Environmental Disasters and Property Values: Evidence from Nepal's Forest Fires

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Abstract

This article employs satellite data on real-time active fire locations to evaluate the impact of forest fires on property values in Nepal. Results show that an additional unit increase in fire radiative power from last month's forest fires causes a 0.61% decrease in residential property values. Property values decline by 4.48% for every additional unit increase in the number of forest fire incidents over the last year. These estimates suggest that policymakers should prioritize wildfire risk awareness and fire prevention programs in areas with higher levels of declined property values associated with recurring forest fire incidents.

Keywords: Wildfires, Fire Radiative Power, Property Values, Hedonic Model, Nepal

Appendix materials can be accessed online at: https://uwpress.wisc.edu/journals/pdfs/LE-98-1-07-Paudel-app.pdf.

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1. Introduction

Estimates from Food and Agricultural Organization (FAO) suggest that forest fires affect an annual average of 19.8 million hectares of forest around the world. Among developing countries, Nepal faces the recurring threat of forest fires every year, losing around 200,000 hectares of land annually to forest fires (Paudel 2021b). Between 2000 and 2019, the Moderate Resolution Imaging Spectroradiometer (MODIS) data show that Nepal faced 47,000 unique forest fire incidents averaging fire radiative power (FRP) of 29.88 Megawatts. More recently, Nepal experienced a reported damage of over 12,000 community-managed forests covering 1.3 million hectares and killing fifteen people in the span of just two weeks in 2016 (Maden 2018). This is important because forests comprise 39.6% of the entire land in Nepal, and play a key role in watershed protection, soil conservation and biodiversity maintenance (Matin et al. 2017). Although estimating the economic cost of forest fires is a public policy issue, it is not clear that households in the developing world understand the risk that such environmental disasters pose to their homes, and carry out any measures to mitigate such risks.

This article investigates the short-term economic impact of forest fires on residential property values across districts of Nepal. To evaluate whether home values capitalize perceived risks of forest fires in a developing country setting, I exploit a plausibly exogenous distribution of past forest fire incidents over districts and month-by-year. Specifically, I combine two different waves of nationwide household surveys conducted in 2014 and 2015 with satellite data on unique forest fire incidents across the entire nation. My empirical specification estimates current self-assessed property values of households that experience different monthly lagged values of fire radiative power, while accounting for the annual incidence of forest fires, district-level unobservable heterogeneity and month-by-year-varying unobservable shocks to current month's property values. I also conduct additional robustness checks, including placebo tests, to strengthen the validity of the estimates on changes in current property values in response to lagged values of fire radiative power associated with forest fires.

Results indicate that forest fires have a strong negative short-term impact on assessed values of

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residential properties. Regression estimates show that an individual property value experiences a 0.61% decline in response to an additional unit increase in last month's fire radiative power from forest fires in the same district. This significant decline in property values is robust across multiple specifications, with estimates ranging from 0.56% to 1.18%. In addition, forest fires that occurred in the last twelve months in a district have a strong impact on current month's assessed property values. Residential values decline by 4.25% for every additional unit increase in the number of forest fires reported in a district over the last year. The magnitude of changes in property values associated with monthly lagged fire radiative power from forest fires is more pronounced among households residing in Karnali and Far-western provinces. A back-of-the-envelope calculation suggests that a significant drop in current property values led by forest fires in the previous month results in an economic loss of Rupees (Rs.) 12,537.4 per individual. At the country level, this figure is equivalent to a property valuation loss of 2.9 US billion dollars, which is approximately 9.5% of Nepal's Gross Domestic Product in 2019.

This article makes a number of contributions to the literature on estimation of economic loss associated with the incidence of forest fires. First, it contributes to a growing literature on capitalization of risk perception into housing prices in response to forest fires (McCoy and Walsh 2018; Kiel and Matheson 2018; Athukorala et al. 2018; Mueller et al. 2018; Athukorala et al. 2016; Hansen and Naughton 2013; Stetler et al. 2010; Donovan et al. 2007; Loomis 2004). To the author's knowledge, this is the first study in the developing world that explores how households value the external costs of forest fires. In particular, households that experience larger magnitudes of forest fire intensity in a previous month report a significant decrease in property values than their counterparts experiencing smaller magnitudes of forest fire intensity. A comprehensive understanding of economic losses from wildfires can inform decision makers on how to best allocate appropriate budget for vegetation management activities and suppression expenditures (Butry et al. 2001).

Second, it sheds light on important sources of heterogeneity in the overall effect of forest fires across different provinces and demographic characteristics. Specifically, I find that households in

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Karnali province and Far-western province incur large losses in property valuation from the occurrence of forest fire incidents. Findings show that a unit additional increase in monthly lagged fire radiative power associated with forest fires causes a decline of 16.21% and 6.63% in current month's assessed residential property values among households in Karnali and Far-western provinces, respectively. Results also indicate that losses in residential property values are more pronounced among households that do not rely on firewood for fuel, highlighting the heterogeneity in the magnitude of economic effects of forest fires.

Finally, the study provides insights on which provinces are at risk from forest fire-led loss in residential property valuations. Empirical estimates from this study can be used to determine which provinces to target, and identify optimal policies for improved forest management. Although policies related to forests and management of environmental resources in Nepal fall under provincial jurisdictions, there exists no existing evidence on the role of institutions in engaging local communities to manage Nepal's forest fires. In fact, Nepal's Department of Forests currently allocates one million US dollars a year to implement forest fire prevention programs. In country settings that offer no concrete policy-level nudges for managing forest fires, this study indicates that policymakers need to take urgent actions to account for economic losses associated with public perception of risk towards forest fires. Examples of such actions include raising awareness on fire prevention, building early warning systems, promoting forest fire committees at the local level, prohibiting grazing during the fire season, and launching training sessions for fire rescue, recovery and rehabilitation. An effective policy accounting for the economic impact of such environmental disasters in the developing world is more pressing because future changes in temperature and precipitation regimes are likely to increase the number of forest fires (Negi et al. 2012).

The remainder of the paper is structured as follows. Section 2 presents a brief background on forest fires in Nepal and discusses the data. Section 3 presents the empirical strategy. Section 4 describes the empirical findings. Section 5 discusses economic and policy implications of the main results and Section 6 concludes.

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2. Background and Data

Background

Nepal is a land-locked country with a total area of 56,956 square miles surrounded by India on three sides and China to the north. Nepal is divided into seven provinces (Province 1, Province 2, Bagmati Province, Gandaki Province, Province 5, Karnali Province and Far-Western Province) and 77 administrative districts. Districts in Nepal, which are smaller administrative divisions within each province, are subdivided in municipalities and rural municipalities. According to the Central Bureau of Statistics of Nepal, each district has an average size of 741.65 square miles with an average population of 344,084 individuals (Paudel 2021a). Topographically, Nepal consists of three distinct ecological zones: mountain, hill, and *terai* (or plains).

Nepal experiences forest fires during the dry season from November to June every year, with high concentrations occurring from March to May (Matin et al. 2017). There exists well-documented evidence that the number of forest fires has increased in Nepal in recent years, mostly affecting natural vegetation and human settlements (Paudel 2021b). Prior literature shows that intentional burning among non-timber forest product collectors (58%), negligence (22%) and accidental causes (20%) are three primary factors behind the overall rise of forest fire incidents in Nepal (Kunwar and Khaling 2006; Matin et al. 2017; Paudel 2021b). These forest fire incidents result in natural regeneration and cause forest degradation, generate haze and smoke with direct repercussions on health outcomes, affect livelihoods of people and damage human settlements.

Forests in Nepal cover almost forty percent of the country's land, one-fourth of which is comprised of community-managed forests (Paudel 2018). Community-managed forests are areas of nationally owned forestland transferred by the government to forest user groups (FUGs) for helping them meet bare subsistence community needs and conserve forests. Each FUG consists of households with equal rights over the resources and has the full authority to use, manage and preserve forests (Leone 2019). The FUG cannot sell or transfer the land and community forestry rights (Thoms 2008). Individual households that do not belong to a specific FUG cannot access

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the community-managed forest. Forest management issues have received significant attention among development practitioners in Nepal. Proponents of community forestry initiatives claim that community-managed forests provide local users with control over natural resources, lower ecological degradation and improve food security (Paudel 2018). More recently, Oldekop et al. (2019) show that community-based forestry is associated with a reduction in deforestation in Nepal.

Nepal provides a unique setting to investigate the linkage between the incidence of forest fires and residential property values. Nepal's government introduced the Forest Fire Management Strategy in 2010 to develop policies and strengthen institutions for managing fires. At the government level, district forest offices are tasked with monitoring and reporting fire incidents. However, forest fire managers and locals do not have adequate tools and resources to suppress forest fires (Mandal 2019). In 2016, the government launched a satellite-based monitoring system to disseminate the information to concerned authorities immediately through short message services (SMS) and emails. Nepal's Department of Forests allocated approximately USD 1 million in 2017 to implement a robust forest fire prevention program. This program provided budget for the construction of a forest fire control room, media mobilization and the construction of ponds and puddles (Gurung 2017). Although district officers periodically conduct week-long awareness campaigns through local radio and newspapers, media reports suggest that such efforts have not been successful in reducing the frequency of forest fires.

At the local level, over one-third of community forest user groups employ mobile forest guards to monitor the incidence of forest fires and help disseminate information on a timely basis when fire breaks out (Gurung 2017). Anecdotal evidence indicates that some community forest groups have access to fire-fighting tools but are not trained to use them. Finally, insurance markets for fire in Nepal have not been fully developed yet. Overall, forest fire-related mitigation strategies have been implemented either at the government level (under federal or provincial jurisdiction) or at the community level with little or no success.

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Data

The core analysis of the study is based on (i) detailed household-level data from the Annual Household Survey (AHS) 2013/14 and 2014/15 in Nepal[1], and (ii) satellite data on active fire incident locations during the same time period available from the Fire Information for Resource Management System (FIRMS), which provides near real-time active fire locations to natural resource managers.[2] The AHS data do not provide information on geographical coordinates of locations where individuals reside. I aggregate the FIRMS data on forest fire incidents at the district level and merge it with the household-level AHS data to construct my empirical sample.

Table 1 provides information on the number of households, provinces and districts sampled in the household survey. Overall, the survey interviewed 30,864 individuals from 7 provinces and 70 districts between January, 2014 and July, 2015. Each row in Table 1 breaks down the number of observations at different levels and average fire-related outcomes across different months by year. For example, the first row in Table 1 shows that 2,033 individuals from 7 provinces and 27 districts were interviewed in January 2014 when 3 forest fire incidents averaging 18.08 Megawatts of fire radiative power took place in 2 districts. Column (8) indicates that a large number of forest fires took place from March to May in 2014. This is consistent with findings from Matin et al. (2017), who report that Nepal usually experiences forest fires during the dry season every year, with high occurrences from March to May.

This study makes use of self-assessed values of residential properties available from the AHS data set. The household survey explicitly asks a homeowner, "If you would like to buy a dwelling just like the one you own today, how much money would you have to pay?" Figure A1 shows the kernel density plot of log-transformed residential property values across the following three categories: the entire sample, the sample of households in urban areas and the sample of households in rural areas. The density plot for log-transformed property values among households in the entire sample is fairly symmetrical. The average log-transformed property values among households in rural areas (Rs. 12.80) is smaller than the overall average (Rs. 13.29) across the entire sample. In urban areas, the density plot of log-transformed property values

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indicates a much larger average value (Rs. 14.10) and standard deviation (Rs. 1.62).

Figure 1 gives the precise locations of unique forest fire incidents in Nepal. The figure indicates that the majority of these incidents take place in the Hills and the southernmost region of the country. Figure 2 shows the district-level variation in the number of forest fires and fire radiative power across the entire country. Finally, Figure 3 explores the relationship between last month's fire radiative power and property values assessed in the current month.[3] This descriptive figure indicates that property values assessed in the current month decline as fire radiative power from the previous month's forest fire events increases.

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3. Empirical Strategy

To assess the impact of forest fires on property prices, I employ the ordinary least squares (OLS) regression as shown below:

$$Y_{i,m} = \beta_0 + \beta_1 Fire_{d,m-1} + \beta_2 FRP_{d,m-1} + \beta_3 \bar{F}_d + \beta_4 \bar{X}_{i,m} + \sigma_d + \delta_m + \alpha_{dm} + \varepsilon_{i,m} \quad (1)$$

where $Y_{i,m}$ is a self-assessed residential property value (in logs) for an individual i in district d in the current month m of a given year. $Fire_{d,m-1}$ is an indicator that equals 1 if a forest fire incident occurred in a district in the previous month. $FRP_{d,m-1}$ is the fire radiative power (FRP), which gives the average rate of radiant heat output from forest fires that occurred in a district in the previous month. $\bar{F}_d$ is a vector of long-term district-level fire outcomes, including the average number of fire events in the last twelve months and the average fire radiative power associated with forest fires during the last year. $\bar{X}_{i,m}$ is a vector of individual controls such as household size, location type (urban or rural), number of rooms, type of the house and the roof. σ_d is a vector of district-level dummies that account for geographical heterogeneity and unobserved fixed factors at the district level such as political power and institutional strength.[4] The second set of fixed effects includes month-by-year fixed effects, δ_m, that account for any month-by-year specific shocks such

as earthquakes, macroeconomic conditions, governmental policies that affect all districts equally during the month of the interview. Finally, α_{dm} represents district-level quadratic monthly time trends that account for possible unobserved trending variables that may influence property values.

Four methodological issues are worth highlighting. First, this study uses a self-assessed value of a residential property as the primary dependent variable in the econometric model, which is consistent with prior literature in the developing world (Nepal et al. 2020; Nepal et al. 2017). The survey explicitly asks a homeowner, "If you would like to buy a dwelling just like the one you own today, how much money would you have to pay?" Although prices of housing units for hedonic analyses should ideally come from transactions in the competitive market where the demand price of a housing unit equals the offer price at equilibrium (Rosen 1974; Taylor 2003), Nepalese rural setting where housing markets are thin presents different challenges. It is not feasible to collect property value data from market transactions (Nepal et al. 2020). According to Nepal et al. (2017), "reported market data, even if available, do not provide the actual price of housing units in Nepal as both sellers and buyers have incentives to understate the actual prices to avoid the stamp duty that both sides are required to pay at the given rates." Rampant under-reporting of the sales price for tax purposes suggests that confidential administrative data from property registration offices in Nepal do not reflect the actual value of residential properties (Nepal et al. 2020). Given that a potential developer survey is not available[5], this study relies on self-assessed values of the housing units. The potential effect of using self-reported prices in a hedonic model is well-documented in the literature (Gonzalez-Navarro and Quintana-Domeque 2016). For example, even if self-reported housing values may be biased to some extent, the magnitude of the estimated bias is relatively small, averaged between 3% and 8% (Nepal et al. 2020; Gonzalez-Navarro and Quintana-Domeque 2016, 2009; Agarwal 2007;Kiel and Zabel 1999; Goodman Jr and Ittner 1992). This indicates that the use of owner's valuations can provide reliable estimates of housing prices and neighborhood characteristics (Kiel and Zabel 1999).

Second, the use of fire radiative power as a proxy for fire intensity is based on recent literature on wildfire events (Tedim et al. 2018;Bowman et al. 2017). For example, Bowman et al. (2017)

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take advantage of daily clusters of fire radiative power between 2002 and 2013 to quantify the occurrence of wildfire events across the globe. Fire radiative power is strongly correlated with fire behavior characteristics that have major economic impact on individuals such as fireline intensity (Johnston et al. 2017; Kremens et al. 2012) and total biomass burned (Kumar et al. 2011). According to Tedim et al. (2018), constraints of fire size need to be considered when conceptualizing a wildfire event. Specifically, size is place-dependent, reflects landscape characteristics and provides little information about losses that depend on fire magnitude (Tedim et al. 2018). Remote sensing experts do not recommend using active fire locations to estimate burned area per fire pixel due to nontrivial spatial and temporal sampling issues.[6] These underlying causes support the use of fire radiative power in the main empirical model.

Third, the household survey does not have information on precise locations (geographical coordinates) of residential properties. Although satellite data provide exact locations of where forest fires occurred, inadequate data on household locations do not allow researchers to compute the physical distance between the location of the household and the site of a forest fire incident. It is therefore beyond the scope of the study to find out which housing units are in close proximity to the fire site. However, survey questionnaires on conditions of houses (including information on foundation of dwelling and materials for outer wall and roofs) indicate that the majority of houses in the sample are likely free of actual fire-related damage. The estimated β_2 can therefore be interpreted as a change in home values associated with perceptions of risk as opposed to damages from fires. Future research on forest fires in the developing world may benefit from adequate micro-level data in isolating the relative effect of different fire-related mechanisms on property prices. Some of these mechanisms include actual fire damage, prevalence of visual dis-amenities and high perceptions of risk.

Finally, it is worth mentioning that satellite data on real-time active fire locations have some limitations. Because satellites detect active fires "by calculating the thermal anomalies on a pixel 1X1 km in size" (Matin et al. 2017) and the center of the pixel reflects the location of the fires, multiple fire incidences within one pixel area may be reported as a single incidence. It is also

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possible that the fire may have started and ended between satellite observations, affecting the quality of individual fire pixels included in the fire data products (Paudel 2021b). These caveats need to be considered when interpreting the findings of studies that rely on applications of satellite data.

4. Results

Forest Fires and Residential Property Values

Table 2 presents estimates of the short-term impact of forest fires on assessed values of residential properties. In column (1), I include two variables for measuring forest fires: whether a forest fire occurred in a district in the last month and the fire radiative power associated with a forest fire in the last month. Moving from left to right in the table, I estimate equation (1) with district fixed effects and month-by-year fixed effects in column (2) while adding a progressively richer set of control variables. In column (3), I add two more variables for measuring forest fires: the number of forest fires in a district in the last twelve months and the average fire radiative power associated with forest fires in the last twelve months. These two factors capture the cumulative effect of forest fire events that have occurred in the last year on current property values. Finally, I include a vector of individual controls as outlined in Section in my most preferred specification in column (4).

I find a strong and negative impact of fire radiative power from last month's forest fires on residential property values assessed in the current month. My preferred specification in column (4) shows that an additional unit increase in last month's fire radiative power decreases current residential property values by 0.61%. This effect is robust across multiple specifications from column (1) to column (3), with coefficient estimates ranging from 0.56% to 1.18%. I also find that property values decline a month after the incidence of forest fires. However, this decrease in property values is not statistically significant across all four columns.

Table 2 shows that total number of forest fire incidents occurred in the last twelve months

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have a strong impact on current residential property values. Column (4) indicates that an additional unit increase in the number of last year's forest fires causes a 4.48% decrease in property values assessed in the current month. Finally, last year's annual fire radiative power associated with forest fires does not have a significant impact on assessed property values in the current month. This analysis suggests that a more recent measure of last month's fire radiative power has a stronger impact on property values assessed in the current month than an overall annual measure of fire radiative power associated with forest fires in the last twelve months.

Forest Fires and Residential Property Values across Provinces

Broad policy functions pertaining to the use of forests and management of environmental resources in Nepal fall under provincial jurisdictions. An effective implementation of fire prevention program at the province level requires complete information about effects of forest fires on property values. I explore the heterogeneity in the impact of forest fires on residential property values in Figure 4. Figure A2 presents the same information with 95% confidence intervals.

Figure 4 shows that all provinces experience negative effects of forest fires on residential property values, with estimates ranging from -0.56% in province no. 2 to -16.21% in Karnali province. An additional unit increase in fire radiative power from last month's forest fires causes residential property values assessed in the current month to decrease by 16.21% in Karnali province, 6.63% in Far-western province, 2.34% in Gandaki province and 1.67% in province no. 5 (see Figure A2). Results also show that current property values decline in response to last month's fire radiative power recorded in province no. 1, province no. 2 and Bagmati province, although estimates in these three provinces are not statistically significant.

The reason behind a much larger impact on property values among western Provinces of Nepal (including Karnali and Far-western Province) is the higher number of forest fire events in these areas compared to the rest of the country. For example, FIRMS data indicate that households belonging to Karnali and Far-Western Provinces in the empirical sample, on average, experienced 2.60 forest fire events in the last month and 3.14 forest fire events over the last year. The number of fire events in other Provinces is much smaller, with 1.41 fire events recorded in the last month and

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2.05 fire events over the last year. The heterogenous effect of forest fires on residential property values indicates that areas with higher negative slope estimates are characterized by large number of fire events in the empirical sample.

These findings on the heterogeneity of estimates across different provinces in Figure 4 suggest that fire prevention programs should be prioritized in Karnali and Far-western provinces with higher levels of declined property values. These areas would see a greater improvement in economic losses in response to fire suppression efforts. Examples of such efforts include raising awareness on fire prevention, building early warning systems, promoting forest fire committees at the local level, prohibiting grazing during the fire season, and launching training sessions for fire rescue, recovery and rehabilitation.

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Forest Fires and Property Values across Socioeconomic Groups

I break down effects of forest fires on residential property values across four different categories of households: (a) households that reside in urban locations, (b) households that reside in rural locations, (c) households that rely on firewood for fuel, and (d) households that do not rely on firewood for fuel. This is important because a comprehensive analysis across different categories of households can reveal widening socioeconomic disparities in the aftermath of disasters such as forest fires and earthquakes (Paudel and Ryu 2018; Paudel 2021a,c).

Figure 5 shows that the impact of last month's fire radiative power on current residential property values is negative and statistically insignificant across both urban and rural households. The impact of forest fires on property values is much more precise among households relying on firewood for fuel. An additional unit increase in fire radiative power from last month's forest fires causes residential property values assessed in the current month to decrease by 0.66% among individuals relying on firewood for fuel. The estimate is approximately 0.82% among their counterparts who do not rely on firewood for fuel. These findings indicate that a decline in residential property values in response to fire radiative power is larger in magnitude among households that do not rely on firewood for fuel. In the empirical sample, 48.29% of households

not dependent on firewood for fuel reside in Karnali Province and Far-western Province of Nepal, which are areas that experience more forest fire events compared to the rest of the country.[7] The heterogenous effect of forest fires documented in Figure 5 indicates that households that do not rely on firewood for fuel reside in areas characterized by large number of fire events and experience significant declines in residential property values.

Robustness Checks

I perform additional tests in the supplementary Appendix to investigate the validity of my prior estimates on the effect of the incidence of forest fires on residential property values.

First, I exclude outliers to evaluate the short-term economic impact of forest fires on residential property values. Specifically, I estimate equation (1) by dropping property values that are either lower than the bottom 2.5th percentile or higher than the top 97.5th percentile distribution. In my most preferred specification in column (4), Table A1 shows that a unit additional increase in last month's fire radiative power decreases current residential property values by 0.56%. This effect is similar in magnitude to the one reported in Table 2. Column (4) also indicates that a unit additional increase in the number of last year's forest fires causes a 3.63% decrease in property values assessed in the current month. Estimates in Table A1 indicate that even when outliers are excluded from the empirical specification, the effect of forest fires on property prices remains strong, negative and statistically significant.

Second, I apply different measures of forest fire intensity to investigate the linkage between forest fires and residential property values. I estimate equation (1) using two different proxies for forest fire intensity: (i) median fire radiative power, and (ii) normalized fire radiative power in a district. Panel A and Panel B in Table A2 show that the effect of last month's median and normalized fire radiative power from forest fires is strong and negative on current month's residential property values. This provides direct evidence that main findings in Table 2 are robust and statistically significant.

Finally, I conduct 500 different sets of placebo tests to examine the robustness of main

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estimates reported in Table 2. The placebo test involves a Monte Carlo analysis in which values for four fire-related variables specified in equation (1) are randomly assigned across a bootstrap sample (random sample with replacement) drawn from the sample population in the study. Specifically, I estimate equation (1) 500 different times using sites where no forest fire took place and compare where the point estimate of my preferred model in column (4) of Table 2 lies with respect to the distribution of the randomly generated treatment effect obtained from placebo regressions. Figure 6 shows the kernel density plot of the coefficient on each fire-related variable obtained from 500 different sets of placebo regressions, along with treatment effect estimate from the fourth column of Table 2 denoted by the solid vertical line. Among two variables of interest that are statistically significant in Table 2, the estimated slope coefficient on *Fire radiative power in the last month* is close to the middle of the distribution from placebo regressions. This implies that the estimated parameter may possibly be susceptible to Type-I error, suggesting that the identification strategy is likely contaminated by omitted variable bias. However, the estimated slope coefficient on *Number of forest fires in the last 12 months* is much further away from the middle of the randomly generated distribution of placebo parameters. This indicates that the strong negative effect of an additional unit increase in the number of last year's forest fires on property values (see Table 2) is robust. At the same time, it is worth pointing out that the identification strategy employed in this study hinges on cross-sectional variation of forest fire indicators. This implies that omitted variable bias may confound the estimated parameter for three other fire-related variables employed in the study. Future research may benefit from an alternate quasi-experimental research design exploiting double differences to account for potential unobservable determinants of residential property values correlated with fire-related indicators.

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5. Discussion

Comparison to Existing Studies

This study is relevant to the broader literature on hedonic valuation in the developing world that uses self-assessed value of a residential property as the primary dependent variable in the

econometric model. For example, Gonzalez-Navarro and Quintana-Domeque (2009) evaluate the reliability of homeowner estimates of housing values in Acayucan, Mexico and document that self-reported home values are reasonably unbiased and precise at the census tract level. In the context of South Asia, Nepal et al. (2017) apply nationally representative, repeated cross-sectional data in Nepal to show that housing values of government and community-managed forest users are lower compared to housing values of private forest users. More recently, Nepal et al. (2020) estimate hedonic price model using self-reported property values and find that city residents place a higher price premium on cleaner neighborhoods of cities in Nepal. This study adds to a growing literature on applications of self-reported housing values in the developing world and provides evidence on the economic impact of forest fires on residential properties of Nepal.

This article is also broadly related to a large number of US studies exploring the economic impact of wildfires on housing prices. Using geo-spatial data on wildfire burn scars and latitude and longitude co-ordinates for residential properties in the Colorado Front Range, McCoy and Walsh (2018) show that housing values in high-risk zones incur an immediate, temporary price shock a year after the wildfire. Loomis (2004) apply linear and semi-log hedonic property models to show that housing values in the town of Pine, two miles from the 1996 Buffalo Creek fire in Colorado, report a 15% drop five years after the fire. In a different study, Mueller et al. (2018) focus on the Schultz Fire near Flagstaff, Arizona and estimate a hedonic property model to conclude that a loss in housing prices declines with distance to the fire site. They find that properties within 5 km of the fire site incur a 31% loss in value, which is much larger than those within 20 km of the fire site experiencing a 6% loss. Relatedly, Mueller et al. (2009) show that home prices within 1.75 miles of a wildfire in counties from Southern California drop by 9.7% and 23% in the year following the first and second wildfire, respectively. Studying 256 wildland fires in northwestern Montana, Stetler et al. (2010) find that sale prices of homes within 5 km of a wildfire burned area were 13.7% lower than equivalent homes at least 20 km from a fire. More recently, Kiel and Matheson (2018) take advantage of single family housing sales data between 2009 and 2012 in Colorado and show that homeowners residing in areas of highest wildfire risk

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experience a 21.9% decline in sale prices. Outside the US, Xu and van Kooten (2013) find that the occurrence of wildfires in the ten years prior to the sale of a property generally has a negative impact on property values. Their estimates indicate that the size of wildfires has a significant influence on sales values and unit prices, while the fire incidence does not. To some extent, this supports the finding that monthly lagged values of fire radiative power have a statistically significant effect on home values assessed in the current month, while the incidence of a forest fire event in the last month does not.

There are several caveats that need to be considered when comparing the US estimates with findings from this Nepal-based hedonic study. First, Nepal's economic context is different from the US setting. Individuals in Nepal are poorer and have inadequate access to risk-mitigating mechanisms such as the provision of house insurance. Second, there exists a dearth of fire management-related policies in Nepal aimed at enhancing wildfire risk awareness through information campaigns. For example, individuals in Nepal do not have access to detailed fire risk maps. Finally, existing US studies have adequate data allowing researchers to consider the impacts of fire through a spatial (i.e. distance to fire) and a visual (i.e. view of a burn scar) dimension. As mentioned in Section 3, it is impossible to isolate the relative effect of different fire-related mechanisms on property values with the revealed preferences data available for this study. Majority of the US studies explore changes in property values over a wider time horizon, while this study focuses on the short-term economic impact of forest fires. Despite these existing differences across markets in conjunction with data limitations, this article shows that a significant drop in property values in the aftermath of wildfires as documented by US studies applies in a developing country setting as well.

Economic and Policy Implications

I have shown that an increase in last month's fire radiative power from forest fires leads to a significant decrease in residential property values of Nepal. To provide a concrete illustration of the magnitude of the estimated impact, I combine slope estimates in Table 2 with average residential property values to generate economic loss per capita from the incidence of forest fires.

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Applying the average residential property value of Rs. 2.05 million, I find that a 0.61% decrease in current property values associated with a unit additional increase in last month's fire radiative power corresponds to an economic loss of Rs. 12,537.4 per individual. To aggregate this estimate to the country level, I multiply the estimated economic loss per individual with the country's population of 28 million people. This exercise indicates that forest fires in Nepal cause a residential property valuation loss of 2.9 billion US dollars, which constitutes approximately 9.5% of Nepal's Gross Domestic Product in 2019. This figure illustrates the economic impact of forest fires in a developing country setting, where individuals exposed to forest fires suffer from poor air quality, damage of physical infrastructure and unavailability of forest resources for livelihoods.[8] Compared to the annual economic cost of forest fires in Nepal, the amount of investments made by the government to prevent forest fires is significantly smaller. For example, Nepal's Department of Forests allocated approximately 1 million US dollars in 2017 to implement a robust forest fire prevention program. Prior literature indicates that inadequate funding is a major channel behind the failure of fire prevention efforts in Nepal (Benndorf and Goldammer 2006). According to Sharma (2005), government agencies in Nepal "do not give priority for fire management in terms of budget" and human resources. This indicates that limited funding for management of forest fires has hindered successful implementation of preventative programs across all districts of Nepal (Sharma 2005).

From a policy perspective, it is useful to determine economic benefits from reduced risks of forest fires in response to fire prevention programs. Specifically, policymakers may implement wildfire risk awareness through public information campaigns such as publicizing fire risk maps in Colorado to minimize economic losses from wildfires (Donovan et al. 2007). Outside the US, countries such as Nepal, India and Bhutan recently implemented a satellite-based early response system that allows the fire management agency to send text message alerts, with details on the size and location of the fire, directly to people living in affected communities. Anecdotal evidence suggests that an effective satellite-based monitoring system has the potential to reduce the incidence of human-led forest fires in Nepal. For example, if the early warning system causes an x unit decrease in fire radiative power associated with reduced frequency of forest fires, the estimate

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available from this study can help quantify gain in property values ($0.0061x$) as a result of the satellite-based early response system. Hedonic estimates from this study, in conjunction with additional estimates of early-warning system induced changes in fire outcomes, can inform policymakers about economic valuations associated with the fire monitoring system across different regions.

The findings of this study have implications on economic outcomes during the ongoing COVID-19 pandemic. In the context of South Asia, lockdowns in response to the virus outbreak have caused a significant short-term decline in the movements of humans across districts and reduced the count of human-induced forest fires in South Asia. More specifically, Paudel (2021b) finds that fire radiative power associated with forest fire events in Nepal decreased by 11.36% in the aftermath of the pandemic. Applying the hedonic estimate in this study, a reduction of 11.36% in fire radiative power corresponds to a 0.25% gain in residential property values. In a business-as-usual scenario, the estimate implies an annual economic benefit of Rs. 25,692 per capita from reduced magnitudes of fire radiative power.

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6. Concluding Remarks

This article examines the short-term impact of forest fire incidents on residential property values in a developing country setting. To assess the economic impact of last month's forest fire intensity on current month's property values, I take advantage of plausibly exogenous distribution of forest fire incidents over space and time. Controlling for district and month-by-year fixed effects and time trends, I find that an additional unit increase in fire radiative power from last month's forest fires causes a 0.61% decrease in current residential property values. Findings also show that property values decline by 4.48% for every additional unit increase in forest fire incidents over the last year. The study further explores the heterogeneity in effects of forest fires on property values across different provinces and socioeconomic groups. Empirical results suggest that fire prevention programs should be prioritized in areas across Karnali and Far-western provinces with higher levels of declined property values.

The study also provides policymakers with estimates of economic losses associated with forest fires. Future research may benefit from quantifying economic benefits from reduced incidence of fire-related outcomes across different forest management regimes. This is especially important in Nepal, where it is well-documented that decentralized forest management systems such as community-based forestry reduce deforestation and poverty (Oldekop et al. 2019). Recent estimates indicate that districts with smaller areas of community-managed forests per capita experienced a 8.11% decrease in the number of forest fire incidents in Nepal (Paudel 2021b). This article can help policymakers quantify differences in property values associated with changes in fire-related outcomes across different areas of community-managed and government-managed forests. This in turn can inform the efficacy of different forest management regimes in suppressing wildfires in the developing world.

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Acknowledgments

The author thanks editor Daniel Phaneuf and two anonymous referees for helpful comments in the review process.

Notes

[1]This data set, a random sample of households from National Population Census 2011, is provided by the Central Bureau of Statistics in Nepal.

[2]The data set can be downloaded at: https://firms.modaps.eosdis.nasa.gov/. The active fires represent the center of a 1 km pixel that is flagged as containing one or more files within the pixel.

[3]To generate this figure, I collapse log-transformed property values assessed in the current month and fire radiative power observed in the last month at the year-month-district level. Using the average and standard deviation for each variable, I construct upper and lower bounds in the following way: Upper bound = average + (1.96*X*standard deviation) and lower bound = average − (1.96*X*standard deviation). Finally, I plot a kernel-weighted local polynomial regression of current month's log property values on last month's fire radiative power associated with forest fire events using average, upper bound and lower bound values.

[4]Prior literature highlights the role of institutions across districts of Nepal (Paudel and Crago 2017;Oli and Treue 2015). For example, Oli and Treue (2015) explain that political instability in Nepal has expedited degradation of government forests as the District Forest Offices appear unable to control illegal extraction of forest products. Similarly, Paudel and de Araujo (2017) explore repercussions of monarchy abolition in 2006 across several districts of Nepal.

[5]It is worth pointing out housing units in Nepal are built by private individuals who first buy land and subsequently contract labor and purchase materials for construction (Nepal et al. 2020). Anecdotal evidence indicates that the availability of a few number of developers has emerged only in the last couple of years.

[6]Giglio et al. (2016) provide more information on active fire detection algorithm and fire products.

[7]Among households relying on firewood for fuel, only 24.51% of them reside in Karnali and Far-western Province.

[8]It is beyond the scope of the study to directly account for negative consequences of forest fires on health, education and labor market outcomes. This suggests that a back-of-the-envelope estimate calculated in this study is a lower bound of the true economic impact of Nepal's forest fires.

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Table 1: Summary of data employed in the study

		Total number of observations					Average	
Year	Month	Individuals	Provinces	Districts	Districts without Forest Fires	Districts with Forest Fires	Count of Forest Fires	Fire Radiative Power
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2014	January	2,033	7	27	25	2	3.00	18.08
2014	February	2,188	7	28	25	3	3.77	19.00
2014	March	2,461	7	31	17	14	9.39	12.32
2014	April	1,540	7	24	2	22	24.43	13.37
2014	May	2,364	7	29	11	18	14.39	15.11
2014	June	1,121	6	16	15	1	1.00	6.10
2014	July	10	1	1	1	0	-	-
2014	September	78	2	3	3	0	-	-
2014	October	1,608	7	22	22	0	-	-
2014	November	2,841	7	34	29	5	2.10	18.13
2014	December	2,588	7	28	25	3	3.47	25.64
2015	January	2,136	6	29	28	1	1.00	16.24
2015	February	1,930	7	28	23	5	3.60	16.54
2015	March	2,225	7	28	23	5	8.19	14.59
2015	April	1,851	7	27	22	5	3.76	9.93
2015	May	2,033	7	25	14	11	6.08	11.09
2015	June	1,292	7	17	8	9	3.44	15.17
2015	July	565	4	7	6	1	1.00	6.56

Notes: Total number of districts in the sample equals the sum of total number of districts with and without forest fires. Fire radiative power is a measure of the rate of radiant heat output associated with forest fire events. Household surveys were not conducted in the month of August in 2014.

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Table 2: Impact of forest fires on property values

	Dependent variable: Log Property Value in the Current Month (Rs.)			
	(1)	(2)	(3)	(4)
Forest fire detected in the last month	-0.0571	-0.0023	-0.0692	-0.0264
	(0.0458)	(0.0476)	(0.0480)	(0.0442)
Fire radiative power in the last month	-0.0118***	-0.0085***	-0.0056**	-0.0061***
	(0.0022)	(0.0022)	(0.0022)	(0.0020)
Number of forest fires in the last 12 months			-0.0535***	-0.0448*** (0.0047)
			(0.0051)	
Fire radiative power in the last 12 months			-0.0014	0.0013
			(0.0069)	(0.0064)
N	30,864	30,864	30,864	30,864
Adjusted R^2	0.0690	0.3121	0.3146	0.4193
Monthly Time Trend	Yes	Yes	Yes	Yes
Month-by-Ecological Zone Fixed Effects	Yes	No	No	No
District Fixed Effects	No	Yes	Yes	Yes
Month-by-Year Fixed Effects	No	Yes	Yes	Yes
Controls	No	No	No	Yes

Notes: Each column reports results from a separate regression estimating equation (1). Fire radiative power is a measure of the rate of radiant heat output associated with forest fire events. *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

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Figure 6: Kernel density plot of regression coefficients from placebo tests

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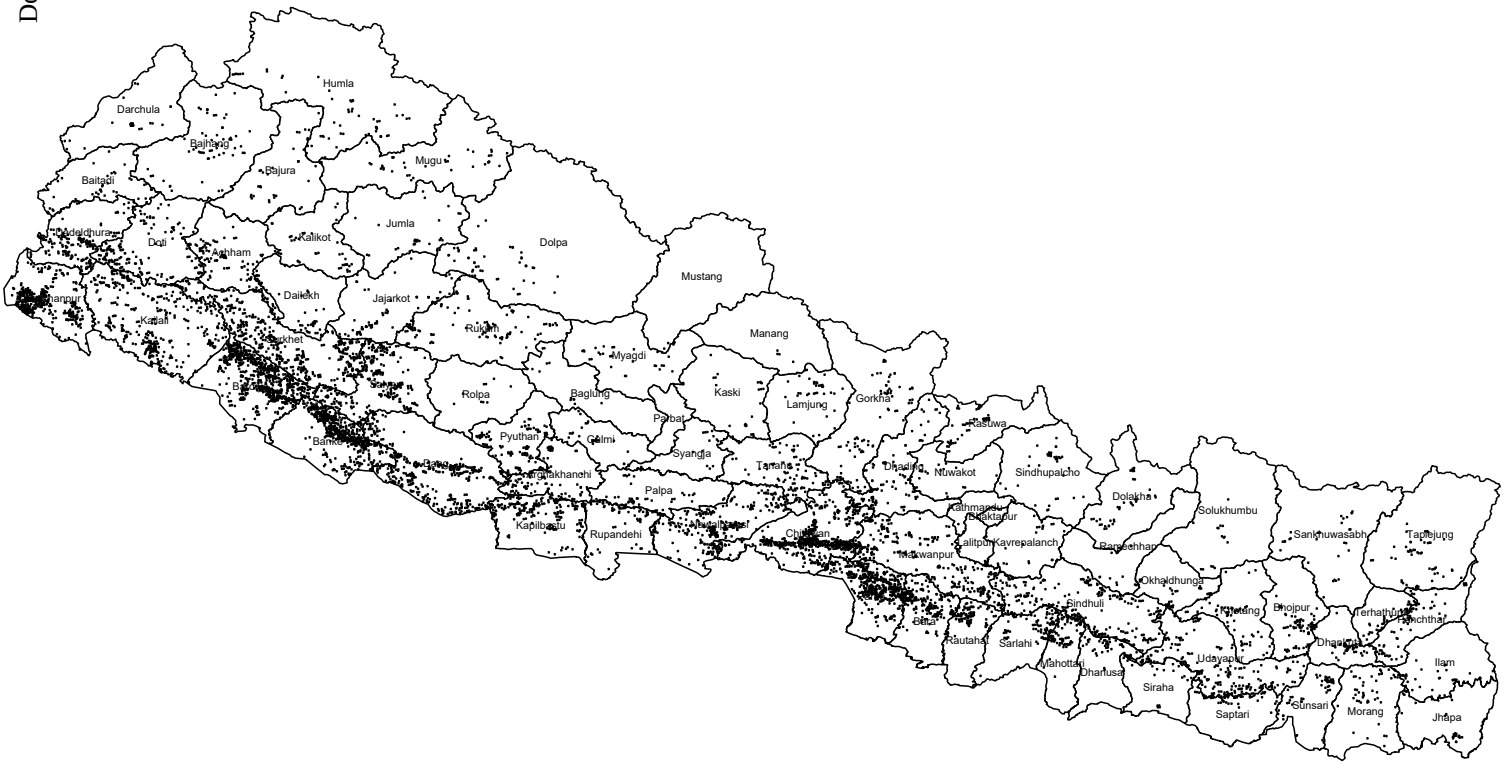
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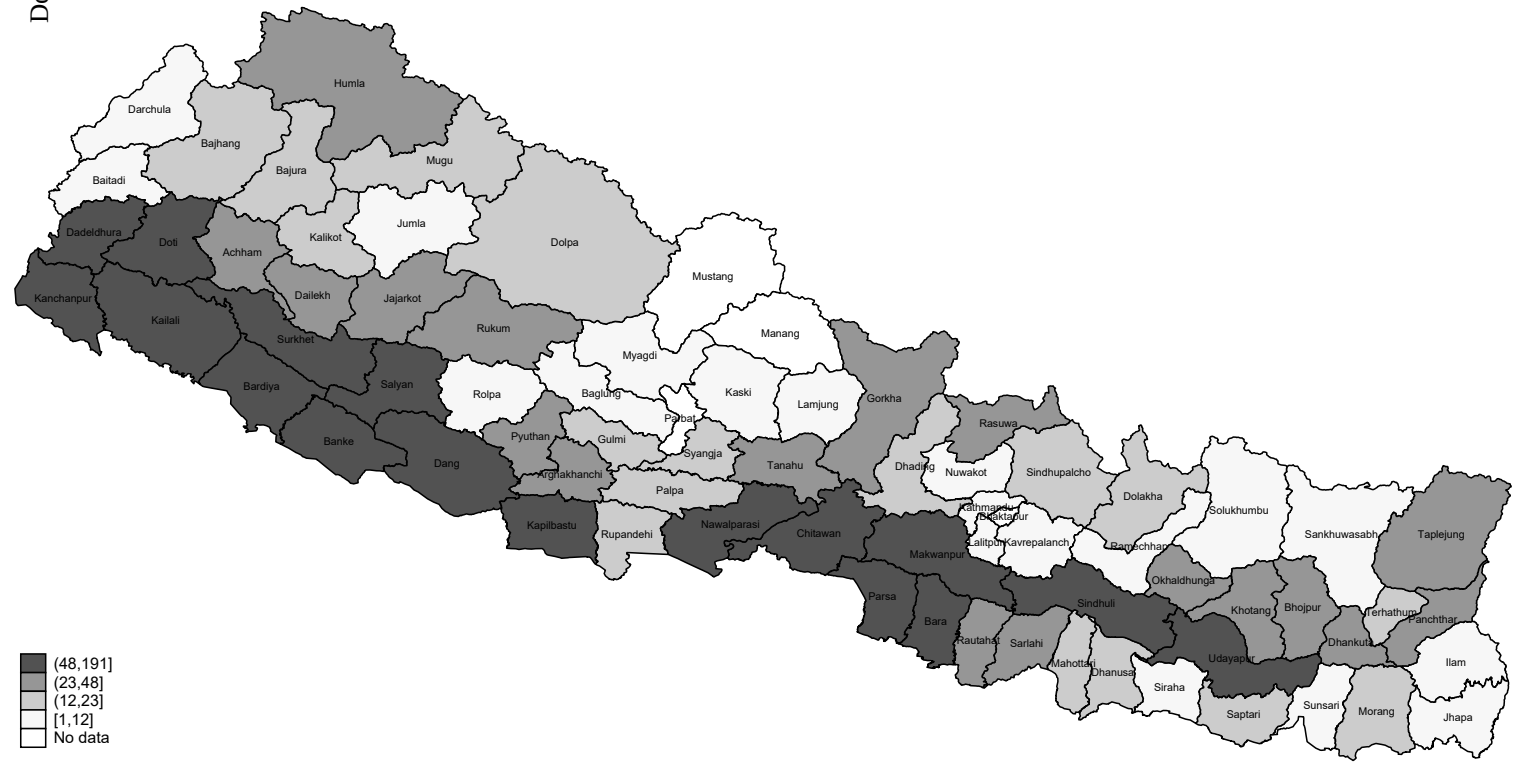
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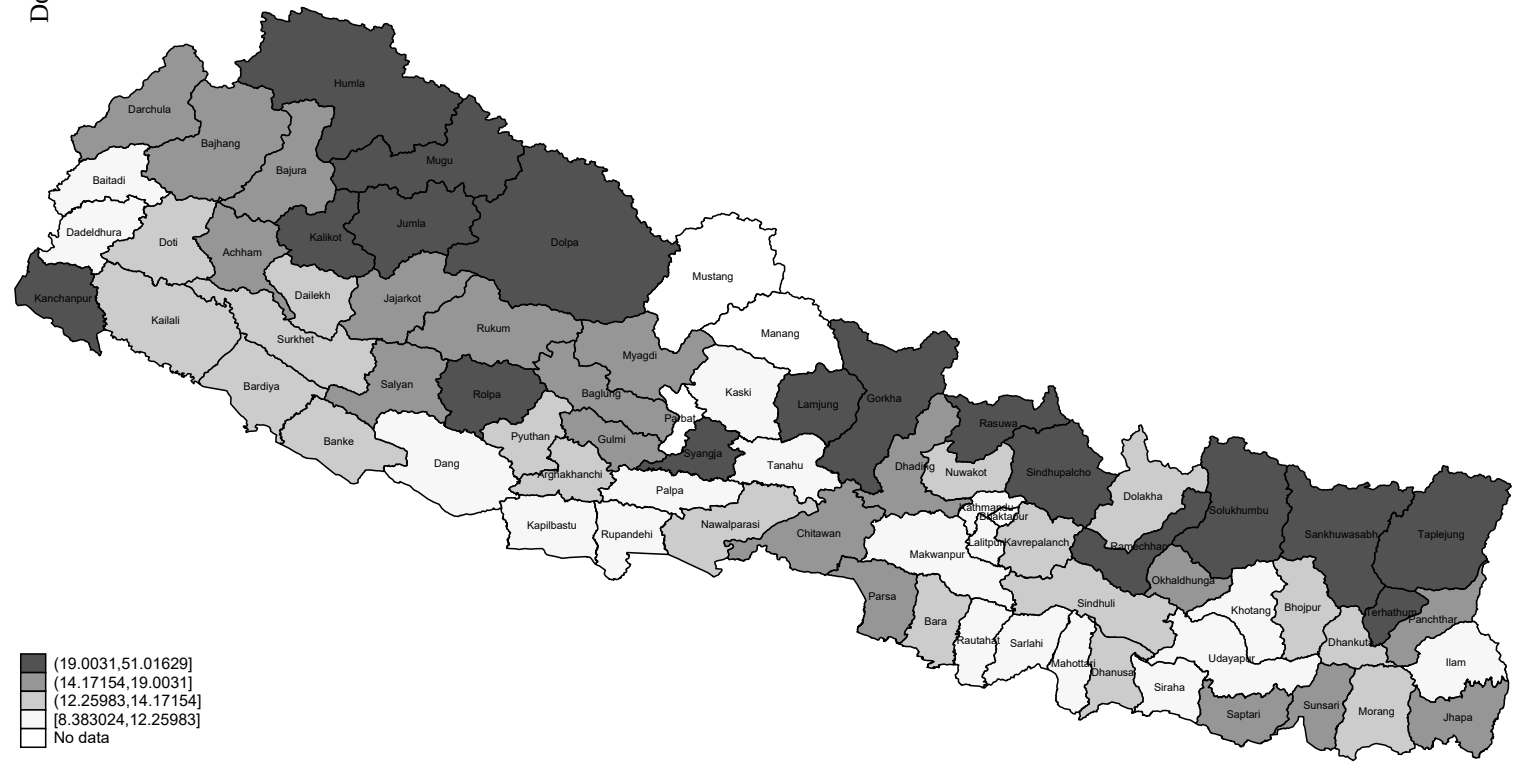
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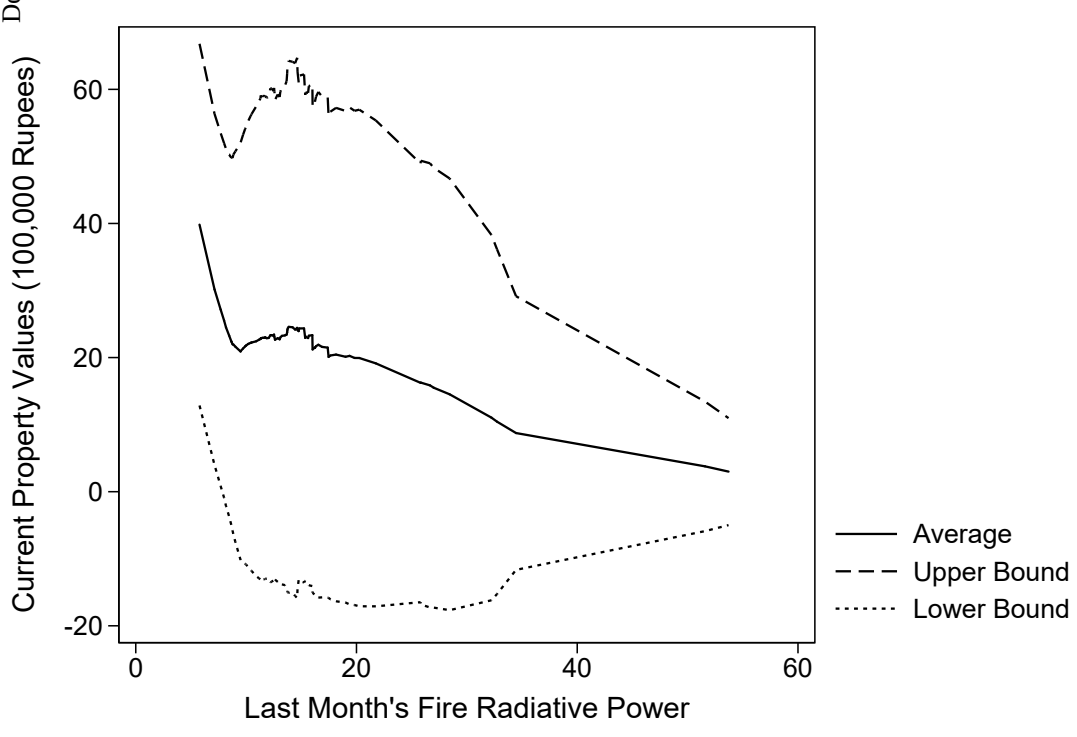
Current Property Values (100,000 Rupees)
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40
20
0
-20
0
20
40
60
Last Month's Fire Radiative Power
Average
Upper Bound
Lower Bound

Far-Western
Karnali Prov
Province 5
Gandaki Prov
Bagmati Prov
Province 1
Province 2
(-.0062742,-.005633]
(-.0167106,-.0062742]
(-.0663695,-.0167106]
[-.1621588,-.0663695]

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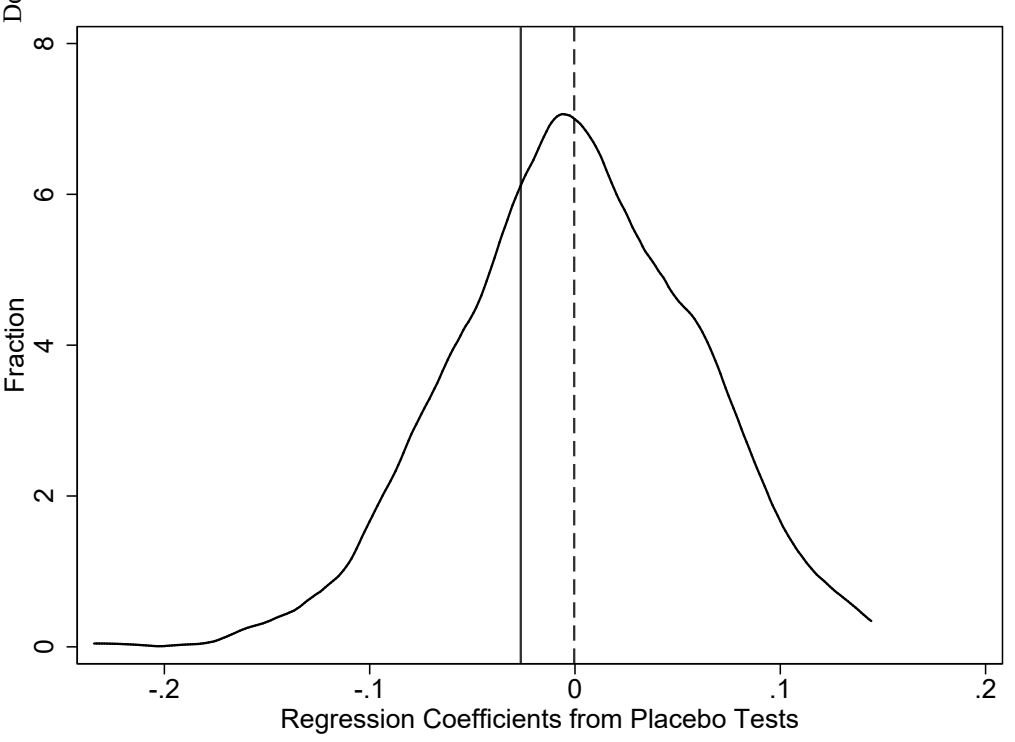
Urban
Rural
Firewood for Fuel
No Firewood for Fuel
95% CI
Average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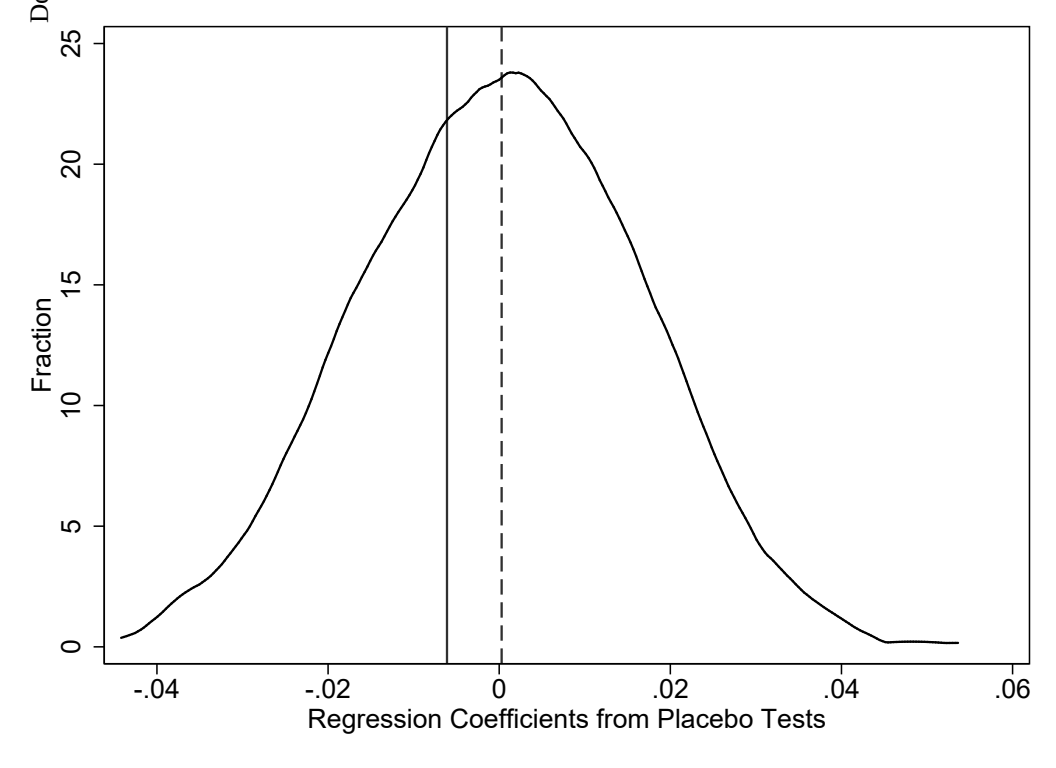
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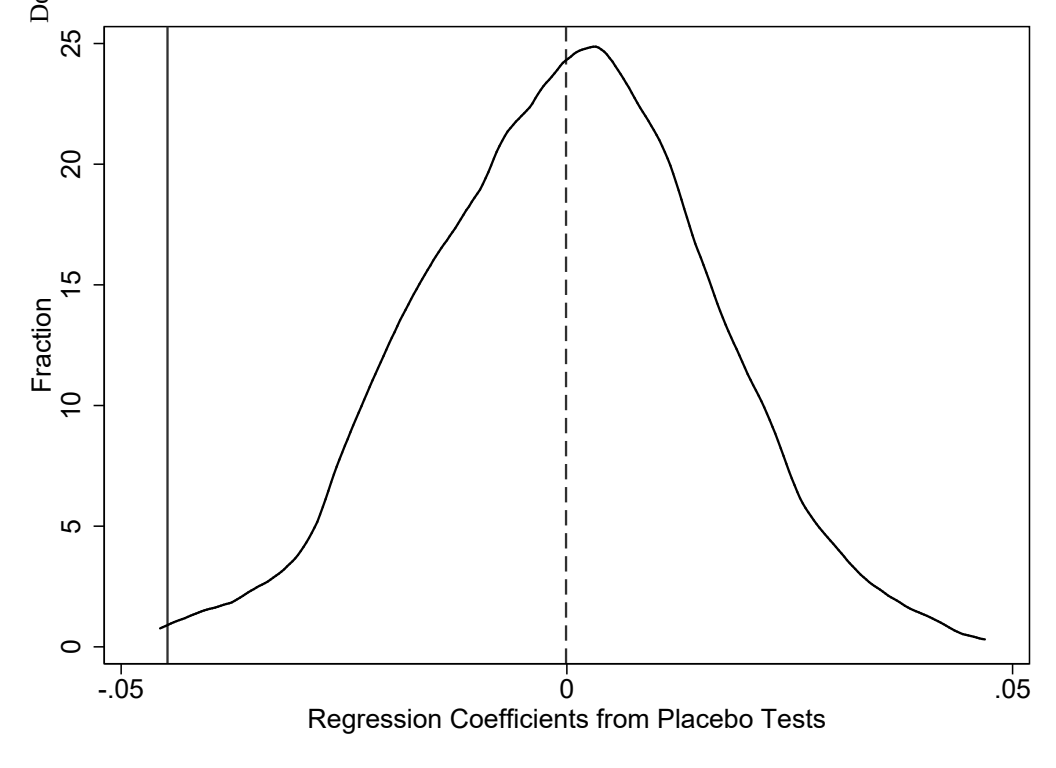
.06
Regression Coefficients from Placebo Tests


Fraction
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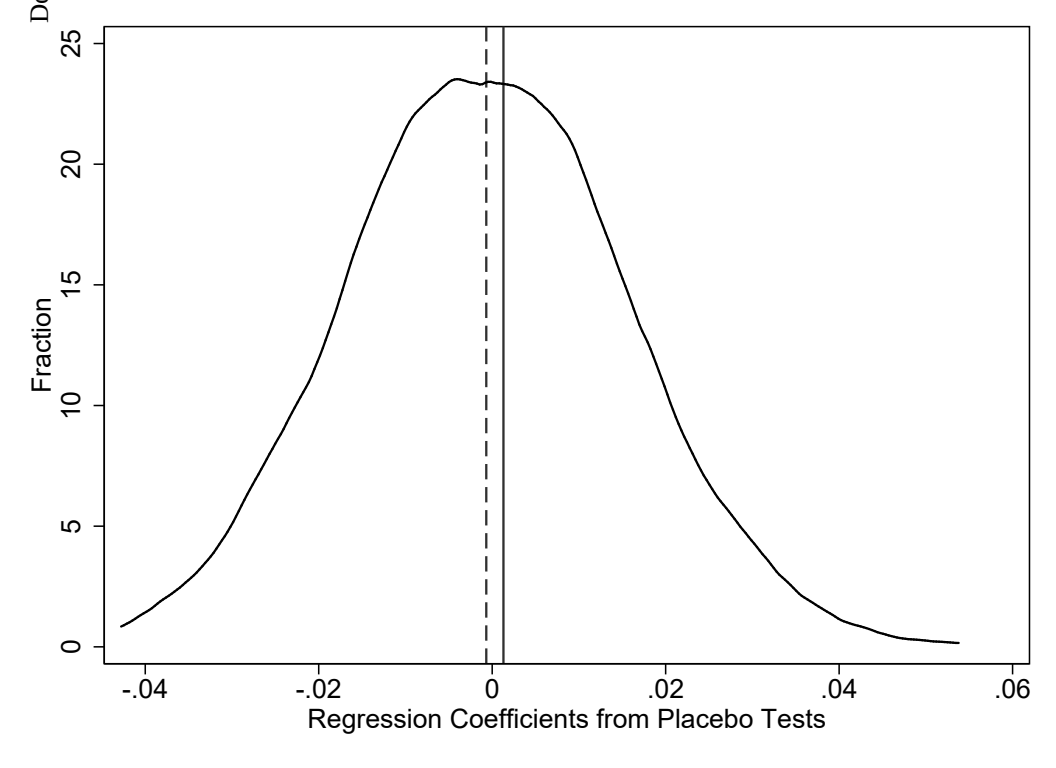
5
10
15
20
25
-.05
0
.05
Regression Coefficients from Placebo Tests


Fraction
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.04
.06
Regression Coefficients from Placebo Tests