Fertilizer Subsidy and Agricultural Productivity: Empirical Evidence from Nepal

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Subsidy and Agricultural Productivity in Nepal[†]

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Abstract

We study the impact of a government-led fertilizer subsidy program in the Hills region of Nepal that aims to enhance agricultural yield of farmers involved with subsistence agriculture. Using data from household surveys conducted before and after the program, we exploit eligibility criterion to show that the subsidy, on average, leads to a significant decrease in the use of chemical fertilizers and annual agricultural yields. Further analysis shows heterogeneity in the effect of the subsidy. Farmers with certificates of land ownership experience an increase in agricultural yield of 10.7 percentage points, and those least likely to provide proofs of land ownership report a decline in yield of 9.4 percentage points. Our results also indicate that farmers who reside within one km from the market benefit from the subsidy and report an increase in annual agricultural yield of 6 percentage points. However, the positive impact of the subsidy decreases with distance; and the effect of the subsidy is negative for farmers living more than 5 km away from the market.

Keywords: Fertilizer subsidy, Agricultural yield, Difference-in-differences, Nepal
JEL Codes: Q1, Q12 and Q18

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1 Introduction

Increasing use of modern inputs such as fertilizer has been successfully linked with agricultural productivity, specifically in the developing world (Takeshima et al., 2016). Proponents claim that there exists a strong relationship between fertilizer use and crop yields, allowing farmers to generate high returns. Carter et al. (2014) report that the introduction of improved seeds and modern fertilizers led to substantial gains in agricultural productivity during the Green Revolution. Similarly, Morris (2007) presents evidence of growth in agricultural yields in Asia and decline of yields in Africa to claim that fertilizer use is strongly associated with productivity and overall economic growth. This has further led to strong advocacy for fertilizer subsidy as a tool to increase fertilizer use among policy makers in developing countries (Sachs, 2004). There exists compelling evidence on significant use of fertilizer subsidies employed by different governments, with fertilizer subsidy constituting 1.52% of gross domestic product (GDP) in India in 2008-09 and 2% of the government's budget in Zambia in recent years (Mondiale, 2008; Paul and Hrima, 2009).

Although large scale input subsidy programs have gained popularity, several arguments against fertilizer subsidy initiatives exist in the literature (Carter et al., 2014). Notably, Schultz et al. (1964) model farmers as rational profit maximizing agents and claim that subsidies distort fertilizer use away from optimal levels. Similarly, Duflo et al. (2011) argue that fertilizer subsidy may lead to failure of supplying the right amount of fertilizer at the right time, specifically in rural areas of developing countries. It is also likely that fertilizer subsidies might turn out to be regressive, with wealthier families well-connected to the government officials benefiting more than subsistence farmers (Chibwana et al., 2010; Pan and Christiaensen, 2012; Lunduka et al., 2013). Finally, massive fertilizer subsidies may lead to overuse of fertilizers and result in negative environmental externalities (Burch et al., 2007).

Nepal's government introduced a subsidy on chemical fertilizers in 2009 for farmers that own at most 0.75 hectares (ha) of land in the Hills region and 4 ha of land in the Plains region respectively. This setting offers a unique opportunity to apply quasi-experimental techniques and identify the effect of fertilizer subsidy on agricultural productivity. In this paper, we conduct the first comprehensive investigation of the impact of the fertilizer subsidy on annual agricultural yield in the first three years of the policy implementation among 32 districts of rural Nepal. We take advantage of a rich nationwide household survey, The National Living Standards Survey (NLSS) conducted by Central Bureau of Statistics in Nepal, to evaluate the impact of fertilizer subsidy on annual agricultural productivity of rural farmers. Using this data set, we are able to compare subsidy-eligible and subsidy-ineligible farmers both before and after the introduction of the fertilizer subsidy. To control for changes in agricultural productivity caused by factors other than the fertilizer subsidy, we apply a difference-in-differences (DD) study design and account for potential confounding factors that affect both subsidy-eligible and subsidy-ineligible farmers. Our estimates provide the first comprehensive empirical assessment of the impact of the fertilizer subsidy on agricultural productivity of rural farming households in Nepal.

The empirical results show that the introduction of fertilizer subsidy is associated with a decrease in annual agricultural yields of 22.6 percentage points. We further show that the subsidy program leads to a decline of 11.1 percentage points in the use of chemical fertilizers. Our results are robust to a broad set of specification and assumption checks. Moreover, different sets of placebo tests reveal that the main effects identified in the study are driven solely by the introduction of a fertilizer subsidy. Our results also indicate that farmers residing within one km from the nearest market benefit from subsidy and experience an increase in annual agricultural yield of 6 percentage points. However, the positive impact of the subsidy program declines with an increase in distance to the nearest market; and the effect of the subsidy is negative for farmers living more than 5 km away from the nearest market.

This paper provides evidence on the role of land ownership certificates in determining the success of a government-led fertilizer subsidy program. The government stipulates that subsidy-eligible farmers present certificates of ownership with information on size of agricultural plot to claim subsidized fertilizers. We find that the lower use of chemical fertilizers is likely a result of this requirement. We offer evidence that farmers that are least likely to provide legal evidence on land ownership report a decline in use of chemical fertilizers of 19 percentage points and a loss in annual agricultural yields of 9.4 percentage points. On the other hand, farmers with certificates of land ownership experience an increase in use of chemical fertilizers of 39.3 percentage points and a gain in annual agricultural yields of 10.7 percentage points. We offer suggestive evidence that fertilizers can be costlier for subsidy-eligible farmers that fail to present certificates of ownership and reside in remote areas of the Hills region, where transportation facilities are inadequate and transportation cost is drastically high (Shrestha, 2010; FAO, 2011). Our results show that the government needs to address farmer's access to land ownership documents for effective supply of subsidized chemical fertilizers and enhanced agricultural yields.

Our work is related to a handful of recent studies that employ randomized controlled trials to evaluate the impact of an input subsidy program on crop production and fertilizer use. For example, Carter et al. (2014) assess the impact of vouchers on input use, agricultural production and different indicators of household well-being in Mozambique. According to Carter et al. (2014), the voucher experiment in Mozambique involves a subsidy for use of fertilizer and improved seeds, and leads to a significant increase in total crop production (21.6%) and per capita daily consumption (14.7%) among the treatment group. Similarly, Beaman et al. (2013) conduct a simple field experiment in southern Mali that provides free fertilizers to women rice farmers and find a massive increase of

31% in rice output. Duflo et al. (2011) also run a field experiment in rural Kenya to estimate the impact of fertilizer subsidies on fertilizer use. While they find that offering free delivery to farmers early in the season increases fertilizer use by 47 to 70 percent, they argue that behavioral biases may limit profitable investments in fertilizer by farmers in developing countries. Contrary to Duflo et al. (2011), positive effects of input subsidies in Mozabmique last up to two annual agricultural seasons after the subsidy offer (Carter et al., 2014).

This paper also contributes to the literature relying on secondary data to examine the effects of a fertilizer subsidy program on household agricultural production in the developing world. Although the results vary in magnitude, prior literature based on nationally representative household surveys in sub-Saharan Africa indicates a substantial increase in maize production among subsidy recipient households. For example, Chibwana et al. (2010) report that households that receive and use the subsidy for mineral fertilizer and hybrid maize seed increase maize production by 447 kilograms per hectare. Ricker-Gilbert et al. (2011) find that an additional kilo of mineral fertilizer increases annual maize production by 1.82 kilograms, and further claim that the positive effect is more pronounced among farmers that have received subsidies for a longer period of time. In a different study, Ricker-Gilbert and Jayne (2012) suggest that high returns from the subsidy program seem to accrue to households at the top of the maize production and value of total crop output distributions.

Recent papers that assess fertilizer subsidy programs focus on gender differences, political motives and distribution. For example, Saenz and Thompson (2017) explore the repercussions of Zambia's input subsidy program on crop allocation patterns by gender and find that subsidies on fertilizers and seeds reduce crop diversification more in male-headed households than in female-headed households. Dionne and Horowitz (2016) investigate the political effects of input subsidy programs in Malawi and report that parties that fail to target distributional programs at the local level may still derive political benefits. Mason et al. (2016) explore the political economy of fertilizer subsidy programs in Zambia to conclude that the government targeted more subsidized fertilizer to households in areas that received strong support in the previous election. Liverpool-Tasie (2014a) uses propensity score matching technique to evaluate the performance of a fertilizer voucher program in Nigeria and highlights the limitations of input programs linked with government bureaucracy. Lastly, a number of studies delve into how fertilizer subsidies affect farmer demand for commercial fertilizer and organic manures in sub-Saharan Africa (Xu et al., 2009; Ricker-Gilbert et al., 2011; Holden and Lunduka, 2012; Liverpool-Tasie, 2014b; Takeshima and Nkonya, 2014).

Finally, this paper is relevant to the broader literature seeking a better understanding of the constraints on technology adoption in agriculture. For example, Foster and Rosenzweig (2010) claim that if technological diffusion leads to development, "it must be the case that technology adoption is incomplete or the inputs associated with the technologies are under-utilized in poor, or slow-growing economies." Previous research has shown that technology adoption is largely influenced by credit constraints and insurance market failures (Gine and Klonner, 2008; Dercon and Christiaensen, 2011). Our results supplement the existing research to indicate that poor implementation of a subsidy for technology adoption leads to a significant decrease in the use of chemical fertilizers. We show that a well-intentioned government-led subsidy program that fails to address institutional factors such as availability of land certificates has a negative impact on agricultural productivity in the developing world.

This paper differs from existing literature examining the impact of fertilizer subsidies in a number of ways. First, it employs the DD approach to account for potential bias originating from time-invariant differences between subsidy-eligible and subsidy-ineligible farming households. Second, it performs different sets of placebo tests to support the validity of the methodological approach used in the study. These tests strengthen the rigor of the study and provide additional confidence in our main findings. The study also performs multiple robustness checks across different household characteristics and further investigates potential mechanisms that explain the documented effect. Finally, most recent studies on fertilizer subsidy programs have focused on countries in sub-Saharan Africa. To our knowledge, this is the first study to use rich household data from a developing country in South Asia and apply a quasi-experimental technique to evaluate the impact of a fertilizer subsidy on agricultural productivity.

The paper proceeds as follows. Section 2 gives a comprehensive overview on the development of fertilizer policy in Nepal and Section 3 presents a conceptual framework of yield response to fertilizer subsidy. Section 4 discusses the empirical model and section 5 describes data and presents the empirical findings of the study. Finally, Section 6 discusses implications of the main results and concludes.

2 Background

Nepal is a land-locked country with a total area of 147,181 square kilometers surrounded by India on three sides and China to the north (See Figure 1). According to 2011 Population Census, the population of Nepal stands at 26.6 million (NDHS, 2012). For administrative purposes, Nepal is divided into five development regions: Eastern, Central, Western, Mid-western, and Far-western. Similarly, the country is divided into 14 zones and 75 administrative districts. Districts are further divided into smaller units, called village development committees (VDCs) and municipalities (NDHS, 2012). Topographically, Nepal is divided into three distinct ecological zones: Mountains, Hills, and *Terai* (or Plains). Twenty-three percent is occupied by the Plains in the southern belt, 42 percent by the Hills in the middle belt and the remaining 35 percent by Mountains in the northern belt. According to Food and Agriculture Organization (FAO), these regions have distinct geological, soil, climatic and hydrological characteristics (FAO, 2011).

The Hills region is located between the Mountains and Plains and includes the middle mountain ranges and *Siwalik Hills*. It is located between an altitude of 700 and 4000 meters, with steeply sloped lands and small valleys. Only 10 percent of the land area is cultivated, and the climatic conditions in this region vary from subtropical to temperate (FAO, 2011). According to FAO (2011), the region has the largest share of the land area at 68 percent, and terraced farms grow a variety of crops such as rice, wheat, maize, fruits and vegetables.

Agriculture remains Nepal's principal economic activity, employing around 66 percent of the population and contributing 38.81 percent to the national GDP (FAO, 2011). Although only about 17 percent of Nepal's total land area is suitable for agriculture, the FAO report shows that the ratio of population to arable land is one of the highest in the world with an annual population percentage growth of 2 percent (FAO, 2011).

Nepal's government data show that fertilizer is expected to contribute 64% to 75% of the total agricultural growth, with a significant increase in use of fertilizers from 31 kilogram (kg) nutrients per hectare (ha) in 1995 to 131 kg nutrient per ha by 2017 (Raut and Sitaula, 2012). In addition, Takeshima et al. (2016) report that the share of farm households using inorganic fertilizers has increased from 53 percent in 1995 to 69 percent in 2010. However, according to Raut and Sitaula (2012), inadequate supply of chemical fertilizers among farmers has persisted for a long period of time even after the deregulation of the fertilizer sector in 1999. Moreover, Takeshima et al. (2016) claim that substantial growth in use of chemical fertilizers in Nepal has occurred mostly in the Terai region, with stagnated levels of fertilizer use in the Hills and the Mountains regions.

It is worth highlighting that 2009 appears to be a significant time period in the agricultural sector of Nepal. Nepal's governmental statistical database shows that annual agricultural yield in the Hills region witnessed a massive growth rate of 15% from 2009 to 2011, as reflected by a steep line in Figure 2(a). Similarly, Figure 2(b) shows that total fertilizer sales in 2010 appears to be slightly lower than those in 2003 and 2004 respectively. Finally, Figure 2(c) shows that price per unit of urea (Rs. / Mt.) appears to display a less volatile pattern, with the presence of a flat line from 2009 onward. These figures strengthen the need to perform a rigorous evaluation of the impacts of the fertilizer subsidy implemented in 2009.

2.1 History of Fertilizer Policy

Mujeri et al. (2012) report that the fertilizer sector development and relevant policy interventions in Nepal can be broadly divided into three phases. Phase I (before 1974) involves the introduction of fertilizers in Nepal in early 1950s. While the level of fertilizer use was low, small quantities of ammonium sulphate mostly came through imports from India and Russia respectively (Shrestha, 2010). This led to the establishment of a government-led enterprise, Agriculture Input Corporation (AIC), that imported fertilizers from the global market and distributed them throughout the country. In response to growing demand for fertilizers, the government implemented non-uniform pricing of fertilizers, with higher per unit price in the Hills region than in the Terai region to account for high transportation costs. As the global price of fertilizers rose, the government ensured that farmers in the Hills region received fertilizers at a price below the actual cost and those in the Terai region paid more than the actual cost to offset the cost of transportation (Shrestha, 2010; Mujeri et al., 2012).

Phase II encompasses the fertilizer subsidy regime from 1974 to 1996 in response to a significant increase in global fertilizer prices. According to Shrestha (2010), the objective of government-led subsidy policy was twofold. First, the government aimed to enhance access to fertilizers at a lower price. Second, it kept the price of fertilizer at least 15 percent higher than in India to discourage the export of fertilizers from Nepal to India. As the demand for fertilizers escalated and continuous rise in fertilizer prices persisted, the government faced massive financial burden. Consequently, farmers started to queue up in the retail outlets, as AIC failed to import fertilizers to meet an increasing demand (Shrestha, 2010; Mujeri et al., 2012). Since then, Nepal has received fertilizers under large grants from countries such as Germany, Canada, Japan and Finland. Shrestha (2010) reports that some countries stopped supplying fertilizers to Nepal after 1991, while others reduced the volume of exports.

Phase III, which began in 1997, involves the end of AIC monopoly in fertilizer trade and the beginning of the government's decision to deregulate the sector. In addition to the government's failure to make adequate subsidy allocation and address a large decline in fertilizer supply, the impetus behind deregulation turned out to be the Asian Development Bank's (ADB) condition for Second Agriculture Production loan (Shrestha, 2010). The deregulation led to the phase-wise removal of subsidies for Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP). Shrestha (2010) explains that the complete removal of subsidy in November 1999 entailed (a) allowing the private sector to import and distribute the fertilizers and (b) phasing out of fertilizer subsidies and deregulating fertilizer prices.[1] Subsequently, the government promulgated Fertilizer Control Order (FCO) in 1999 to ensure quality control in fertilizer production. It also formulated National Fertilizer Policy (NFP) in 2002 to ensure the supply of good quality fertilizers and promote integrated plant nutrient management system (IPNS) for efficient and balanced use of fertilizers (Shrestha, 2010; FAO, 2011).

Even after the adoption of fertilizer deregulation policy in 1997, the Agriculture Input Company Limited (AICL) and private traders suffered from price fluctuations in the overseas market, leading

[1] Shrestha (2010) points out that although price subsidy was eliminated, transport subsidy continued for selected districts of Hills region for sometime.

to a large decrease in supply of fertilizers.[2] Shrestha (2010) claims that farmers instead resorted to adulterated substandard fertilizers easily available in the markets. Overall supply of fertilizers in remote areas deteriorated further, as transportation cost is substantially higher in the hilly areas.

2.2 Current Fertilizer Policy

In response to failure of the deregulation policy to address access to fertilizers and agricultural productivity, the government began to review and revise the existing policy framework (Mujeri et al., 2012). In November 2008, the Ministry of Agriculture and Cooperatives (MOAC) forwarded the proposal to review the fertilizer policy to the Council of Ministers (COM). The COM subsequently approved the proposal to provide support for chemical fertilizers targeting small and marginal farmers. As a result, the government reinstated the provision of fertilizer price subsidy in March 2009 for a maximum of 100,000 metric ton per year (Shrestha, 2010). Based on the subsidy policy, farmers that own at most 0.75 ha of agricultural land in the Hills region and 4 ha in Terai region are eligible to receive subsidized fertilizers for three crops a year.[3] The policy mandates that the government grants 58% subsidy on urea, 38% on DAP and 2 percent on potassium. Table 1 provides nationwide sales of chemical fertilizers and the amount of subsidy allocated by the government. According to Shrestha (2010), the current government policy prohibits private sector businesses from taking part in distribution and sales of chemical fertilizers.

Shrestha (2010) discusses the characteristic features of the government's fertilizer subsidy policy. The policy mandates that the price of fertilizers procured under the import parity price (IPP) scheme would be fixed between 20 to 25 percent higher than the price prevailing on the Indian side of the border for five import points - Biratnagar, Birgunj, Bhairahawa, Nepalgunj and Dhangadi. According to FAO (2011), the Government of Nepal allocates U.S. $20 million every year to cover this price differential. The subsidy does not account for transportation costs (Shrestha, 2010). Given that the government has taken sole responsibility in procuring and distributing chemical fertilizers since 2009, there currently exists no private sector business involved with the supply chain. To implement the policy effectively, the Fertilizer Supply and Distribution Management Committee, headed by the Chief District Officer, facilitates the affairs related to supply and distribution of subsidized fertilizers at the district level (Shrestha, 2010). AICL distributes and sells the subsidized fertilizers to private shops, cooperatives and consumers. The Ministry of Agricultural Development reports that primary sources of fertilizers for farmers

[2] AIC was terminated to form two companies, (a) AICL responsible for fertilizer business and (b) National Seed Company Limited (NSCL) responsible for seed business.

[3] According to Ministry of Agricultural Development, the government didn't impose the maximum limit of 100,000 metric ton a year from 2010 onward. It is also worth noting that the government implemented a nationwide 50% subsidy on organic fertilizers in 2016 (Ministry of Agricultural Development, 2017).

have remained the same before and after the policy change in 2009. Table 2 shows the percentage distribution of chemical fertilizer sources across three ecological zones of Nepal. These sources include government offices, non-governmental organizations (NGOs), private shops and cooperatives. Farmers need to present certificates of land ownership (*"Lalpurja"*) to obtain subsidized chemical fertilizers from these sources.[4] Such certificates include owner name and photograph, contact information and amount of agricultural plot.

3 Theoretical Framework

We assume that agricultural yield (y) is a function of input variables (x) that are under the farmer's control and exogenous variables (Z) that are beyond the farmer's control. Consistent with Xu et al. (2006), the yield response function can be written as below:

$$y = f(x_i, Z), i = 1, ...n \tag{3.0.1}$$

where y is the stochastic crop yield, x_i is the ith input variable and Z represents a vector of exogenous variables. In the context of this study, assume that the government intervenes and implements a financial incentive scheme for an agricultural input, say fertilizers. Following Sumelius et al. (2003), the farmer's expected profit maximizing decision under a subsidy of k_i for ith agricultural input can be written as:

$$\underset{x_i}{\text{Max}} \quad pE(y) - \sum_{i=1}^{n} w_i(1 - k_i)x_i \quad \text{subject to} \quad x_i \geq 0 \tag{3.0.2}$$

where p is the output price, w_i is the ith input price, and E is the expectation operator. Assuming that the yield response function is strictly concave with diminishing marginal product of input i (see Figure 3), the first order condition for the optimal level of input i can be written as:

$$\frac{\partial E(y)}{\partial x_i} = \frac{w_i(1 - k_i)}{p} \tag{3.0.3}$$

As explained in Ricker-Gilbert et al. (2009), Figure 3 shows that point A gives the profit maximizing level for a farmer who doesn't use any fertilizer and point B gives the profit maximizing level of fertilizer for a farmer who uses some positive quantity of fertilizer. Note that the tangent line to the production function gives the ratio of input (fertilizer) price and output (crop yield) price. In addition, (3.0.3) shows that offering fertilizers to farmers at a subsidized rate

[4] Sources of fertilizers are usually closed on Saturdays. Farmers are able to obtain subsidized fertilizers six days a week.

lowers the input output price ratio, suggesting that farmers initially at point B may apply more fertilizer and attain point C in the production function curve (Ellis, 1992; Ricker-Gilbert et al., 2009). Based on this figure, we expect that fertilizer subsidy will lead to higher agricultural productivity.

The factors that determine agricultural yield are conditioned on variables such as farmer's ability, risk aversion and land tenure status (Ricker-Gilbert et al., 2009). We take these factors into account by including socioeconomic and demographic characteristics that capture household's preferences, experience and the ability to enhance crop production. Specifically, we control for specific socioeconomic and demographic backgrounds such as age, gender, caste, religion affiliation and educational status of the household head, household size and land tenure status (Lise, 2000; Adhikari et al., 2004; Dolisca et al., 2006; Torgler et al., 2011). These household controls are particularly important as Oli and Treueb (2015) have found that age of the household head has a significant role in making decisions on household economic activities and that men are more likely to participate in extra household activities in the patriarchal Nepalese society. Moreover, there is well-established literature on the linkage between age of the household head and crop production and diversification (Gauchan et al., 2005; Birol and Villalba, 2008). According to Gauchan et al. (2005), gender composition influences crop production through the channel of household's "preferences for consumption and production and experienced level of cultivation." Similarly, education is positively associated with a household's ability to obtain information on farming practices and to enhance crop diversification (Saenz and Thompson, 2017).

In addition, we employ household size as a proxy for household's labor availability for agricultural activities (Jayne and Shipekesa, 2012). Among wealth-related variables, increase in remittances of a household most likely intensifies household's crop production and propensity to engage in other activities (Saenz and Thompson, 2017). Consistent with Gauchan et al. (2005), we put emphasis on wealth-related variables that affect crop diversity through their "association with larger farm sizes and ability to bear risk." We, therefore, include remittance and loan status, ownership of livestock and agricultural land, number of rooms in the house, area of housing plot, sales price of the house and monthly consumption of food and non-food items as control variables.

Finally, we account for distance to the nearest market and agricultural expenditure in the main empirical specification. Gauchan et al. (2005) explain that distance from the homestead to the market is "a major component of the cost of engaging in market transactions." More recently, Saenz and Thompson (2017) argue that distance, a proxy for transportation costs, is likely to have a positive relationship with crop diversification. We also control for household expenditure allocated towards purchase of agricultural items.

4 Empirical Specification and Identification Strategy

The main challenge for identification is that the fertilizer subsidy program was launched across the entire nation at a time of growing political stability with the end of the Maoist insurgency and the fall of the 238 years-old monarchy. Thus, the large increases (or decreases) in agricultural yields could simply reflect broader trends and may not be caused by the subsidy program. The study addresses this identification challenge by employing a double difference strategy using a large representative household survey conducted in 2003, 2004, 2010 and 2011.

4.1 Identification

To estimate the effect of the fertilizer subsidy on agricultural productivity, this study uses a difference-in-differences (DD) approach. The approach employs subsidy-ineligible farmers in the Hills region as controls, and compares changes in annual agricultural yield of subsidy-eligible farmers to changes in annual agricultural yield of ineligible farmers before and after the subsidy policy change. The farmers ineligible for the subsidy program serve as an especially useful comparison group because they would have been exposed to all the other changes that were taking place in the Hills region during the period of interest (such as policies aimed to increase household incomes and enhance public investment in agriculture). This allows one to take into account the fact that any observed change in the agricultural outcome of eligible farmers might be driven by trends or other events happening in the Hills region of the country. The study estimates the following equation to identify the effect of being eligible to receive fertilizers at a lower price:

$$\ln Y_{ijk} = \beta_0 + \beta_1 Elig_{ijk}.Post_{ijk} + \beta_2 Elig_{ijk} + \beta_3 Post_{ijk} + \mathbf{X}'_{ijk}.\beta_4 + u_{ijk} \quad (4.1.1)$$

where $\ln Y_{ijk}$ is the log transformation of annual agricultural yield (kg) per ha of agricultural land for household i living in a village j located at a district k, $Elig_{ijk}$ is a dummy equal to 1 for subsidy-eligible farming households, $Post_{ijk}$ is a dummy equal to 1 for the period of fertilizer subsidy introduction i.e. 2010 and 2011, and X_{ijk} is a vector of household controls. Household controls include household size, area of housing plot, number of rooms in the house, sale value of the house, ownership of agricultural land and livestock, outstanding loan, receipt of remittance, distance from the house to the nearest market, average monthly food and non-food consumption, adequacy of food consumption, annual expenditure on fertilizers and other agricultural inputs. Similarly, household head characteristics include age, gender, education status, caste status, religion and native language type. In addition, the controls include district-level dummies to account for geographical heterogeneity and unobserved fixed factors at the district level such as political power and institutional strength. The specification also includes month and day dummies to account for survey interview fixed effects. The main parameter of interest is β_1 (the double-difference estimate), which measures the change in outcomes of subsidy-eligible farming households with respect to subsidy-ineligible farming households in the Hills region.

5 Data and Results

The core analysis of the paper is based on the Nepal Living Standards Survey 2010-11 (NLSS III) and 2003-04 (NLSS II) conducted by Central Bureau of Statistics.[5]

Figure 4 shows the kernel density plot of annual log agricultural yield (kg / ha) among farming households belonging to the treatment and control group before and after the subsidy program. Overall, there is no substantial change in the distribution of annual agricultural yield in the control cohort before and after the subsidy program. However, it is striking that the distribution of annual agricultural yield in the treatment cohort shifts to the left after government's decision to subsidize chemical fertilizers.

Table 3 provides sample means of the outcome and control variables for both treatment and control groups before the introduction of fertilizer subsidy. From the summary statistics, we see some significant differences between subsidy-eligible and subsidy-ineligible farmers in the Hills region before the introduction of fertilizer subsidy (hereafter "pre-treatment"). For example, the control group has a much larger share of households that speak Nepali as mother tongue, belong to high caste group, own livestock and have received remittance in the past. We account for these differences by estimating Eq. (4.1.1) with a progressively rich set of controls for demographic, socioeconomic, and district characteristics. We show β_1 in each of these specifications, but focus our discussion on specifications with the full set of household controls, district dummies and interview month and day dummies.

5.1 Parallel paths assumption

The DD strategy requires that annual agricultural yields of subsidy-eligible and subsidy-ineligible farmers in the Hills region evolve in a parallel way in absence of the introduction of fertilizer subsidy. Figure 5 plots the average annual yield over time among subsidy-eligible and subsidy-ineligible farmers to test the validity of the parallel paths assumption. The figure clearly shows similar trend in annual yield for both groups of households before the subsidy program.

[5]Central Bureau of Statistics conducted NLSS III from February 2010 to February 2011 and NLSS II from January 2003 to April 2004. For the NLSS III and NLSS II sample selection, seventy five districts were grouped into fourteen strata: mountains, urban areas of the Kathmandu valley, other urban areas in the hills, rural eastern hills, rural central hills, rural western hills, rural mid-western hills, rural far-western hills, urban Terai, rural eastern Terai, rural central Terai, rural western Terai, rural mid-western Terai, and rural far-western Terai.

We formally test the parallel paths assumption by testing for differences in pre-treatment trends of annual yields between treatment and control groups. In the first specification, the coefficient on *Year X Subsidy-eligible* measures the pre-treatment yearly trend for subsidy-eligible farmers compared to subsidy-ineligible farmers (Column (1), Table 4). Similarly, in the second specification, the coefficient on *Month X Subsidy-eligible* measures the pre-treatment monthly trend for subsidy-eligible farmers compared to subsidy-ineligible farmers (Column (2), Table 4).

In both specifications, the coefficient on the interaction term is small and not statistically significant, showing that the trend in annual agricultural yield is not statistically different between subsidy-eligible and subsidy-ineligible cohort before government's decision to subsidize chemical fertilizers. We therefore fail to reject the null hypothesis of parallel paths. Given that the parallel paths assumption holds, the double-difference estimates provide an unbiased estimate of the impact of fertilizer subsidy program on farmer's annual agricultural yield.

5.2 Impact of subsidy on agricultural productivity

Table 5 presents the results on impact of the fertilizer subsidy on annual agricultural yield of farmers in the Hills region. The coefficient on *Subsidy-eligible X Post subsidy* measures the change in agricultural yields for subsidy-eligible farmers compared to subsidy-ineligible farmers and is therefore the one that interests us. In the basic DD specification in column (1), this coefficient is highly significant and shows that subsidy-eligible farmers in the Hills region have a significant decrease in the annual agricultural yield with respect to subsidy-ineligible farmers. Accounting for control variables and additional interview fixed effects, we find slightly smaller negative estimates. Columns (2), (3) and (4) show that the coefficients on the interaction term are -0.209, -0.225 and -0.189 respectively. Finally, column (5) additionally controls for the unobservable district-level heterogeneity by including district fixed effects. This is our preferred specification, and confirms the previous finding: there is a significant decrease in the annual agricultural yield of eligible farmers compared to ineligible counterparts after the introduction of fertilizer subsidy. The magnitude of the coefficient implies a sizable decrease in the annual agricultural yield of 22.6 percentage points after the subsidy program.

5.3 Impact of subsidy on fertilizer usage

Fertilizer usage is one of the primary channels by which the subsidy can affect agricultural yield of the farmers. We expect that farmers eligible for the subsidy can purchase chemical fertilizers at lower cost, and would therefore increase their use of chemical fertilizers. To further investigate lower agricultural productivity among subsidy-eligible farmers, we explore the effect of the subsidy on the use of chemical fertilizers in Table 6.

Panel A shows that the log amount of organic and chemical fertilizer applied (kg / ha) is significantly higher among subsidy-eligible farmers, with a substantially high coefficient of 0.109 in the interaction term in our preferred specification (column (5)). The positive effect of fertilizer usage, as shown by the coefficient of the interaction term, is consistent across different specifications (from column (2) to column (5)). However, when we restrict the analysis to use of chemical fertilizers alone, we find the opposite effect. The log amount of chemical fertilizers applied is significantly lower among subsidy-eligible farmers, with a statistically significant coefficient of -0.111 in the interaction term in our preferred specification (Panel B, column (5)). These estimates show that total use of chemical fertilizers among subsidy-eligible farmers has declined after the subsidy.

Given that the subsidy is designed for chemical fertilizers only, our results suggest that decrease in agricultural yields of subsidy-eligible farmers might be attributable to reduced use of chemical fertilizers. Consistent with our finding, Takeshima et al. (2016) report that total chemical fertilizer use in the Hills region has stagnated. There also exists well-documented evidence on acute shortage of chemical fertilizers during the peak season of farming in the Hills region of Nepal (Himalayan Times, 2015; Nepal Republic Media, 2016; Ministry of Agricultural Development, 2017). Moreover, estimates suggest that the government is currently able to meet only 57% of the overall demand for chemical fertilizers.[6]

5.4 Requirement of land ownership certificates

To understand why fertilizer subsidy may have led to a decrease in agricultural yield, we explore the requirement of land ownership certificates to obtain subsidized fertilizers. The government stipulates that subsidy-eligible farmers present certificates of land ownership to claim subsidized fertilizers. Such certificates, known as *"lalpurja"*, include the following information: name, contact information and photograph of the owner as well as details of the agricultural plot owned. Subsidy-eligible farmers that possess certificates of land ownership can purchase chemical fertilizers at lower cost. However, those who have no official documentation of ownership cannot receive the subsidy despite being eligible on the basis of plot size.

To further investigate lower use of chemical fertilizers among subsidy-eligible farmers, we categorize farmers into two groups: (a) farmers that have land ownership certificates and (b) farmers that are least likely to have land ownership certificates.[7]

[6] According to Ministry of Agricultural Development (2017), annual demand for chemical fertilizers is approximately 785,000 Mt., but the government is able to allocate subsidy for a maximum of only 270,000 Mt. of chemical fertilizers.

[7] The survey does not directly ask the households whether they have certificates of land ownership. Instead, it asks the households whether they have used land and property ownership documents as collateral to secure the loan to purchase agricultural inputs. By definition, households that present such documents have certificates of ownership.

Table 7 breaks down the impact of the fertilizer subsidy on fertilizer usage and agricultural yield for two categories of households above. Panel A shows that the log amount of total chemical fertilizer applied (kg / ha) is significantly lower among subsidy-eligible farmers with no land ownership certificates, with a substantially low coefficient of -0.190 in the interaction term in our preferred specification (column (4)). This means that farmers that are least likely to provide legal evidence on land ownership report a decline in use of chemical fertilizers of 19 percentage points. Similarly, they experience a loss in annual agricultural yields of 9.4 percentage points. On the other hand, panel B shows that farmers with certificates of land ownership are more likely to use chemical fertilizers by 39.3 percentage points (column (4)), suggesting that proof of land ownership is a crucial factor in the success of the fertilizer subsidy program. Moreover, the subsidy, on average, leads to an increase in annual agricultural yields of 10.7 percentage points among farmers with certificates of land ownership. These estimates show that total use of chemical fertilizers and annual agricultural yields have improved among subsidy-eligible farmers that are able to present certificates of land ownership. These results suggest that the government needs to address farmer's access to land ownership documents to ensure the success of the subsidy program.

5.5 Treatment effect among different sub-groups

We evaluate the impact of the fertilizer subsidy program among households of different socioeconomic status and demographic characteristics. Prior studies have highlighted the need to perform treatment effect across different population sub-groups in a developing country setting. For example, there exists substantial evidence that fertilizer subsidies might turn out to be regressive, with wealthier families well-connected to the government officials benefiting more than subsistence farmers (Chibwana et al., 2010; Pan and Christiaensen, 2012; Lunduka et al., 2013; Sibande et al., 2015). Previous literature has also shown that lower caste households participate relatively less in social activities (Agrawal and Gupta, 2005; Maskey et al., 2006). Moreover, Oli and Treueb (2015) explain that men in rural Nepal are considered responsible for village development and governance, and women are disinclined to participate. Finally, gender inequality in agriculture involves issues such as control over resources, decision-making and labor requirements (Saenz and Thompson, 2017).

To empirically test the claims made in prior literature, we perform the treatment effect analysis for four specific groups: (a) high caste households, (b) non-high caste households, (c) male-headed households and (d) female-headed households. We estimate the DD specification similar to Eq. (4.1.1) in Table 8, accounting for control variables and additional fixed effects. Columns (1),

Similarly, it is fair to assume that those households that fail to provide any land ownership documents as collateral to secure the loan are least likely to have certificates of land ownership.

(2), (3) and (4) show that the coefficients on the interaction term are negative and statistically significant, with more pronounced impact among female-headed households (-0.391) and high caste groups (-0.337). Contrary to the notion that female-headed households are less responsive to the subsidy program (Saenz and Thompson, 2017), our results suggest otherwise. Although Saenz and Thompson (2017) report that male and female farmers in Zambia traditionally grow different crops resulting in differential response to the subsidy program, we find no significant difference in DD estimates of annual yield between male-headed and female-headed farming households. While estimates among non-high caste groups are statistically insignificant, results in Table 8 show that overall negative treatment effect estimates are robust across households of different observable characteristics.

We also evaluate heterogeneous treatment effects across farmers belonging to three groups: (a) those living within 1 km of the market, (b) those living between 1-5 km of the market and (c) those living more than 5 km away from the market. To determine whether DD estimate among subsidy-eligible farmers living closer to the market is significantly higher than that among subsidy-eligible farmers who live further away, we are interested in the coefficients of the triple interaction terms in Table 9. Columns (1), (2), (3), (4) and (5) show that the coefficients on the first triple interaction term are 0.656, 0.587, 0.538, 0.639 and 0.343 respectively. The estimate in our preferred specification (5) indicates that the eligible farmers residing within one km from the nearest market experience an increase in annual agricultural yield of 6 percentage points after the subsidy program compared to ineligible counterparts.

We further find that the DD estimates for farmers living between 1-5 km of the market are strikingly lower than those for farmers living within 1 km of the market, suggesting that the positive effect of fertilizer subsidy on agricultural yield decreases with an increase in distance. Columns (1), (2), (3), (4) and (5) show that the coefficients on the second triple interaction term are 0.218, 0.185, 0.159, 0.229 and 0.166 respectively. While these estimates are not statistically significant, their magnitude relative to the first triple interaction term suggests that the positive effect of fertilizer subsidy on agricultural yield decreases with an increase in distance. Table 9 also indicates that negative average treatment effect estimates reported in Table 5 are mostly explained by farmers living more than 5 km away from the market. The coefficients of the double interaction term (Post subsidy X Subsidy-eligible) range from -0.402 to -0.283 across all possible specifications, and are statistically significant at the 5% level.

Finally, Figure 6 plots the DD estimates against distance and shows that the positive effect of the subsidy is pronounced among farmers that live within 1 km from the market, and the impact starts to decrease as distance to the market increases. While the reason for this effect needs to be studied further, these estimates suggest that complementary policies aimed at improving the ability of farmers to gain access to chemical fertilizers may improve agricultural productivity in a developing country setting.

5.6 Robustness Checks

This section discusses various robustness checks to further validate the findings shown in the previous section. We perform multiple placebo tests to show that the primary impact of fertilizer subsidy on agricultural productivity is directly attributable to the government's subsidy on chemical fertilizers. These results strengthen the validity of the identification strategy employed in this study.

5.6.1 Placebo tests

As further check that changes in annual agricultural yield are directly attributable to fertilizer subsidy, we run five different sets of placebo tests in the study. We provide discussion of each set of placebo test below:

First, we assign the treatment of subsidy to farmers in the Hills region during the pre-treatment period. Specifically, we test whether there is any differential effect on annual agricultural yield for subsidy-eligible farmers in the first seven months compared to the last seven months in the pre-treatment regime. This allows us to check if changes in agricultural productivity began before the implementation of fertilizer subsidy. We find that there is no significant change in the annual agricultural yield of subsidy-eligible farmers before the start of the fertilizer subsidy program in the Hills region of Nepal. Estimates in Panel A (Table 10) show that the coefficient on the interaction term is quite small and not significantly different from zero. This strengthens the claim that change in annual agricultural yield for subsidy-eligible farmers is not potentially driven by events that happened before the implementation of fertilizer subsidy.[8]

Second, we assign fake treatment of subsidy to farmers in the Mountains region, where the government didn't implement any fertilizer subsidy policy change. Specifically, we investigate if there exists any differential impact on annual agricultural yield between subsidy-eligible farmers and their counterparts in the Mountains region. Estimates in Panel B (Table 10) show that the coefficients on the interaction term are statistically insignificant, suggesting that there is no impact on agricultural productivity of farmers in the Mountains region.

Third, we assign fake treatment of subsidy to farmers in the Plains region during the pre-treatment period.[9] Similar to the first placebo test, we assign false treatment of fertilizer

[8]We also ran a similar DD exercise with log amount of fertilizer applied (kg / ha) as an outcome variable for additional robustness check, and found no differential change. This gives us more confidence that change in fertilizer use among subsidy-eligible farmers didn't begin before the actual subsidy implementation in March 2009. Results are available upon request.

[9]Note that we can't use data for farmers in the Plains region from 2010 and 2011 because the government

subsidy to farmers with at most 0.75 ha of agricultural land in the Plains. Consistent with prior findings, we don't find any statistical significance on the interaction term across different empirical specifications (Panel C, Table 10). As expected, we don't observe any significant effect on annual agricultural yields among farmers in the Plains region.

Fourth, we use multiple false subsidy eligibility criteria in the Hills region to perform additional placebo tests. These tests define subsidy eligibility in the following way: (a) eligible for subsidy if farmer owns at most 0.65 ha of land, and ineligible if farmer owns between 0.65 and 0.75 ha of land, (b) eligible for subsidy if farmer owns at most 0.55 ha of land, and ineligible if farmer owns between 0.55 and 0.75 ha of land, (c) eligible for subsidy if farmer owns at most 0.45 ha of land, and ineligible if farmer owns between 0.45 and 0.75 ha of land, (d) eligible for subsidy if farmer owns more than 0.85 ha of land, and ineligible if farmer owns between 0.75 and 0.85 ha of land, (e) eligible for subsidy if farmer owns more than 0.95 ha of land, ineligible if farmer owns between 0.75 and 0.95 ha of land and (f) eligible for subsidy if farmer owns more than 1.5 ha of land, ineligible if farmer owns between 0.75 and 1.5 ha of land. Using each subsidy eligibility criterion, we estimate treatment effect (Table 11) and don't find any statistical significance in the interaction term.

Finally, we show that estimating our main specification but using 2011 as the "post" year and 2010 as the "pre" year does not lead to significant and negative coefficients (Table 12). Our results are also robust to the use of flexible controls for household demographics and additional fixed effects. These sets of placebo tests strengthen the rigor of our identification strategy, and provide additional confidence that main treatment effect results are directly linked with the implementation of the fertilizer subsidy program in the Hills region of Nepal.

6 Discussion and Conclusion

This paper is the first empirical investigation of the impact of a government-led fertilizer subsidy program on annual agricultural yield in Nepal. We employ the difference-in-differences approach to find that the introduction of fertilizer subsidy leads to a significant decrease in annual agricultural yield of 22.6 percentage points and a sizable decline in chemical fertilizers usage of 11.1 percentage points respectively. Our results are robust to a broad set of specification and assumption checks. We also perform different sets of placebo tests to show that the main effects identified in the study are driven solely by the introduction of a fertilizer subsidy. Our results also indicate that farmers residing within one km from the market benefit from subsidy and experience an increase in annual agricultural yield of 6 percentage points. However, the positive impact of

introduced a subsidy on chemical fertilizers for farmers that own at most 4 ha of agricultural land in the Plains region. We also don't have data on farmers belonging to the subsidy-ineligible group ($>$ 4 ha) in the Plains region.

the subsidy program declines with an increase in distance to the nearest market; and the effect of the subsidy is negative for farmers living more than 5 km away from the nearest market.

This study also delves into potential mechanisms that explain the failure of the well-intentioned subsidy program. Specifically, we provide evidence on the role of land ownership certificates in determining the success of a government-led fertilizer subsidy program. As the government stipulates that subsidy-eligible farmers present certificates of land ownership to claim subsidized fertilizers, we find that the lower use of chemical fertilizers is likely a result of farmer's inability to provide such certificates. Our results indicate that farmers with certificates of land ownership experience an increase in use of chemical fertilizers of 39.3 percentage points and a gain in annual agricultural yields of 10.7 percentage points. On the other hand, farmers that are least likely to provide legal evidence on land ownership report a decline in use of chemical fertilizers of 19 percentage points and a loss in annual agricultural yields of 9.4 percentage points. These results show that the government needs to address farmer's access to land ownership documents for enhanced supply of subsidized chemical fertilizers and improved agricultural yields. Our regression estimates are, however, subject to the usual caveat - particularly important in developing countries - that we assume no significant differences in time-variant unobservable characteristics between subsidy-eligible farmers and their counterparts.[10] While we are not able to formally test whether time-varying unobservables affect yield differently for both groups, such concerns appear to be more pronounced in the Plains region than in the Hills region (Ministry of Agricultural Development, 2017).

The findings of the paper are important as they provide rigorous evidence that a fertilizer subsidy, when coupled with the government's absolute involvement in the distribution of chemical fertilizers, leads to perverse outcomes for rural farmers with no certificates of land ownership. Previous literature has claimed that low agricultural productivity has contributed to poverty persistence in agriculture-based countries (Christiaensen, 2007; Morris, 2007; Dercon and Christiaensen, 2011). This paper does not intend to suggest that all agricultural input subsidies lead to adverse outcomes among rural farmers. If anything, we believe a vibrant discussion on implementing agricultural policies effectively should be encouraged among policy makers since it appears from our study that fertilizer subsidy of the type instituted in rural Nepal can be ineffective. Our findings underscore the importance of taking into account farmer's access to land ownership documents when formulating fertilizer subsidy policies in developing countries.

[10]Unobservables include access to better technology and improvement in soil fertility over time.

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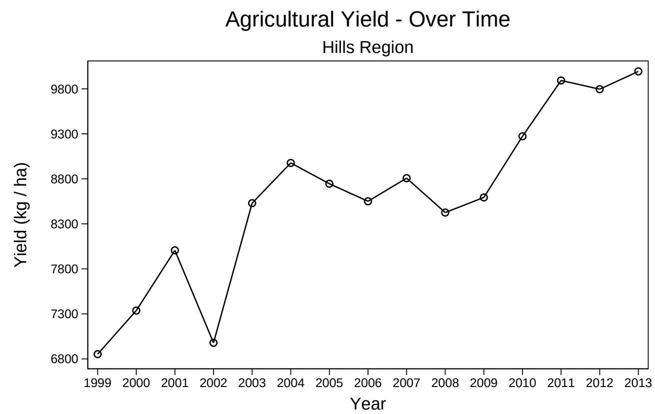
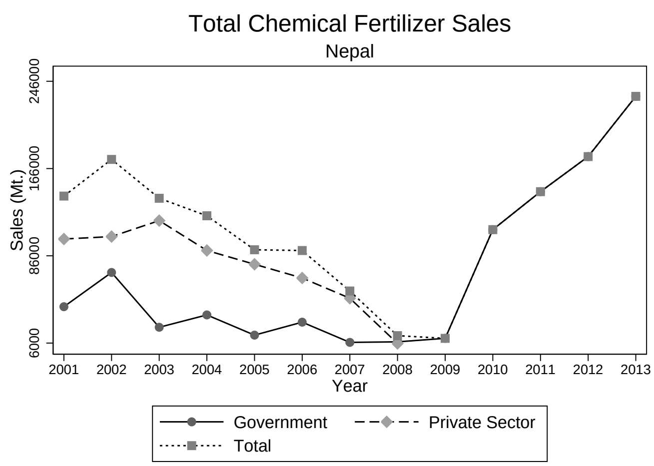
Figure 1: Map of Nepal

Source: Nepal Demographic and Health Surveys (NDHS) 2011 report. See NDHS (2012) for more details.

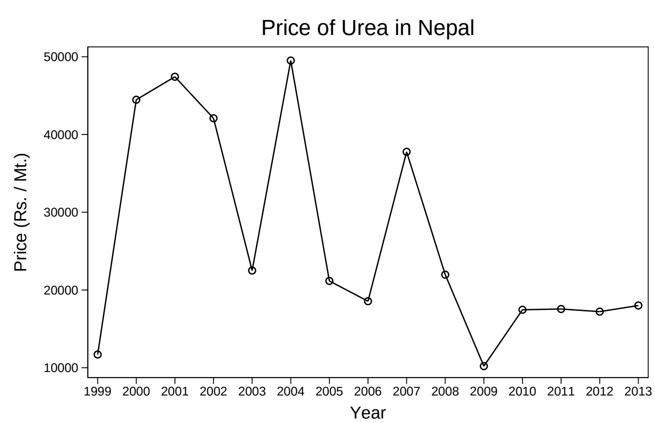
Figure 2: Annual agricultural yield, chemical fertilizer sales and prices over time



(a) Total agricultural yield (kg / ha) in the Hills region



(b) Total chemical fertilizer sales



(c) Inflation-adjusted Prices of Urea in Nepal

Notes: (a) accounts for yield in paddy, maize, millet, wheat and barley. (b) includes total chemical fertilizer sales from both private sector and Agriculture Input Company Limited (AICL). For more details, see Ministry of Agricultural Development (2014).

Figure 3: Yield response to fertilizer

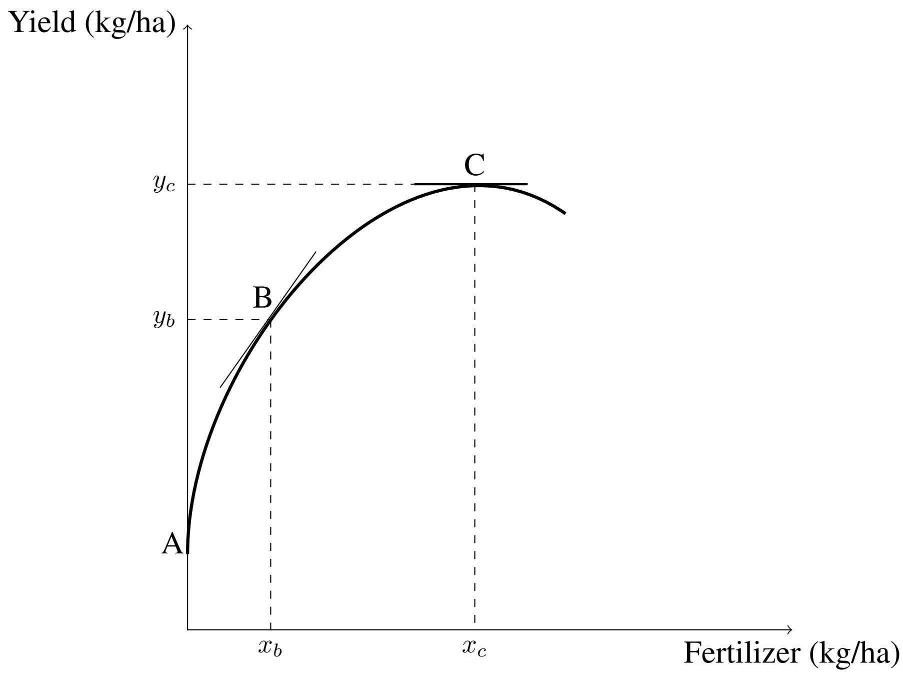


Figure 4: Kernel density plot of annual agricultural yield before and after the subsidy program

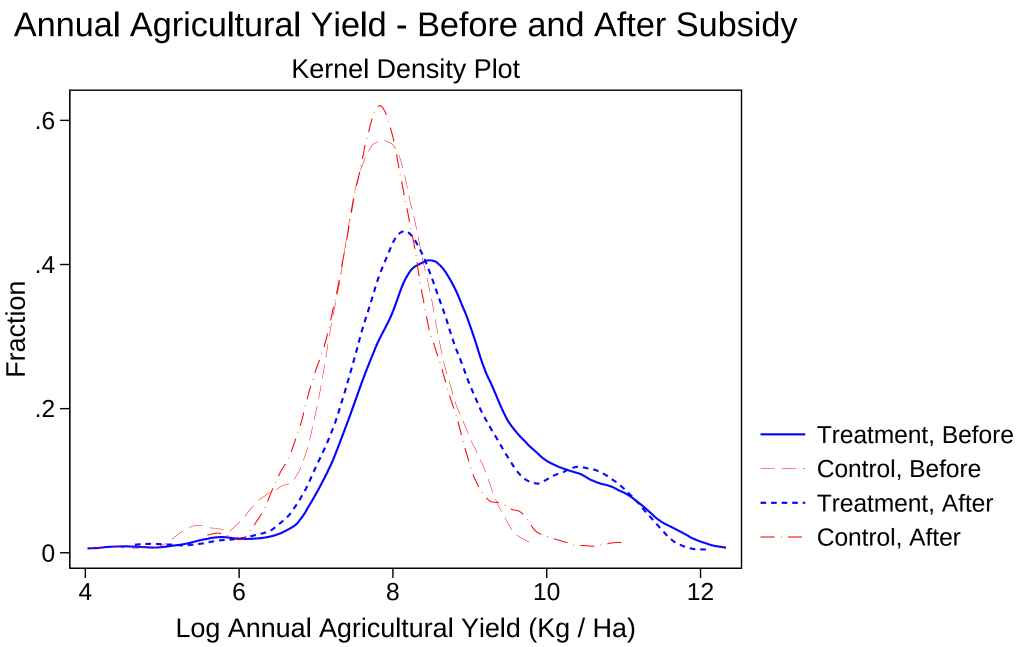


Figure 5: Testing the parallel paths assumption

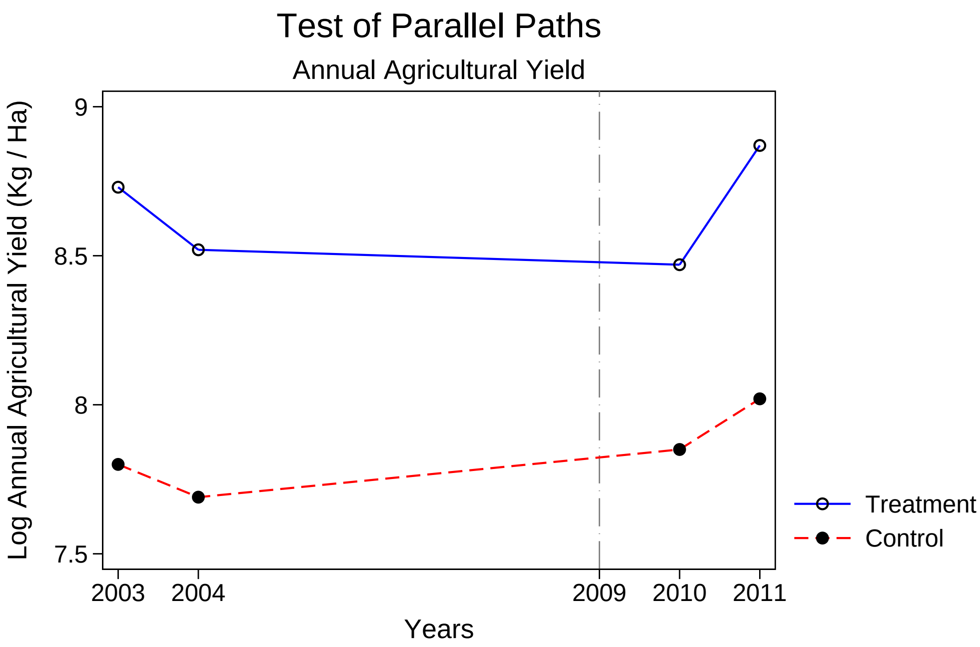
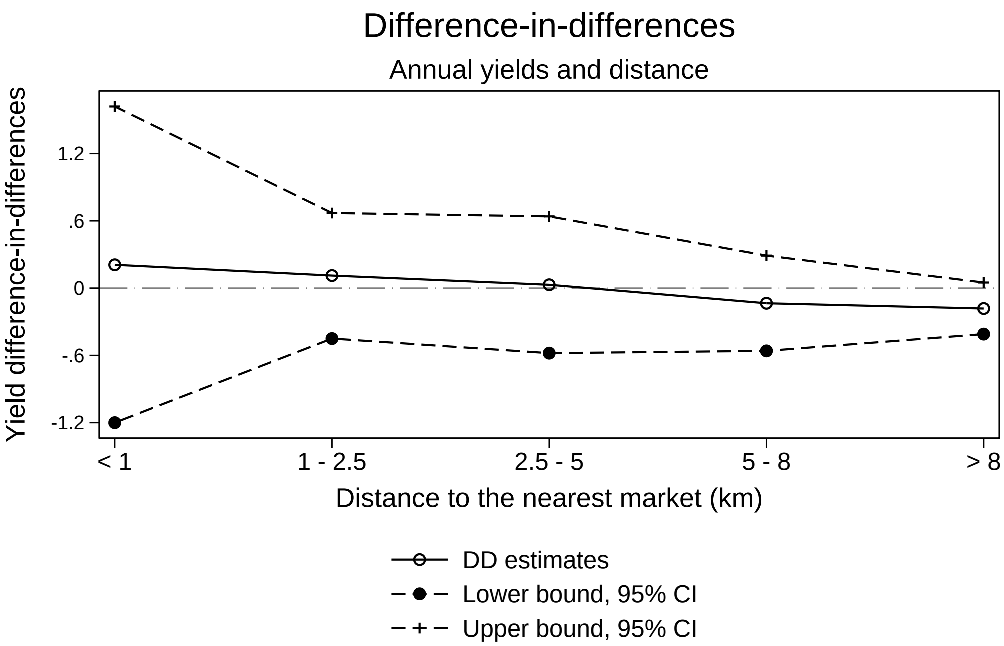


Figure 6: Difference-in-differences estimates and distance to the nearest market



Note: Annual yield difference-in-differences estimates account for household controls, month and district fixed effects.

Table 1: Government subsidy on chemical fertilizers, 2010-2015

Year	Amount of chemical fertilizer (kg)	Total subsidy allocated (Rs.)	Subsidy (Rs. per kg)
(1)	(2)	(3)	(4)
2010	81,593,850	1,370,518,260	16.80
2011	131,479,980	2,468,626,806	18.78
2012	112,126,050	3,147,851,750	28.07
2013	220,543,050	5,539,176,299	25.12
2014	188,863,350	3,360,216,413	17.79
2015	206,539,900	3,961,138,859	19.18

Note: Data available from official government documents at Ministry of Agricultural Development, Nepal.

Table 2: Percentage distribution of chemical fertilizers sources for farmers, 2010-2011

Source:	Mountains		Hills		Terai (Plains)
		Overall	Subsidy-eligible	Subsidy-ineligible	
	(1)	(2)	(3)	(4)	(5)
Government office	6.95 %	3.45 %	3.33 %	3.71 %	2.90 %
Non-governmental organization (NGO)	1.07 %	4.37 %	4.68 %	3.71 %	6.41 %
Private shops	87.17 %	83.68 %	84.11 %	82.76 %	86.5 %
Cooperative and community	4.81 %	8.49 %	7.88 %	9.81 %	4.20 %

Note: Statistics available from Nepal Living Standards Survey 2010-11 (NLSS III).

Table 3: Summary statistics - NLSS sample before the fertilizer subsidy program

Characteristics	Before Fertilizer Subsidy Treatment (1)	Control (2)	Difference (1) - (2)	N
Log annual agricultural yield (kg per ha)	8.695	7.788	0.907***	850
	(0.084)	(0.070)	(0.084)	
Age of household head	45.232	49.765	-4.533***	850
	(1.046)	(0.871)	(1.046)	
Household head is male	0.763	0.812	-0.049	850
	(0.031)	(0.026)	(0.031)	
Household head is Hindu	0.822	0.850	-0.028	850
	(0.028)	(0.023)	(0.028)	
Speaks Nepali as mother tongue	0.674	0.788	-0.114***	850
	(0.034)	(0.028)	(0.034)	
Belongs to high caste	0.423	0.588	-0.165***	850
	(0.037)	(0.031)	(0.037)	
Attended educational institution in the past	0.465	0.412	0.053	850
	(0.037)	(0.031)	(0.037)	
Household size	5.202	6.173	-0.971***	850
	(0.161)	(0.134)	(0.161)	
Owns livestock	0.859	0.988	-0.129***	850
	(0.022)	(0.018)	(0.022)	
Owns agricultural land	0.944	0.988	-0.044***	850
	(0.015)	(0.012)	(0.015)	
Area of housing plot (Sq. Feet)	1529.829	2139.721	-609.892***	850
	(93.875)	(78.211)	(93.875)	
Received remittance in the past	0.279	0.415	-0.136***	850
	(0.034)	(0.029)	(0.034)	
Has outstanding loan	0.666	0.738	-0.072**	850
	(0.034)	(0.029)	(0.034)	
Monthly food consumption is adequate	0.785	0.819	-0.034	850
	(0.030)	(0.025)	(0.030)	
Log Adjusted sale price of the house (Rs.)	13.622	13.492	0.130	834
	(0.362)	(0.301)	(0.362)	
Distance to the nearest market (km)	23.788	30.191	-6.403**	828
	(3.238)	(2.684)	(3.238)	
Total number of rooms in the house	4.075	4.604	-0.529***	850
	(0.171)	(0.142)	(0.171)	
Log monthly consumption expenditure (Rs. per capita)	8.812	8.825	-0.013	850
	(0.221)	(0.184)	(0.221)	
Log annual adjusted fertilizer expenditure (Rs. per ha)	8.016	6.460	1.556***	849
	(0.108)	(0.090)	(0.108)	
Log annual adjusted agricultural (non-fertilizer) expenditure (Rs. per ha)	1.226	1.390	-0.164*	849
	(0.093)	(0.078)	(0.093)	

Notes: High caste group comprises of the household heads who are either Brahmins or Chhetris. Agricultural yield is based on four primary cash crops, namely paddy, maize, millet and barley. Monthly consumption involves food, frequent and non-frequent non-food items. Food consumption expenditure involves monthly purchase of bread, biscuit, noodles, rice, wheat, maize, beans, eggs, oil, vegetables, fruits, meat, sugar, sweets, tea, coffee, fruit juices, alcoholic drinks, cigarettes, tobacco and meals taken outside home. It also comprises monthly market value of food consumed that is produced at home and not purchased from the market. Price and expenditure-related variables are expressed in 2003 Rupees (Rs.) throughout the main analysis to account for inflation.

Table 4: Testing the parallel paths assumption

	Dependent Variable: Log Annual Agricultural Yield (kg per ha)	
	(1)	(2)
Subsidy-eligible	0.824***	0.847***
	(0.142)	(0.228)
Year	0.111	
	(0.138)	
Year X Subsidy-eligible	0.099	
	(0.194)	
Month		0.000
		(0.009)
Month X Subsidy-eligible		0.005
		(0.014)
Constant	7.698***	7.785***
	(0.106)	(0.163)
N households	850	850
R^2	0.121	0.121

Note: Standard errors, clustered by villages, are in parentheses. *** denotes significance at the 1 percent level.

Table 5: Double difference (DD) estimate of the impact of fertilizer subsidy on annual agricultural yield (kg/ha) in the Hills region

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
Subsidy-eligible	0.907***	0.315***	0.323***	0.330***	0.365***
	(0.121)	(0.074)	(0.069)	(0.076)	(0.073)
Post subsidy	0.077	-0.083	-0.374	-0.758	-0.439
	(0.089)	(0.118)	(0.375)	(0.645)	(0.368)
Subsidy-eligible X Post subsidy	-0.260*	-0.209**	-0.225**	-0.189*	-0.226**
	(0.132)	(0.096)	(0.090)	(0.098)	(0.094)
Constant	7.788***	4.131***	4.376***	4.960***	5.322***
	(0.075)	(0.348)	(0.530)	(0.628)	(0.439)
Household controls	No	Yes	Yes	Yes	Yes
Month fixed effects	No	No	Yes	Yes	Yes
Day fixed effects	No	No	No	Yes	Yes
District fixed effects	No	No	No	No	Yes
N Households	2033	1937	1937	1937	1937
R^2	0.093	0.430	0.456	0.587	0.656

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annual adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 10% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 6: Double difference (DD) estimate of the impact of fertilizer subsidy on amount of fertilizer applied in the Hills region

	Panel A: Dependent Variable: Log Chemical and Organic Fertilizer Applied (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
Subsidy-eligible	1.551***	-0.096*	-0.108**	-0.074*	-0.086*
	(0.177)	(0.049)	(0.048)	(0.044)	(0.045)
Post subsidy	0.025	-0.445***	-0.613***	-0.327**	-0.408**
	(0.182)	(0.063)	(0.100)	(0.160)	(0.177)
Subsidy-eligible X Post subsidy	-0.136	0.122*	0.123*	0.089	0.109**
	(0.228)	(0.066)	(0.065)	(0.061)	(0.055)
N Households	2011	1920	1920	1920	1920
R^2	0.140	0.884	0.890	0.913	0.931
	Panel B: Dependent Variable: Log Chemical Fertilizer Applied (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
Subsidy-eligible	1.608***	0.224***	0.211***	0.216***	0.202***
	(0.175)	(0.050)	(0.046)	(0.043)	(0.046)
Post subsidy	-0.161	-0.520***	-0.805***	-0.231	-0.476
	(0.167)	(0.076)	(0.125)	(0.368)	(0.344)
Subsidy-eligible X Post subsidy	-0.392**	-0.178***	-0.169***	-0.182***	-0.111*
	(0.197)	(0.064)	(0.062)	(0.058)	(0.058)
N Households	1927	1844	1844	1844	1844
R^2	0.185	0.879	0.884	0.908	0.919
Household controls	No	Yes	Yes	Yes	Yes
Month fixed effects	No	No	Yes	Yes	Yes
Day fixed effects	No	No	No	Yes	Yes
District fixed effects	No	No	No	No	Yes

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annual adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 7: Double difference (DD) estimate of the impact of fertilizer subsidy on amount of fertilizer applied and annual agricultural yield in the Hills region

	Panel A: Households with no certificates of land ownership					
	Log Dependent variable: Chemical Fertilizer Applied (kg / ha)				Agricultural Yield (kg / ha)	
	(1)	(2)	(3)	(4)	(5)	(6)
Subsidy-eligible	1.430***	0.208***	0.191***	0.278***	0.802***	0.258***
	(0.205)	(0.066)	(0.061)	(0.068)	(0.128)	(0.089)
Post subsidy	-0.219	-0.543***	-0.485***	-0.305**	0.123	-0.250
	(0.219)	(0.093)	(0.122)	(0.134)	(0.115)	(0.273)
Subsidy-eligible X Post subsidy	-0.345	-0.157*	-0.160**	-0.190**	-0.179	-0.094
	(0.241)	(0.082)	(0.076)	(0.077)	(0.156)	(0.113)
Household controls	No	Yes	Yes	Yes	No	Yes
Month fixed effects	No	No	Yes	Yes	No	Yes
District fixed effects	No	No	No	Yes	No	Yes
N Households	1072	1029	1029	1029	1123	1075
R^2	0.152	0.872	0.878	0.896	0.077	0.566

	Panel B: Households with certificates of land ownership					
	Log Dependent variable: Chemical Fertilizer Applied (kg / ha)				Agricultural Yield (kg / ha)	
	(1)	(2)	(3)	(4)	(5)	(6)
Subsidy-eligible	1.352***	0.113	0.067	0.013	0.967***	0.043
	(0.354)	(0.093)	(0.096)	(0.121)	(0.274)	(0.325)
Post subsidy	-0.277	-0.692***	-0.179	0.031	-0.113	-0.555
	(0.326)	(0.171)	(0.317)	(0.321)	(0.187)	(0.687)
Subsidy-eligible X Post subsidy	0.204	0.007	0.092	0.393*	0.069	0.107
	(0.426)	(0.161)	(0.170)	(0.212)	(0.311)	(0.372)
Household controls	No	Yes	Yes	Yes	No	Yes
Month fixed effects	No	No	Yes	Yes	No	Yes
District fixed effects	No	No	No	Yes	No	Yes
N Households	188	178	178	178	199	186
R^2	0.177	0.912	0.925	0.951	0.151	0.792

Notes: The household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annual adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 8: Impact of fertilizer subsidy on annual agricultural yield (kg/ha) among different sub-groups

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)			
	High Caste	Non - High Caste	Male	Female
	(1)	(2)	(3)	(4)
Subsidy-eligible	0.368***	0.336***	0.324***	0.299*
	(0.081)	(0.103)	(0.073)	(0.156)
Post subsidy	-0.147	-0.045	-0.133	-0.013
	(0.108)	(0.143)	(0.099)	(0.227)
Subsidy-eligible X Post subsidy	-0.337***	-0.138	-0.170*	-0.391*
	(0.114)	(0.120)	(0.088)	(0.218)
Constant	5.477***	4.086***	4.661***	3.533***
	(0.522)	(0.402)	(0.333)	(0.860)
Household controls	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Day fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
N Households	902	1035	1472	465
R^2	0.547	0.567	0.563	0.519

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annual adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 10% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 9: Differential impact of the fertilizer subsidy on annual agricultural yield by distance to the closest market

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
Subsidy-eligible	0.999***	0.388***	0.392***	0.409***	0.386***
	(0.148)	(0.096)	(0.086)	(0.097)	(0.086)
Post subsidy	0.106	-0.035	-0.365	-0.856	-0.272
	(0.102)	(0.130)	(0.389)	(0.649)	(0.298)
Within 1 km of the market	0.155	0.028	-0.034	0.061	-0.124
	(0.305)	(0.293)	(0.259)	(0.308)	(0.269)
Between 1-5 kms of the market	0.145	0.040	-0.008	0.058	-0.001
	(0.164)	(0.126)	(0.117)	(0.134)	(0.135)
Post subsidy X Subsidy-eligible	-0.402**	-0.303**	-0.319***	-0.306**	-0.283**
	(0.171)	(0.123)	(0.116)	(0.125)	(0.116)
Post subsidy X Within 1 km	-0.091	-0.195	-0.066	-0.211	-0.199
	(0.341)	(0.308)	(0.285)	(0.349)	(0.317)
Subsidy-eligible X Within 1 km	-0.513*	-0.438**	-0.416**	-0.468*	-0.105
	(0.263)	(0.215)	(0.209)	(0.256)	(0.244)
Post subsidy X Subsidy-eligible X Within 1 km	0.656*	0.587**	0.538**	0.639*	0.343
	(0.349)	(0.272)	(0.258)	(0.325)	(0.313)
Post subsidy X Between 1-5 kms	-0.091	-0.185	-0.122	-0.264	-0.252
	(0.204)	(0.168)	(0.159)	(0.182)	(0.187)
Subsidy-eligible X Between 1-5 kms	-0.100	-0.132	-0.095	-0.129	-0.078
	(0.273)	(0.176)	(0.155)	(0.159)	(0.146)
Post subsidy X Subsidy-eligible X Between 1-5 kms	0.218	0.185	0.159	0.229	0.166
	(0.304)	(0.210)	(0.194)	(0.205)	(0.197)
Constant	7.741***	4.254***	4.546***	5.212***	5.138***
	(0.083)	(0.319)	(0.502)	(0.619)	(0.477)
Household controls	No	Yes	Yes	Yes	Yes
Month fixed effects	No	No	Yes	Yes	Yes
Day fixed effects	No	No	No	Yes	Yes
District fixed effects	No	No	No	No	Yes
N Households	1987	1937	1937	1937	1937
R^2	0.101	0.434	0.461	0.591	0.659

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annual adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 10: Placebo test I: Validity of double difference design

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
	Panel A: Hills Region, Pre-treatment Period				
Subsidy-eligible	0.907***	0.332***	0.297***	0.461***	0.371***
	(0.151)	(0.098)	(0.096)	(0.126)	(0.131)
Post subsidy	0.030	0.107	0.383	-0.124	-1.244
	(0.143)	(0.153)	(0.385)	(0.588)	(0.782)
Post subsidy X Subsidy-eligible	0.002	-0.032	0.010	-0.101	-0.007
	(0.212)	(0.149)	(0.135)	(0.176)	(0.162)
Constant	7.776***	4.289***	3.796***	4.463***	3.946***
	(0.109)	(0.472)	(0.522)	(0.636)	(0.736)
N households	850	811	811	811	811
	Panel B: Mountains Region				
Subsidy-eligible	0.336**	0.443***	0.126	0.210	0.210
	(0.149)	(0.118)	(0.106)	(0.157)	(0.157)
Post subsidy	0.034	0.007	0.368	4.311***	4.311***
	(0.188)	(0.200)	(0.418)	(0.867)	(0.867)
Post subsidy X Subsidy-eligible	-0.098	-0.207	0.142	0.049	0.049
	(0.253)	(0.218)	(0.212)	(0.222)	(0.222)
Constant	7.574***	3.626***	2.598	3.427	3.323
	(0.073)	(1.306)	(2.502)	(3.726)	(3.697)
N households	361	339	339	339	339
	Panel C: Plains Region, Pre-treatment Period				
Subsidy-eligible	1.888***	0.471***	0.494***	0.487***	0.487***
	(0.137)	(0.103)	(0.104)	(0.139)	(0.139)
Post subsidy	0.300	0.246*	1.130***	1.569**	1.569**
	(0.191)	(0.130)	(0.292)	(0.742)	(0.742)
Post subsidy X Subsidy-eligible	-0.049	0.099	0.090	0.077	0.077
	(0.211)	(0.135)	(0.122)	(0.129)	(0.129)
Constant	8.212***	3.884***	4.270***	4.588***	4.588***
	(0.124)	(0.262)	(0.365)	(0.646)	(0.646)
N households	897	870	870	870	870
Household controls	No	Yes	Yes	Yes	Yes
Month fixed effects	No	No	Yes	Yes	Yes
Day fixed effects	No	No	No	Yes	Yes
District fixed effects	No	No	No	No	Yes

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annually adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 10% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 11: Placebo test II: Validity of double difference design

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)					
	Within 0.75 ha			More than 0.75 ha		
	(1)	(2)	(3)	(4)	(5)	(6)
Subsidy-eligible	0.316**	0.209**	0.170*	0.022	-0.241	-0.261*
	(0.128)	(0.094)	(0.099)	(0.224)	(0.173)	(0.145)
Post subsidy	-2.878***	-2.716***	-2.728***	2.082*	-0.599	-0.118
	(0.593)	(0.594)	(0.587)	(1.112)	(1.199)	(1.188)
Post subsidy X Subsidy-eligible	-0.013	0.011	0.073	-0.364	-0.123	-0.184
	(0.181)	(0.127)	(0.128)	(0.288)	(0.215)	(0.194)
Constant	4.856***	4.842***	4.895***	4.345***	4.805***	4.450***
	(0.786)	(0.790)	(0.781)	(1.314)	(1.262)	(1.238)
Eligibility Criterion (ha)	<=0.65	<=0.55	<=0.45	>=0.85	>=0.95	>=1.05
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Day fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N households	1314	1314	1314	623	623	623
R^2	0.716	0.716	0.717	0.622	0.629	0.638

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annually adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

Table 12: Placebo test III: Validity of double difference design

	Dependent Variable: Log Annual Agricultural Yield (kg / ha)				
	(1)	(2)	(3)	(4)	(5)
Subsidy-eligible	0.618***	0.091	0.095	0.176**	0.209***
	(0.101)	(0.069)	(0.068)	(0.072)	(0.078)
Post subsidy	0.169	0.256*	0.487**	0.146	0.085
	(0.153)	(0.147)	(0.219)	(0.120)	(0.120)
Post subsidy X Subsidy-eligible	0.232	0.023	0.038	-0.249	-0.242
	(0.331)	(0.218)	(0.192)	(0.189)	(0.203)
Constant	7.855***	4.521***	4.202***	5.544***	5.523***
	(0.055)	(0.809)	(0.804)	(0.960)	(0.975)
Household controls	No	Yes	Yes	Yes	Yes
Month fixed effects	No	No	Yes	Yes	Yes
Day fixed effects	No	No	No	Yes	Yes
District fixed effects	No	No	No	No	Yes
N households	1183	1126	1126	1126	1126
R^2	0.077	0.424	0.456	0.613	0.671

Notes: Household controls include age of the household head, gender, religion affiliation, native language type, caste status, educational status, household size, ownership of agricultural land and livestocks, remittance provision, outstanding loan, adequacy of food consumption, adjusted sale price of the house, total number of rooms in the house, area of housing plot, distance to the nearest market, log monthly consumption per capita, log annually adjusted fertilizer and agricultural (non-fertilizer) expenditure per ha of agricultural land. Standard errors, in parentheses, are clustered at the village level. *** indicates significance at the 10% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.