female labor supply, whereas Wiegand et al. (2017) examine the effect of road development on poverty status by male and female head households. Fiorini and Sanfilippo (2022) estimate gender-specific impacts of road improvements in Ethiopia.

gap, I estimate the impact of Sindhuli Road on gender-related business establishments: the number of newly established firms with male (female) managers and the number of male (female) workers in new firms. Table 7 reports the results of the PSW estimation for gendered outcomes across industries. In Panel A for the aggregate industry, the coefficient of Sindhuli Road is significant and positive for both male and female outcomes. Specifically, the opening of Sindhuli Road increased the number of new firms with male and female managers by 65% and 161%, respectively. Meanwhile, Sindhuli Road increased male and female employment in newly established firms by 116% and 166%, respectively. These results suggest the larger aggregate benefits for female than male managers/workers.

---Table 7 here---

I also estimate the PSW regression for the gendered outcomes across industries. In Panel B for manufacturing, the coefficient is significant and positive for male-managed firms but is not significant for female-managed firms. In Panel C for wholesale and retail, the coefficient is significant and positive for female-managed firms but is not significant for male-managed firms. The impact of Sindhuli Road on this outcome differs by gender for these industries. In Panel D for accommodation and food services, the coefficient is significant and positive for both male- and female-managed firms. Meanwhile, Panel E for other services shows insignificant coefficients for both male- and female-managed firms. Additionally, the coefficient is significant and positive for both male and female employment in manufacturing, wholesale and retail, and accommodation and food services, suggesting that Sindhuli Road produces the similar employment effects by gender. However, the coefficient is significant and positive only for male employment in other services.

5.4. Further Issues

This section discusses further issues. First, the nonrandom placement of Sindhuli Road is a source of bias for causal inference, but the previous results do not reveal the direction of the bias. To this end, I estimate all the specifications by OLS and PSW methods and compare these estimates of the coefficient of Sindhuli Road. Assuming that selection bias in the OLS estimates is reduced by the PSW method, I compute the ratio of the OLS estimates to the PSW estimates: $|\hat{\beta}_{OLS}|/|\hat{\beta}_{PSW}|$. Appendix Figure 1 shows a histogram of the ratio for 128 specifications and suggests that the OLS estimates are smaller in size than the PSW estimates, with the mean value of 0.697. A possible interpretation is that confounding factors would cause a downward bias in the OLS estimates by about 30%. Thus, it is crucial to reduce selection bias for causal inference.

Second, while neighboring wards adjacent to local treatment wards are excluded for possible spatial spillovers, I assess whether Sindhuli Road promotes firm entry in the neighboring wards. Specifically, I exclude local treatment wards from the sample and define $Road_i$ as a dummy variable that takes on unity for the neighboring wards, and zero otherwise. I estimate a logit model with the new treatment variable to compute new propensity scores and estimate equation (1). The results in Appendix Table 4 show that the coefficient of neighboring wards is not significant across alternative outcomes. Thus, the new opening of the road would not promote new businesses in the neighborhood of Sindhuli Road.

Finally, the accumulated impact of partial road completion is not considered previously because this investigation needs firm-level panel data and my census data in 2018 may not adequately capture firm entries in earlier years. However, there remains a question of whether firm entries were induced before road completion. To this end, I extend my framework to analyze the number of formal and informal firms established in 2014, 2013, or 2012 as a proxy for past entries. In estimating a propensity score, I lagged covariates by 3 years, including industrial agglomeration, formal share, foreign share, built-up and cropland areas, and firm entry (i.e., 2005-2011). The results in Appendix Table 5 show that the coefficient of Sindhuli Road is not significant for firm entries in 2014, but significant and positive in 2013 and 2012. While the coefficients are significant and positive for formal firms in these years, they are significant and positive for informal firms only in 2012. Thus, there is some evidence of preemptive entry before road completion.

6. The Role of Transport Costs

My discussions up to this point have highlighted the significant contribution of Sindhuli Road to the growth of new business establishments in local treatment wards. Compared with the previous literature, my treatment effects are relatively large in magnitude. For instance, Fiorini and Sanfillippo (2022) find no impact of road improvements on employment in Ethiopia, whereas Gibbons et al. (2019) find a 0.4% increase in employment within 20 kilometers from new road infrastructure in the U.K. Holl (2004) finds a 14% increase of manufacturing establishments within 10 kilometers from a motorway in Spain. In the case of India, Asher and Novosad (2020) estimate a 27% increase in employment for nonfarm firms from new rural roads, while Ghani et al. (2016) find a 26% increase in manufacturing employment within 10 kilometers from the Golden Quadrilateral highway. By contrast, I estimate a 132% increase in employment for new firms in Table 3. While my estimates are not strictly comparable for methodological differences, it raises a question of what factors can explain the sizable impacts in my study.

A key feature of my analysis is that the new opening of Sindhuli Road would induce a modal shift from porters and pack animals to vehicles such as trucks and buses for transportation along mountain roads.[19] Because such a modal shift is associated with a large decline in transportation

[19] Although the modal shift was not directly observed, the emergence of transportation by vehicle should promote local services for vehicle repair along the roads. Appendix Figure 2 shows that this

costs and time, it is likely to yield sizable economic impacts.[20] Meanwhile, prior work typically examines the economic impacts resulting from highway construction and an improvement of road quality and networks (Raitzer et al., 2019). While these infrastructure investments are associated with an increase in transport speed and an improvement in market access, a decline in transportation costs and time should be more modest compared with the new opening of mountain roads. Thus, a large change in transport costs and time along Sindhuli Road is a plausible explanation for the sizable impact of road completion.

To support the transport-cost explanation, a simple approach is to compare a change in transport modes and costs along Sindhuli Road before and after the new opening. However, there is little systematic empirical data on transport costs by mode: for instance, transport costs by porter and pack animal in a pre-opening period are a key baseline, but not systematically surveyed. To infer the magnitude of transportation cost savings from a modal shift, I examine a difference in transport prices between transportation means by human and vehicle. Specifically, I assume that transport prices depend on fixed costs and variable costs of transport distance between origin and destination regions. For origin *r* and destination *s*, a transport price per kilogram for transport mode, $m \in \{Porter, Truck\}$, is specified:

$$p_{rs}^{m} = f_m + \beta_m d_{rs} \tag{4}$$

where f_m is a parameter of fixed costs to transport a good by mode *m*; d_{rs} is the geographic distance of transportation, with β_m indicating the relationship between transport prices and distance (Louveaux et al., 1982).[21] Equation (4) shows that the difference in transport prices between transportation by porter and vehicle is determined by the parameters of fixed costs and transport distance. To estimate these parameters, I specify the following model for each transport mode:

$$p_{rs}^{m} = f_m + \beta_m d_{rs} + \varepsilon_{rs} \tag{5}$$

where ε_{rs} is an error term.

For estimation, I surveyed transport prices by porter and pack animal along the Everest trekking route from the origin of Lukla in March 2023 and along the Langtang Valley from the origin of Shyabru Bensi in February 2024. Data on transport by vehicle come from public transportation fares over inter-provincial routes reported by the Nepalese Department of Transportation Management in 2023. Information on delivery charges for one kilogram or one

predicted change at the extensive margin is consistent with a sharp increase in the number of firms for vehicle repair services in local treatment wards along Sindhuli Road from 2015.

[20] The geographic location of Sindhuli Road connecting Kathmandu and India is also a crucial source of the large impacts.

[21] For simplicity, I do not consider other determinants such as long-haul economies, economies of transport densities, and directional imbalance of transport flows (Caves et al., 1984; Tanaka and Tsubota, 2017).

unit package is collected from a private transport firm: the Garuda Express in Kathmandu. Table 8 shows the estimation results of equation (5) for each transport mode. The coefficients, f_m and β_m, are significant and positive for all these modes, suggesting the presence of fixed costs and the positive relationship between transport prices and distance for each transport mode.

---Table 8 here---

To compare transport prices by mode, Figure 2 shows the fitted values of the linear regression models by mode in Table 8. It is evident that transport prices by porter are systematically larger than those by truck. For instance, the predicted transport price per kilogram is 204 and 24.7 Nepalese rupees (NPR) for a transport distance of 100 kilometers by porter and truck, respectively, suggesting that porter transport prices are 8.3 times higher than truck. Such a large difference is partly due to scale economies in truck transportation. To mitigate this influence, I also illustrate small shipping fees by a private delivery firm. Delivery transport prices are higher than porter within a transport distance of 80 kilometers because the former has larger fixed costs. Meanwhile, porter transport prices exceed the delivery for more than 80 kilometers, with the price difference increasing rapidly with distance. Thus, a modal shift from porter to truck should reduce transport costs significantly along Sindhuli Road.

---Figure 2 here---

Bus transportation is another modal shift along mountain footpaths and facilitates passenger transportation in mountain regions. To compare travel costs for passengers, I assume that walking for an hour has an opportunity cost of hourly labor income, which is equivalent to the hourly minimum wage of 56 NPR in 2023. Given that walking speed is 5 kilometers per hour, travel costs by walk are a linear function of travel distance in kilometers with a positive slope of 11.2(=56/5). Meanwhile, travel costs can be predicted from the regression model for bus fares in column (4) of Table 8. The predicted travel costs are shown for these modes in Appendix Figure 3. For instance, the travel costs for a travel distance of 100 kilometers are 1,120 NPR for walking and 336 NPR for bus, respectively. Walking travel costs are 3.3 times higher than those by bus, with the cost differences increasing rapidly with distance. Thus, a modal shift from walking to taking the bus should decrease travel costs substantially.

7. Conclusion

This paper assesses the economic impact of mountain roads by estimating the causal effect of Sindhuli Road on new business establishments in Nepal: new paved roads built on previously mountain trails with elevations between 200 and 1500 meters and traversing 160 kilometers. I find that the new opening of Sindhuli Road increased new establishment entry in the formal and informal sectors along the road. The estimated impacts of road completion are heterogeneous across construction sections, industries, and genders. The large positive impact on establishment entry in accommodation and food services is consistent with anecdotal evidence on a subsequent increase in traffic flows along the road.

As compared with the previous estimates on road impacts, my estimates are substantially large and suggest a sizable decline in transportation costs resulting from road completion. From a long-run perspective, new paved roads in mountain areas should cause a modal shift from porters and pack animals to transportation by vehicle, which should reduce transportation costs and time substantially. To infer the size of transportation cost savings from the modal shift, I surveyed transport prices by porter and pack animal along mountain trekking routes in Nepal and show that porter transport prices are strikingly larger than prices for transport by truck. This finding suggests that returns to investment in road infrastructure can be large in mountainous countries such as Nepal, with a significant barrier of high transportation costs to economic activity (Jacoby, 2000; Charlery et al., 2016; Shrestha, 2020).

I conclude by discussing some implications. The construction of Sindhuli Road is supported financially by Japan's ODA and my analysis demonstrates the positive impact of foreign aid in infrastructure on local business creation (Hudson, 2004; Tanaka and Tsubota, 2013; Nishitateno, 2024). Formal evidence on local benefits of road infrastructure provides an economic justification for large-scale foreign aid on infrastructure construction. However, a cost-benefit analysis of the construction project is not conducted, and further research is needed to examine the extent to which the construction project is a cost-effective instrument for welfare (Jacoby, 2000; Gertler et al., 2024). Meanwhile, building road infrastructure in mountainous areas can cause adverse environmental impacts such as deforestation, ecological destruction, and soil erosion. Road construction in mountains should account for both economic benefits and environmental impacts.

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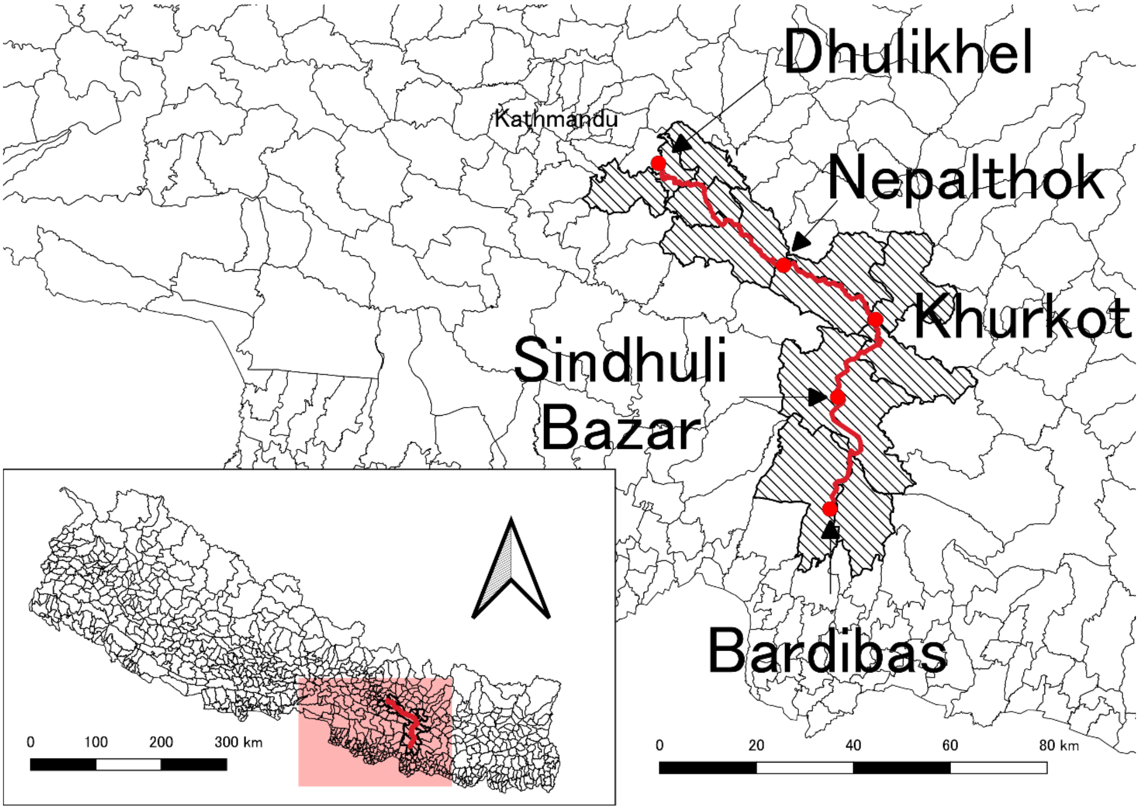
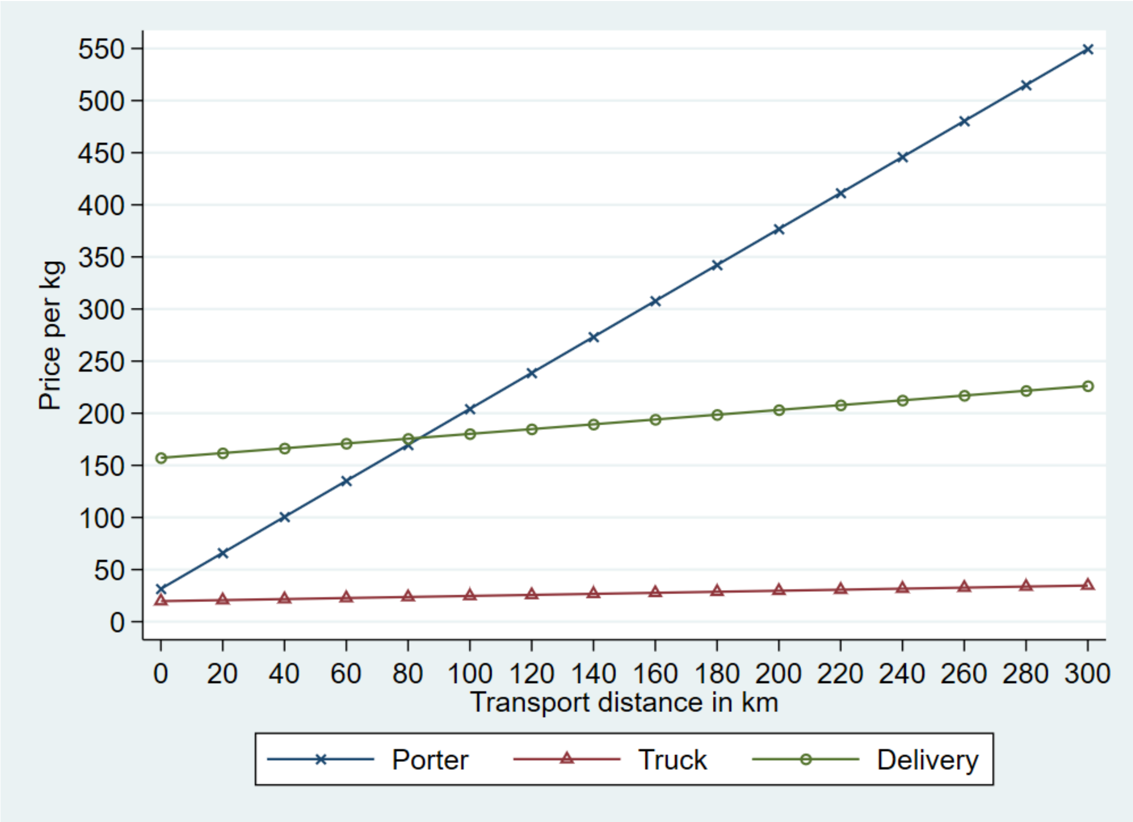
Figure 1. The Map of Sindhuli Road



Notes: The map shows the administrative boundaries of local municipalities. The shaded area along Sindhuli Road indicates local municipalities with treatment wards.

Source: Author's construction using the GIS data from the Nepalese Survey Department.

Figure 2. Transport price and distance by mode



Notes: The figure shows the fitted values of the linear regression models in Table 8. The vertical axis is a transport price per kilogram in Nepalese rupees. The horizontal axis is transport distance in kilometers. Porter shows transport prices by porter and pack animal along the Langtang Valley (from Shyabru Bensi) and Everest trekking route (from Lukla). Truck shows public transportation fares in inter-provincial routes reported by the Department of Transportation Management in 2023. Delivery shows the delivery charges for 1 kilogram or one unit package by the Garuda Express located in Kathmandu.

Table 1. A Summary of Sindhuli Road

Section	Location		Construction Period		Distance
	Origin	Destination	Start	End	
1	Bardibas	Sindhuli Bazar	1996	1998	37 km
2	Sindhuli Bazar	Khurkot	2001	2009	36 km
3	Khurkot	Nepalthok	2008	2015	37 km
4	Nepalthok	Dhulikhel	1998	2002	50 km

Source: Kamei (2016).

Table 2. Summary statistics of outcome variables

Variable	Treatment N	Treatment Mean	Treatment Std. dev.	Control N	Control Mean	Control Std. dev.
ln(no. of firms)	54	3.61	0.97	6,539	3.42	1.13
ln(no. of formal firms)	53	2.31	1.34	6,123	2.22	1.31
ln(no. of informal firms)	54	3.19	0.91	6,508	3.04	1.09
ln(employment)	54	4.59	1.00	6,539	4.11	1.24
ln(formal employment)	53	3.73	1.41	6,123	3.19	1.52
ln(informal employment)	54	3.81	0.89	6,508	3.54	1.13
ln(sales)	54	0.74	1.31	6,533	-0.10	1.57
ln(formal sales)	52	0.10	1.84	6,037	-0.70	1.91
ln(informal sales)	54	-0.30	1.24	6,506	-0.91	1.43

Notes: Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in millions of Nepal rupees from both operating and non-operating activities for all, registered, and unregistered firms that were established during the period.

Source: Nepalese Economic Census 2018.

Table 3. Propensity-score weighting estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent	Firms	Formal firms	Informal firms	Employment	Formal employment	Informal employment	Sales	Formal sales	Informal sales
Sindhuli Road	0.73***	0.71**	0.70***	0.84***	0.95***	0.70***	1.20***	1.25***	0.96***
	(0.26)	(0.34)	(0.24)	(0.22)	(0.29)	(0.19)	(0.27)	(0.29)	(0.28)
Ln(Area)	-0.25***	-0.51***	-0.16**	-0.29***	-0.50***	-0.17***	-0.41***	-0.65***	-0.27***
	(0.060)	(0.095)	(0.064)	(0.056)	(0.087)	(0.057)	(0.082)	(0.14)	(0.084)
Ln(Elevation)	-0.43*	-0.34	-0.47*	-0.39*	-0.32	-0.39*	-0.32	-0.29	-0.39
	(0.26)	(0.30)	(0.26)	(0.21)	(0.22)	(0.23)	(0.25)	(0.24)	(0.31)
District fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of observations	6,593	6,176	6,562	6,593	6,176	6,562	6,587	6,089	6,560
R-squared	0.38	0.31	0.39	0.40	0.32	0.37	0.39	0.30	0.37

Notes: Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in both operating and non-operating activities for all, registered, and unregistered firms that were established during the period. Parentheses show standard errors clustered by municipality. Constant is not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent	Firms	Formal firms	Informal firms	Employment	Formal employment	Informal employment	Sales	Formal sales	Informal sales
Panel A: dependent variables in level									
Sindhuli Road	60.7***	27.8***	32.8***	159.0***	106.4***	52.6***	4.45***	4.11***	1.19***
	(20.4)	(10.2)	(10.4)	(43.6)	(29.4)	(14.9)	(1.03)	(1.00)	(0.31)
Panel B: excluding control wards within 15 kilometers from Dhulikhel, Khurkot, or Bardibas									
Sindhuli Road	0.87***	0.90***	0.81***	0.98***	1.17***	0.78***	1.41***	1.49***	1.13***
	(0.26)	(0.33)	(0.24)	(0.22)	(0.28)	(0.19)	(0.26)	(0.28)	(0.28)
Panel C: excluding control wards within 30 kilometers from Dhulikhel, Khurkot, or Bardibas									
Sindhuli Road	0.94***	1.08**	0.89***	1.06***	1.33***	0.82***	1.55***	1.58***	1.27***
	(0.36)	(0.47)	(0.32)	(0.31)	(0.41)	(0.27)	(0.35)	(0.38)	(0.34)
Panel D: excluding neighboring districts in Dhulikhel (Kathmandu, Bhaktapur, and Lalitpur)									
Sindhuli Road	0.72***	0.70**	0.69***	0.83***	0.95***	0.69***	1.20***	1.24***	0.96***
	(0.26)	(0.34)	(0.24)	(0.22)	(0.29)	(0.19)	(0.27)	(0.29)	(0.28)
Panel E: excluding neighboring districts in Bardibas (Siraha and Sarlahi)									
Sindhuli Road	0.75***	0.72**	0.71***	0.86***	0.97***	0.71***	1.22***	1.27***	0.98***
	(0.26)	(0.34)	(0.24)	(0.22)	(0.29)	(0.19)	(0.27)	(0.29)	(0.29)

Notes: Propensity-score weighting estimation is used. Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in both operating and non-operating activities for all, registered, and unregistered firms that were established during the period. Parentheses show standard errors clustered by municipality. Constant and control variables are not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Heterogeneous effects by section

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent	Firms	Formal firms	Informal firms	Employment	Formal employment	Informal employment	Sales	Formal sales	Informal sales
Bardibas to Sindhuli Bazar	1.28***	1.43***	1.21***	1.31***	1.59***	1.07***	1.81***	1.85***	1.54***
	(0.23)	(0.31)	(0.21)	(0.21)	(0.29)	(0.19)	(0.26)	(0.30)	(0.24)
Sindhuli Bazar to Khurkot	0.61*	0.52	0.67**	0.79***	1.02***	0.65**	1.32***	1.33***	1.15***
	(0.33)	(0.39)	(0.31)	(0.29)	(0.34)	(0.28)	(0.35)	(0.35)	(0.41)
Khurkot to Nepalthok	-0.84***	-1.14***	-0.78***	-0.59***	-0.75***	-0.44*	-0.70***	-0.34***	-0.80
	(0.099)	(0.31)	(0.27)	(0.091)	(0.15)	(0.23)	(0.14)	(0.11)	(0.70)
Nepalthok to Dhulikhel	0.50*	0.28	0.44	0.67*	0.49	0.58**	0.99*	0.75	0.67
	(0.29)	(0.38)	(0.27)	(0.39)	(0.48)	(0.28)	(0.56)	(0.74)	(0.41)
Control	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of observations	6,593	6,176	6,562	6,593	6,176	6,562	6,587	6,089	6,560
R-squared	0.42	0.34	0.42	0.41	0.33	0.39	0.40	0.31	0.38

Notes: The propensity-score weighting estimation is used. Control includes the log of area, the log of the average elevation, and district-level fixed effects. Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in both operating and non-operating activities for all, registered, and unregistered firms that were established during the period. Parentheses show standard errors clustered by municipality. Constant is not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Heterogeneous effects by industry

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent	Firms	Formal firms	Informal firms	Employment	Formal employment	Informal employment	Sales	Formal sales	Informal sales
Panel A: manufacturing									
Sindhuli Road	0.42	0.63**	0.31	0.54*	0.95***	0.31	0.69*	0.97*	0.41
	(0.27)	(0.25)	(0.25)	(0.31)	(0.33)	(0.20)	(0.41)	(0.51)	(0.33)
Panel B: wholesale and retail									
Sindhuli Road	0.66**	0.51	0.64**	0.68**	0.43	0.62***	0.98***	0.86**	0.91***
	(0.30)	(0.44)	(0.26)	(0.27)	(0.42)	(0.22)	(0.36)	(0.43)	(0.31)
Panel C: accommodation and food services									
Sindhuli Road	1.03***	0.21	1.06***	1.27***	0.65**	1.18***	1.72***	0.85**	1.27***
	(0.27)	(0.30)	(0.20)	(0.26)	(0.32)	(0.18)	(0.28)	(0.36)	(0.22)
Panel D: other services									
Sindhuli Road	0.47***	0.074	0.59***	0.86***	0.74***	0.47**	1.11***	0.84***	0.85***
	(0.18)	(0.10)	(0.18)	(0.22)	(0.19)	(0.18)	(0.21)	(0.23)	(0.25)

Notes: Propensity-score weighting estimation is used. Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in both operating and non-operating activities for all, registered, and unregistered firms that were established during the period. Parentheses show standard errors clustered by municipality. Constant and control variables are not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Heterogeneous effects by gender

Dependent	(1) Male-managed firms	(2) Female-managed firms	(3) Male employment	(4) Female employment
Panel A: All industries				
Sindhuli Road	0.50**	0.96**	0.77***	0.98***
	(0.20)	(0.40)	(0.20)	(0.28)
Panel B: manufacturing				
Sindhuli Road	0.49**	0.54	0.66**	0.69**
	(0.23)	(0.36)	(0.27)	(0.32)
Panel C: wholesale and retail				
Sindhuli Road	0.31	0.85**	0.52**	0.81**
	(0.24)	(0.42)	(0.24)	(0.34)
Panel D: accommodation and food services				
Sindhuli Road	0.78***	0.92***	1.19***	1.08***
	(0.22)	(0.24)	(0.25)	(0.28)
Panel E: other services				
Sindhuli Road	0.21	0.084	0.60***	0.21
	(0.16)	(0.11)	(0.17)	(0.20)

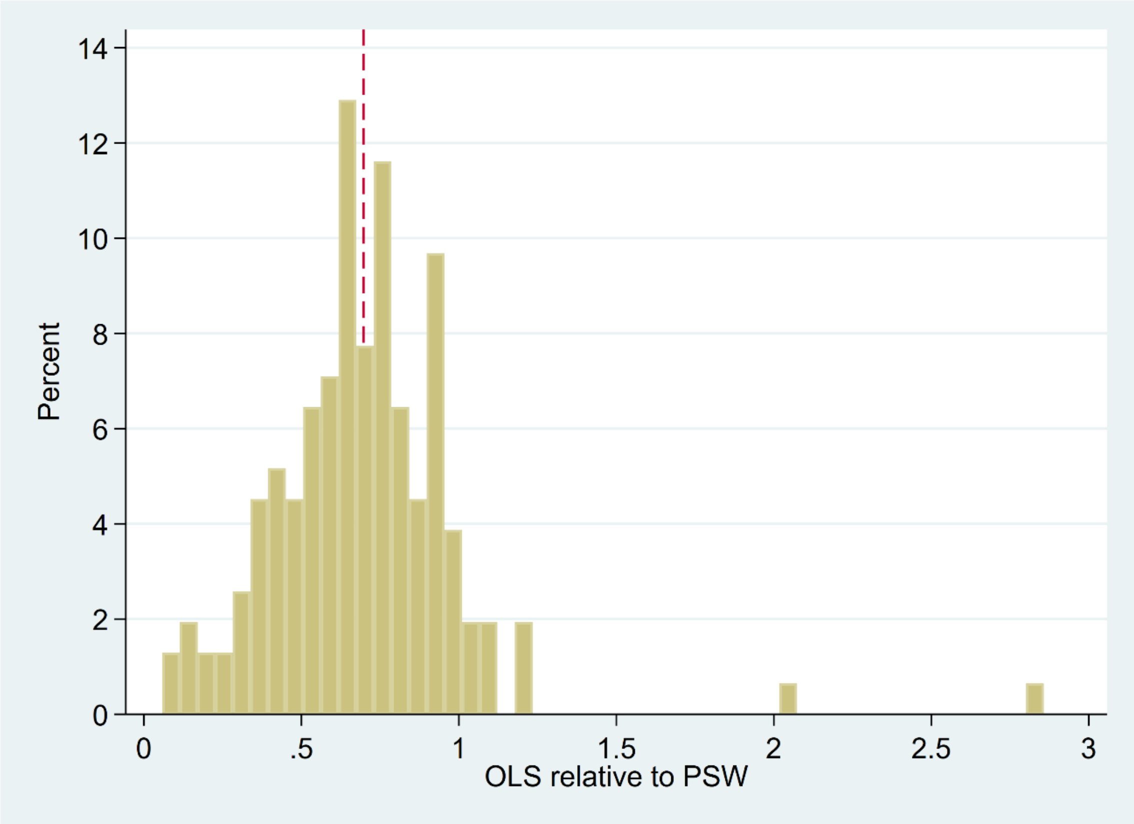
Notes: Propensity-score weighting estimation is used with the control variables on ward-level area and elevation and district-level fixed effects. Male (female) managed firms are the log of the number of firms that were established from April 2015 to April 2018 with male (female) managers. Male (female) employment is the log of the total number of male (female) workers in all firms that were established during the period. Parentheses show standard errors clustered by municipality. Constant and control variables are not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Estimation results of transport price and distance by mode

	(1)	(2)	(3)	(4)
Mode	Porter	Truck	Delivery	Bus
Dependent	price per kg	price per kg	price per kg	fare
Constant	31.5***	19.7***	157.2***	62.6***
	(4.01)	(2.34)	(2.52)	(12.8)
Distance	1.73***	0.050***	0.23***	2.73***
	(0.36)	(0.0040)	(0.0082)	(0.032)
No. of observations	30	47	481	280
R-squared	0.49	0.58	0.58	0.97
Mean of transport price	50	41	197	1,166
Mean of transport distance	10.5	428.7	175.2	403.3

Notes: Price is measured in Nepalese rupees. Distance is transport distance in kilometers. Porter shows transport prices by porter and pack animal along the Langtang Valley (from Shyabru Bensi) and Everest trekking route (from Lukla), which were surveyed by the author in February 2024 and March 2023, respectively. Truck and Bus show public transportation fares in inter-provincial routes reported by the Department of Transportation Management in 2023. Delivery shows the delivery charges for 1 kilogram or one unit package by the Garuda Express located in Kathmandu, for which Google Map is used to compute transport distance for each route. Robust standard errors are reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

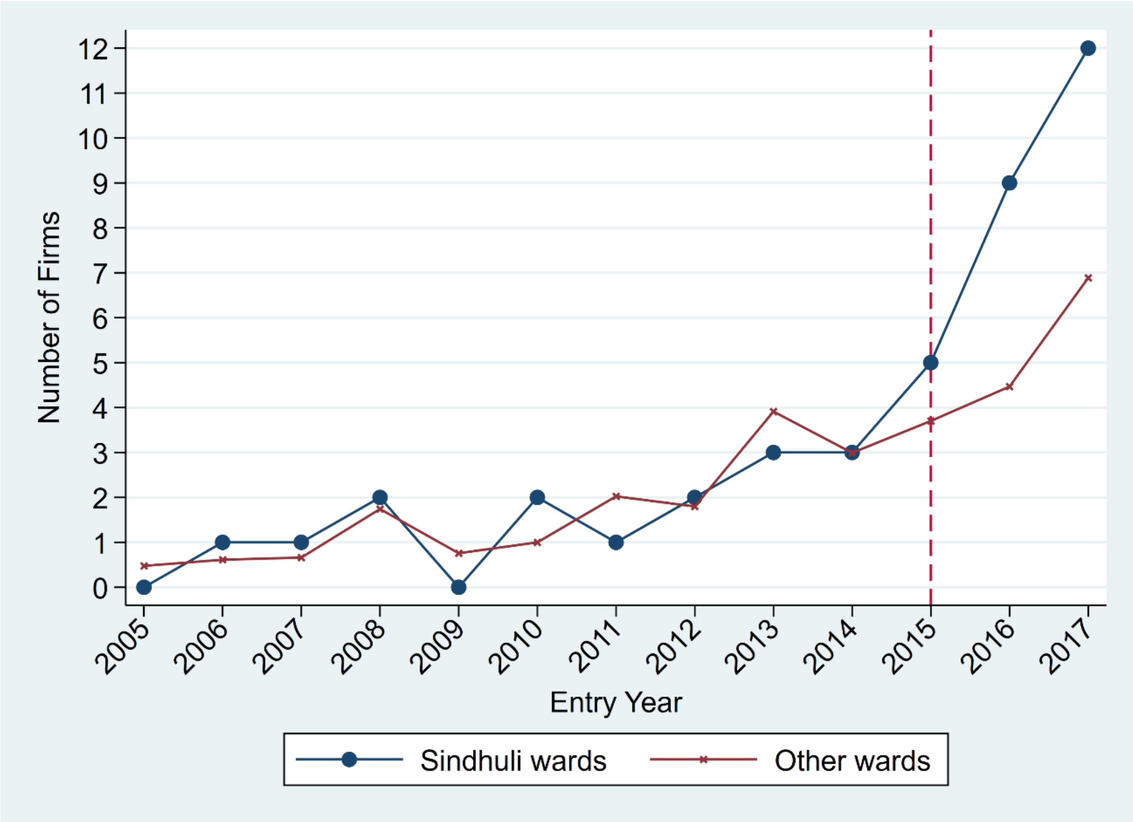
Appendix Figure 1. Histogram of the ratio of OLS estimates to PSW estimates



Notes: Histogram shows a distribution of the ratio of OLS estimates to propensity-score weighting (PSW) estimates; the same specifications are estimated by PSW and OLS methods and the ratio is computed from the absolute values of the estimated coefficients of Sindhuli Road. The vertical line shows a mean value of the ratio of OLS estimates to PSW estimates: 0.697.

Source: Author’s calculation.

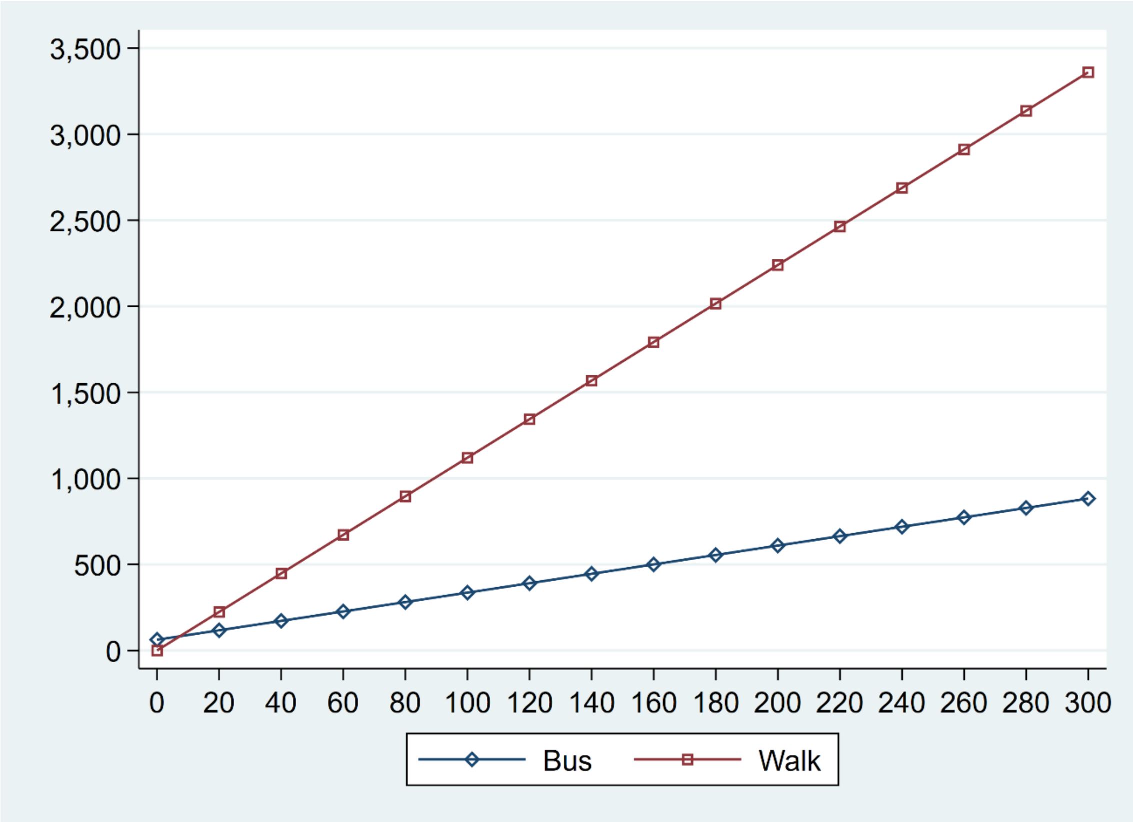
Appendix Figure 2. Firms in vehicle repair services along Sindhuli Road



Notes: The industry of vehicle repair services is defined by the code of 4542 in the International Standard Industrial Classification revision 4: maintenance and repair of motor vehicles. The number of firms in this industry by entry year is aggregated over 54 local treatment wards along Sindhuli Road. Other wards indicate the normalized number of firms in control wards by entry year, where the number of firms in 2010 takes a value of one.

Source: Author's calculation using the Nepalese Economic Census.

Appendix Figure 3. Travel costs by mode



Notes: The figure for Bus shows the fitted values of the linear regression models in column (4) of Table 8. The vertical axis is a transport fare in Nepalese rupees. The horizontal axis is transport distance in kilometers. It is assumed that that walking for an hour has an opportunity cost of hourly labor income, which is equivalent to the hourly minimum wage of 56 NPR in 2023. Given that walking speed is 5 kilometers per hour, travel costs in NPR by walk are a linear function of travel distance in kilometers with a positive slope of 11.2(=56/5).

Appendix Table 1. List of municipalities along Sindhuli Road

Section	Province	District	Municipality
1	Province 2	Dhanusa	Mithila
1	Province 2	Mahottari	Bardibas
1	Bagamati	Sindhuli	Kamalamai
2	Bagamati	Sindhuli	Golanjor
2	Bagamati	Sindhuli	Sunkoshi
3	Bagamati	Ramechhap	Manthali
3	Bagamati	Ramechhap	Khandadevi
4	Bagamati	Kavrepalanchok	Dhulikhel
4	Bagamati	Kavrepalanchok	Panchkhal
4	Bagamati	Kavrepalanchok	Temal
4	Bagamati	Kavrepalanchok	Namobuddha
4	Bagamati	Kavrepalanchok	Panauti
4	Bagamati	Kavrepalanchok	Roshi

Appendix Table 2. Description and summary statistics of covariate variables

Variable	Definition	Mean	Std. dev.
Industrial agglomeration	The number of firms that were established before 2014 over the area	37.0	279.8
Formal share	The share of registered firms that were established before 2014	0.545	0.208
Foreign share	The share of foreign-owned firms that were established before 2014	0.005	0.019
Built-up area change	A difference in built-up area between the 2000-2005 and the 2006-2011 averages	0.006	0.022
Built-up area	The 2013-2014 average of built-up area	0.049	0.200
Cropland change	A difference in cropland area between the 2000-2005 and the 2006-2011 averages	-0.108	0.339
Cropland area	The 2013-2014 average of cropland area	5.545	3.738
ln(population)	Log of municipality-level population size in 2011	10.39	0.805
Firm entry in 2014	The number of firms established in 2014	9.136	19.85

Note: The number of observations is 6,643.

Appendix Table 3. Balancing between treatment and control groups

Variable	Standardized differences		Variance ratio	
	Unmatched	Matched	Unmatched	Matched
Industrial agglomeration	-0.089	-1.75E-07	0.01	0.28
Formal share	0.321	1.54E-07	0.66	0.74
Foreign share	-0.124	-1.89E-06	0.08	0.46
Built-up area change	0.108	-4.69E-07	0.47	0.20
Built-up area	-0.023	-3.41E-07	0.08	0.16
Cropland area change	0.328	-1.78E-08	1.95	1.25
Cropland area	0.461	2.30E-07	1.63	0.86
ln(population)	0.074	2.76E-07	0.27	0.33
Firm entry in 2014	-0.071	-2.85E-08	0.32	1.01
Firm entry in 2013	-0.067	-2.31E-08	0.22	0.62
Firm entry in 2012	-0.023	-1.21E-08	0.39	0.88
Firm entry in 2011	0.092	2.10E-08	0.67	0.85
Firm entry in 2010	0.007	5.55E-08	0.44	0.93
Firm entry in 2009	0.029	1.46E-07	0.50	0.83
Firm entry in 2008	0.017	-1.44E-08	0.73	1.42
Firm entry in 2007	0.057	-1.27E-07	0.44	0.54
Firm entry in 2006	-0.004	-1.34E-07	0.33	0.58
Firm entry in 2005	0.039	-1.26E-07	0.50	0.87

Appendix Table 4. Propensity-score weighting estimation of spatial spillovers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent	Firms	Formal firms	Informal firms	Employment	Formal employment	Informal employment	Sales	Formal sales	Informal sales
Neighboring wards	-0.037	0.16	-0.16	0.23	0.27	0.13	0.082	-0.32	-0.0070
	(0.12)	(0.15)	(0.12)	(0.15)	(0.19)	(0.13)	(0.21)	(0.35)	(0.17)
Control	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of observations	6,630	6,209	6,599	6,630	6,209	6,599	6,624	6,122	6,597
R-squared	0.33	0.27	0.33	0.31	0.24	0.33	0.32	0.28	0.32

Notes: Neighboring wards belong to the same municipality of local treatment wards exposed to the new opening of Sindhuli Road. The estimation excludes the local treatment wards from the sample. Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established from April 2015 to April 2018. Employment, formal employment, and informal employment are the log of the total number of workers in all, registered, and unregistered firms that were established during the period. Sales, formal sales, and informal sales are the log of average monthly revenues/sales in both operating and non-operating activities for all, registered, and unregistered firms that were established during the period. Control includes the log of area, the log of the average elevation, and district-level fixed effects. Parentheses show standard errors clustered by municipality. Constant is not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Appendix Table 5. Propensity-score weighting estimation of pre-treatment entries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent		Firms			Formal firms			Informal firms	
Entry year	2014	2013	2012	2014	2013	2012	2014	2013	2012
Sindhuli Road	0.31	0.49**	0.61***	0.58***	0.55**	0.48**	0.17	0.17	0.39***
	(0.23)	(0.23)	(0.19)	(0.22)	(0.24)	(0.24)	(0.17)	(0.19)	(0.12)
Control variables	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of observations	6,068	6,222	5,578	4,754	4,872	4,364	5491	5,805	4,460
R-squared	0.31	0.27	0.26	0.30	0.29	0.30	0.25	0.23	0.25

Notes: Firms, formal firms, and informal firms are the log of the number of all, registered, and unregistered firms that were established in corresponding entry year. Control includes the log of area, the log of the average elevation, and district-level fixed effects. Parentheses show standard errors clustered by municipality. Constant is not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.