

Does private sector involvement improve the distribution efficiency of subsidized fertilizer? A natural experiment from Nepal

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Abstract

Despite the government spending significant amounts on fertilizer subsidies, Nepal's average fertilizer application rate is lower than in other South Asian countries. The low application is attributed to poor access to fertilizer and an inefficient distribution system. The government of Nepal issued a "Fertilizer Distribution Directive (FDD) 2020" to improve the distribution system. We assessed the impacts of involving the private sector in selling fertilizer to farmers. We examined whether the market transaction cost proxied by farmers' search cost (communication and travel cost), travel time to visit the stores, and the opportunity cost of time spent in purchasing fertilizer have been reduced by FDD 2020. A difference-in-difference approach refined with propensity score matching was used to estimate the fertilizer distribution efficiency using survey data from 619 households across six districts. Private sector involvement was found to reduce travel time to fertilizer retailers by about 10 min and transaction costs to purchase subsidized fertilizer by about 20 Nepalese Rupees (NPR) per season, compared to the conventional approach of sale by farmer cooperatives. Implementation of the directive has removed the bias of cooperatives selling fertilizer only to members, especially medium and large-scale farmers. The directive and private sector involvement have led to a more equitable and efficient distribution of subsidized fertilizer. However, the government should routinely monitor and regulate the fertilizer mainly targeted to the private fertilizer retailers.

KEYWORDS

cooperatives, fertilizer distribution directive, fertilizer distribution efficiency, natural experiment, Nepal, subsidized fertilizer

JEL CLASSIFICATION

C51, Q12, Q13, Q18

1 | INTRODUCTION

Fertilizer plays a critical role in increasing crop yield and meeting the food demand of growing populations. In

Nepal, the government (GoN) allocates significant funds (about 30% of the agricultural budget in 2019/20) for fertilizer subsidies (MOF, 2020). However, the national average fertilizer application is 87 kilograms (kg) per hectare,

which is lower than the South Asian (SA) average of 135 kg per hectare (WDI, 2018). The current supply of subsidized fertilizer in Nepal is only about 60% of estimated annual demand of 840,000 metric tons (t) (Gautam, Gaihre et al., 2022). Kyle et al. (2017) reported that only 25% of farmers could purchase all the fertilizer they sought. In addition to the short supply, the inefficient fertilizer distribution system is argued to be another reason for the low use of fertilizer in the country (World Bank, 2016).

The public sector in Nepal controls the current supply of subsidized fertilizer. Fertilizer is imported and sold by the parastatal companies Agriculture Inputs Company Limited (AICL) and Salt Trading Corporation Limited (STCL). Subsidies are given for only three major fertilizers: urea, di-ammonium phosphate (DAP), and muriate of potash (MoP). Up to September 2020, AICL and STCL had sold fertilizer to farmers only through agricultural cooperatives. As a result, farmers associated with cooperatives are reported to have easier access to fertilizers than non-members (World Bank, 2016). However, private providers such as agrovets (agri-input retailers) have wide networks in rural areas. Farmers in areas not served by cooperatives had little or no access to fertilizer and, given the limited number and scattered locations of agricultural cooperatives, farmers had to wait in line for hours to purchase fertilizer and make several phone calls beforehand to confirm their availability or, in remote areas with poor telecommunication networks, physically visit to the nearest cooperative to check. All these factors have increased the market transaction cost of purchasing subsidized fertilizer.

Addressing transaction costs is very important in developing economies. Such costs deter the entry of small farmers into the input and output markets (Pingali et al., 2005; Renkow et al., 2004) and affect the choices of channel used to access output markets (Fafchamps et al., 1999), which crops to grow (Omamo, 1998), marketed supply responses (Goetz, 1992; Jayne, 2014; Key et al., 2000; Omamo, 1998), household labor (Stifel & Minten, 2008), input use (Winter-Nelson & Temu, 2005), and, ultimately, agricultural productivity (Stifel & Minten, 2008). Reducing transaction costs can increase farmers' participation in competitive markets, promote equity, lead to efficiency gains, and help to reduce poverty (Dercon, 2003).

In September 2020, the GoN implemented the Subsidized Fertilizer Distribution Directive 2020 (FDD 2020) to improve the efficiency of the fertilizer distribution system. The directive devolves authority and responsibility to local levels (a lower unit of government commonly called "Palika" in Nepali; Palika and local government are used interchangeably) for equitable and efficient fertilizer distribution. The local government agencies estimate fertilizer demand, liaise with the provincial government

for supplies, recommend strategically located fertilizer retailers to AICL for registration, and monitor fertilizer distribution. This is the first time the GoN issued a directive to include the private sector in distributing subsidized fertilizer, with the expectation of increasing farmers' access to fertilizer and improving the efficiency of fertilizer distribution. Such gains may come from reduced farmer travel time for farmers to fertilizer retailers and reduced transaction costs (Ward et al., 2020). Further, allowing agrovets to sell subsidized fertilizer will likely lead to crowd-in their sales, as farmers can do one-stop shopping for all the agriculture inputs they need.

There is extensive literature on agriculture input marketing and market reforms to encourage the private sector related to subsidized fertilizer distribution. Freeman and Kaguongo (2003) assessed the effects of fertilizer market liberalization policies in Kenya and found a substantial entry of private traders in the retail fertilizer trade when fertilizers are sold at full market prices. Kaiyatsa et al. (2019) estimated the impact of a farm input subsidy program on the quantity of subsidized fertilizer sold by the large-scale private sector (eligible to sell subsidized fertilizer) and the amount of commercial (unsubsidized) fertilizer sold by small-scale, independent dealers in Malawi. Gautam, Choudhary et al. (2022) studied the behavior of private retailers in a regulated input market and assess the non-compliance behavior of private sector in selling subsidized fertilizers in Nepal. These studies assessed the effects of policy on fertilizer traders' business performance — that is, the quantity of fertilizer sold — with little attention to whether or not private sector participation improved farmers' access to fertilizer. Nepal farmers' relatively low use of fertilizer and high dependency on imported fertilizer is similar to the case of farmers in Africa, but in contrast to extensive research addressing the latter, there are few studies on fertilizer subsidy programs and policies in Nepal (Bhandari & Neupane, 2016; Kyle et al., 2017; Paudel & Crago, 2017; Raut & Sitaula, 2012). To the best of our knowledge, this is the first study in Nepal and elsewhere that assesses the impact on transaction costs from policy changes that encourage private sector in fertilizer distribution. Further, globally this is one of the few studies (Fu et al., 2022) conducted to empirically test whether farmer cooperatives are biased to benefit members over non-members and if that effect can be eliminated through institutional changes and innovations.

Following FDD 2020, of the over 600 agrovet dealers registered across provinces as of April 2022, more than half (approximately 315) had already sold subsidized fertilizer to farmers in 2021 (Gautam, Gaihre et al., 2022). Whether or not the directive promoted equitable and efficient distribution by agrovets is assessed in the present study. Our study specifically aims to (1) estimate the effects of the

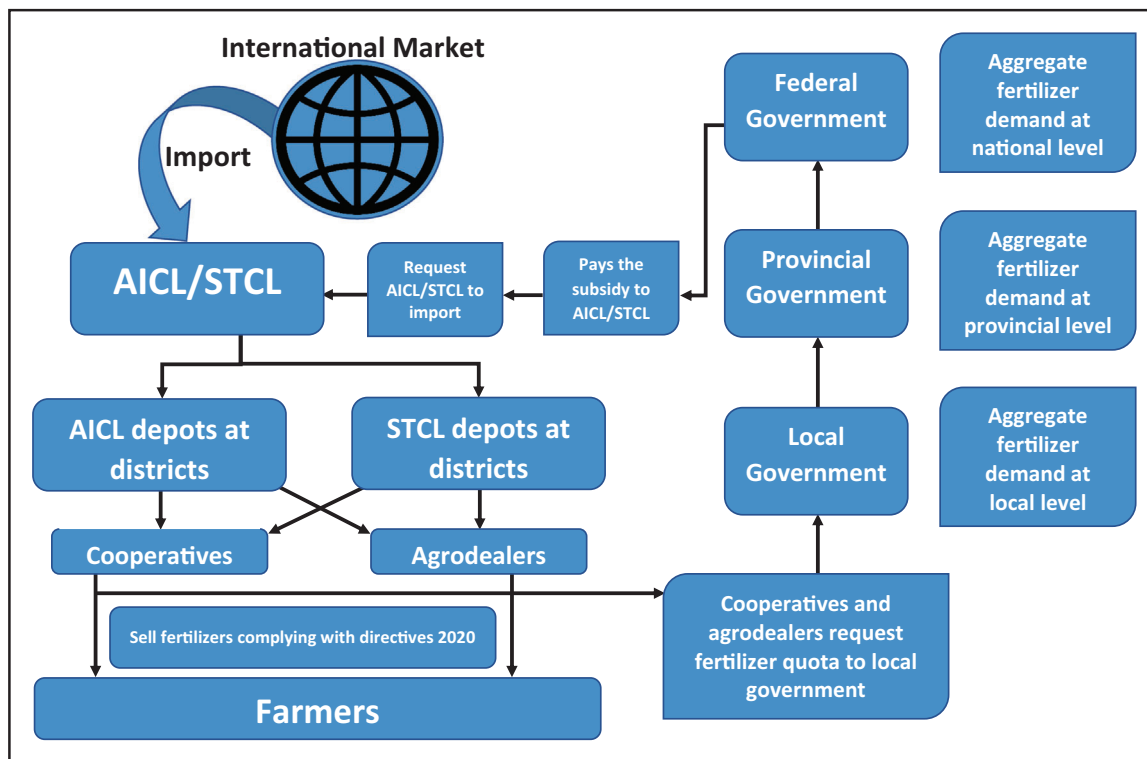


FIGURE 1 Subsidized fertilizer distribution program.

FDD 2020 on market transaction costs; (2) estimate its impact on subsidized fertilizer prices paid and the quantity purchased; and (3) assess whether or not the directive has promoted the equitable distribution of fertilizer to the farmers.

In the following sections, we discuss Nepal's subsidized fertilizer distribution program, present the study methodology and data, describe, and discuss the results, provide a robustness check, and conclude with a summary and policy implications.

2 | SUBSIDIZED FERTILIZER DISTRIBUTION PROGRAM IN NEPAL

FDD 2020 defined the roles and responsibilities of three government levels in improving the distribution of subsidized fertilizer (Figure 1). Local governments estimate and send the provincial government their requirements for the three types of fertilizer (urea, DAP, and MOP). The requirements are aggregated by the provincial government and passed on to federal agencies, which aggregate demand from the seven provinces to determine budget allocations for subsidies and the volume of fertilizer that AICL and STCL should import. The parastatal companies procure the fertilizer from international markets through an open global tender. The volume of imports is based on international vendors' price quotes and the subsidy

amount received. AICL and STCL sell fertilizer to retailers through their provincial and branch offices. For fertilizer distribution to farmers, local governments select retailers (cooperatives or agrodealers) at strategic locations so that farmers have easy access. The selected retailers get an official recommendation letter for a distribution license from AICL, STCL, or both. Registered retailers collect fertilizer from provincial or branch offices of AICL and STCL. Although local governments allocate fertilizer for each retailer, AICL and STCL adjust proposed volumes based on their stocks. Therefore, the volume of fertilizer given to each retailer also depends on the total number of fertilizer retailers in Palika and the size of their service area. Retailers record fertilizer sales, including the price and quantity of fertilizer purchased. Farmers who buy fertilizer provide personal details (a copy of citizenship, phone number) and information about their land holdings.

3 | METHODOLOGY AND DATA

3.1 | Study area, survey design, and sample

The selection of study sites and survey design were based on exploratory visits to potential sites and discussions with fertilizer sector stakeholders. These stakeholders included

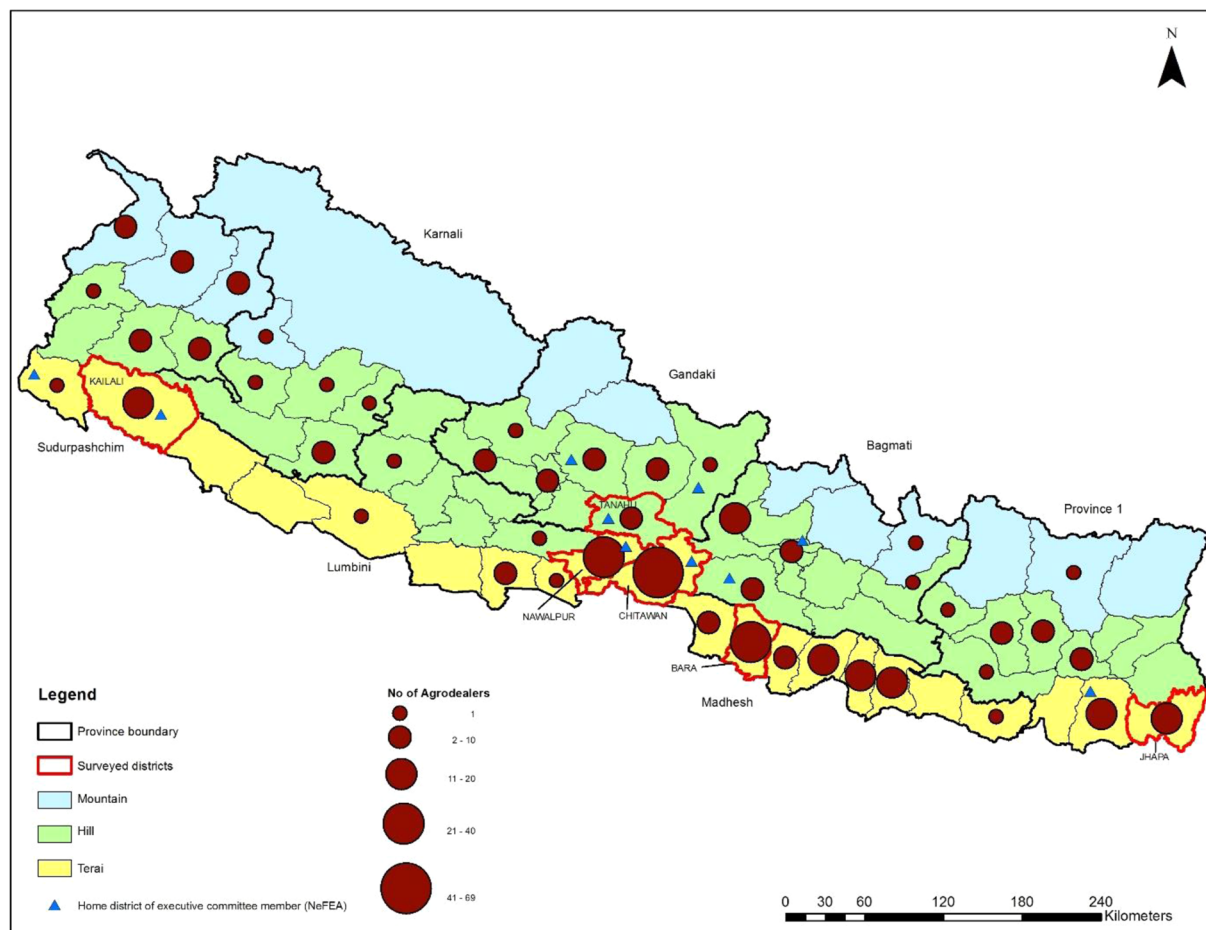


FIGURE 2 Surveyed districts and distribution of authorized agrodealers selling subsidized fertilizer in Nepal.

the Ministry of Agriculture and Livestock Development, provincial and local governments, and fertilizer importers (AICL and STCL). Based on a preliminary understanding of the implementation status of FDD 2020, particularly the involvement of private sector, six districts (Jhapa, Bara, Chitwan, Nawalpur, Kailali, and Tanahun) with a high number of agrovets registered to sell fertilizer and represent mainly the Terai Region were chosen (Figure 2). The districts represent five of Nepal's seven provinces; the two provinces not included either have low chemical fertilizer use by farmers (Karnali Province) or a low number of agrovets authorized to sell subsidized fertilizer at the time of this study (Lumbini Province).

A key informant interview with farmers, cooperatives, and agrovets verified the effects of FDD 2020 on farmers' access to fertilizer. It informed the development of a survey questionnaire covering household socioeconomic characteristics, agriculture production, fertilizer usage, distance traveled, time spent purchasing fertilizer, and impacts of Covid-19 on fertilizer availability. The questionnaire was pretested with respective stakeholders, finalized based on their feedback, and surveyed approximately 100 households per district — 50 served by agrovets (treatment

ward) and 50 served by cooperatives (control ward) — for an across-district total of 619 households (Table A1).¹ We selected two Palikas per district where private retailers had sold subsidized fertilizer in the previous year. For each local level, we selected a treatment and a control ward. About 25 farm households were randomly selected from the treatment and control wards in a Palika using a systematic sampling approach.

No baseline survey was conducted to collect pre-intervention data. We relied instead on household heads' recollections of fertilizer purchases, travel times, communication costs, etc., for 2020 and 2021, assuming that a single interview was sufficient to collect this information reliably and accurately. That confidence owed partly to our knowledge of the effort required by farmers (phone calls, visits to retailers) to arrange and carry out fertilizer purchases and the fact that fertilizer must be purchased outside the household (unlike seed and labor) and constitutes farmers' most expensive input, and, in most instances, maybe the only purchased input.

¹ Ward is an administrative unit and includes at least three hundred households. A palika is made of around seven wards.

3.2 | Measurement of transaction costs

Transaction costs were measured as per Key et al. (2000), who broadly classed them as fixed or variable (or proportional). Fixed costs include those incurred irrespective of the input purchased or output sold, such as original search cost, negotiation, and enforcement costs. They mainly affect farmers' decision to participate in the markets. On the other hand, once the market information is sought and contacts with buyers/sellers are made, additional costs such as transportation cost per unit of product purchased constitute variable costs.

We focused on input markets and found that fixed transaction costs were most important for farmers seeking subsidized fertilizer. As a measure of market transaction cost, we used fertilizer search cost, which includes the phone (communication) cost, cost of travel to confirm fertilizer availability, and the opportunity costs (based on the daily wage rate of NPR 550²) of time spent waiting in line while purchasing fertilizer and travel time to confirm the availability of fertilizer.

3.3 | Nature of policy interventions—natural experiment design

Although the randomized control trial (RCT) is considered the most reliable approach to measure the impacts of any intervention, it is not always feasible for political or ethical reasons. An alternative is a quasi-experimental design (Fong et al., 2006; Gliner et al., 2016), where researchers control the intervention. Since FDD 2020 was issued in September 2020 and changed policies for the distribution and purchase of subsidized fertilizer, we considered this a unique “natural experiment” that allows us to identify FFD's impact.

The survey was conducted in April 2022. More than 315 agrovets had sold subsidized fertilizer in 2021. We have a treatment group (farmers who purchased fertilizer from agrovets), a control group (farmers who purchased fertilizer from cooperatives), and pre-intervention and post-intervention measures for treated and control groups. The policy intervention is unlikely to influence the farmers' travel time to purchase subsidized fertilizer for the control group, as the same cooperative has served them over the past several years.

We compare the difference in the pre-intervention to post-intervention values for the outcome in the treatment group relative to the control group. We evaluated the impact of the FDD 19 months after its implementation. We think 19 months is a reasonable enough period for this nat-

ural experiment to see a change in our outcome variables of interest due to FDD implementation. The outcomes of interest (dependent variables) are quantity of fertilizer purchased, price paid, market transaction costs, and farmer's opportunity costs for time spent on fertilizer purchases and travel to purchase fertilizer.

3.4 | Empirical model

We assessed if the engagement of agrovets reduced market transaction costs and influenced the quantity purchased and prices of subsidized fertilizer for farmers. Although we selected the different wards of the same Palika that share many characteristics, there might still have been some unobservable characteristics that were likely to vary across the treatment and control wards but were assumed to be fixed over time. Therefore, we constructed the panel data and estimated the difference-in-difference (DiD) model to control for time-invariant unobserved heterogeneity.

The DiD compares changes in outcomes for farmers who purchased fertilizer from agrovets and cooperatives before and after the directive. Any general trend affecting both the treatment and control groups is removed in this approach. The control group is expected to accurately represent the change in outcomes that the treatment group would have experienced in the absence of the treatment. The DiD method provides an unbiased effect estimate only if the outcome of interest follows a similar trend between the treated and control groups in the absence of the intervention. Given that we only have one pre-intervention observation, we were not able to conduct the parallel test that requires at least two pre-intervention periods (Ryan et al., 2015).

Further, a concern is that the program and intervention groups may vary in ways that can affect their trends over time. The propensity score methods combined with the DiD are commonly used to handle this confounding effect. We refined the DiD method by using propensity score matching with the pre-intervention data to ensure the comparison group is like the treatment group. The balancing test conducted before and after the propensity score matching is shown in Table A2. We applied the double differences to the matched sample, allowing us to deal with the observable heterogeneity in the initial conditions. The DiD model for the matched sample can be specified as follows:

$$Y_{it} = \alpha + \beta_1 W_{it} + \beta_2 Y_t + \beta_3 (Y_t \times W_{it}) + \varepsilon_{it} \quad (1)$$

where Y_{it} indicates the outcome variables before and after implementation of the directive, W_{it} is a binary variable if a farmer survey is from the treatment or control group

² One USD was equivalent to NPR 118.1

from the matched sample, Y_t is a binary variable indicating the pre- and post-treatment periods, α is a constant intercept and ε_{it} is an error term. The impact of the directive is captured by the coefficient β_3 and provides the average treatment effects on the treatment group.

Although the basic assumption of DiD is that other covariates do not change over time, some variables are likely to vary. Therefore, we included time-varying variables in the regression model to estimate the net effect of the FDD implementation on the outcome. In particular, we controlled for Covid-19 effects on fertilizer accessibility in 2020 and 2021. The Covid-19 pandemic has been found to affect vegetable farmers' inputs and outputs market participation, and market integration in Pakistan (Ullah et al., 2022). Equation (1) is extended by including the time-variant characteristics (X_{it}) as follows:

$$Y_{it} = \alpha + \beta_1 W_{it} + \beta_2 Y_t + \beta_3 (Y_t \times W_{it}) + \gamma X_{it} + \varepsilon_{it} \quad (2)$$

We assessed the robustness of DiD estimates using the fixed effects regression. This approach controls for households' unobserved and time-invariant characteristics that can affect outcome variables.

We also verified whether the cooperates sold fertilizer to all farmers or if they were biased toward their members in sales. We estimated two models — one before FDD 2020 and one after. Dependent variables of interest were amounts of subsidized urea, DAP, and MOP purchased (Q_{ift}) by households with and without cooperative membership in 2020 and 2021. In addition, we created explanatory variables based on if a farmer is a member of the cooperative that sells subsidized fertilizer (M_{ift}) and whether the same farmer has purchased subsidized fertilizer from the cooperative or not (C_{ift}). To assess the bias effects, we created an interaction term between these two explanatory variables. If the coefficient of the interaction term is positive and significant, this means the cooperatives are selling more fertilizer to members than non-members. First, we estimated a parsimonious model as follows:

$$Q_{ift} = \alpha_{ft} + \beta_{ft} M_{ift} + \gamma_{ft} C_{ift} + \delta_{ft} C_{ift} \times M_{ift} + \varepsilon_{ift} \quad (3)$$

where ε_{ift} is a random noise. The parameters of interest here is δ_{ft} .

We also control for additional covariates (X_{if}) that are likely to influence the purchase of subsidized fertilizer and estimated the full model as below:

$$Q_{ift} = \alpha_{ft} + \beta_{ft} M_{ift} + \gamma_{ft} C_{ift} + \delta_{ft} C_{ift} \times M_{ift} + \varphi X_{if} + \varepsilon_{ift} \quad (4)$$

Both models were separately estimated before and after FDD 2020. We also assessed whether agrovets are likely to

be biased towards the non-cooperative members and farmers with landholdings of more than .5 ha. Since we sampled households at the ward level, households from the same ward are more likely to be correlated. Failing to consider the clustering will lead to small standard errors and large t-statistics. To improve our inference, we use heteroskedasticity robust-standard errors clustered at the ward level for all inferences.

4 | RESULTS AND DISCUSSION

4.1 | Summary statistics of the variables

Summary statistics of variables used in the analysis are shown in Table 1. The mean differences of most variables were insignificant between the treatment and control groups, suggesting the treatment and control samples share similar socioeconomic and agricultural characteristics. However, variables such as cooperative membership status, education level of household head, relation status with the owner of agrovets or cooperatives selling subsidized fertilizer, exposure to media (watch agriculture-related programs on television), land holdings, fertilizer hoarding behavior, and access to paved roads were statistically significant ($p < .1$) between the treatment and control groups.

On average, 30% of sampled households were members of cooperatives that sell subsidized fertilizer. As expected, the proportion of such households was higher in the control group (51%) than in the treatment group (9%). On average, household heads had six years of education. The mean difference in the years of schooling between the control and treatment groups is statistically significant, with a higher education level in the control group (about six years) than in the treatment group (about five years). About 26% of the households had a close friendship with or were relatives of owners of cooperatives or agrovets that sold subsidized fertilizer, with higher values (31%) in the control group than in the treatment group (22%).

Among households sampled, 61% frequently watched agriculture-related programs on television, with a higher portion in households from the control group (65%) than the treatment group (58%). On average, sampled households owned .7 hectares (ha) of cultivable land, and households from the control group owned more (.13 ha) than in the treatment group. Since fertilizer is not available year-round, farmers typically purchase higher amounts and store it, a practice followed by about 16% of all households sampled and more prevalent (19%) in the control group than the treatment group (14%). About 46% of the sampled households have access to paved (blacktop) roads, an advantage enjoyed by more households from the control

TABLE 1 Descriptive statistics of household characteristics

Variables	Treatment group	Control group	Pooled	Mean difference ¹
A household is a member of a cooperative that sells subsidized fertilizer (1/0)	.09 (.28)	.51 (.50)	.30 (.46)	−.426*** (.0327)
Family size (count)	6.30 (3.20)	6.40 (3.18)	6.35 (3.18)	−.0993 (.256)
Male-headed household (1/0)	.87 (.34)	.82 (.38)	.85 (.36)	.0431 (.0290)
Highest year of education by household head	4.79 (4.95)	5.96 (5.02)	5.37 (5.02)	−1.177*** (.401)
Age of household head (years)	52.31 (12.05)	52.08 (13.25)	52.19 (12.65)	.229 (1.019)
Number of years the household has lived in the surveyed location	43.07 (17.37)	42.04 (17.22)	42.56 (17.29)	1.035 (1.391)
Owner of the cooperatives/agrodealer is close friend/relative in 2021 (1/0)	.22 (.41)	.31 (.46)	.26 (.44)	−.0858** (.0353)
Rate economic condition as good (1/0)	.15 (.35)	.19 (.39)	.17 (.37)	−.0464 (.0301)
Actively engaged in farming (1/0)	.93 (.25)	.94 (.23)	.94 (.24)	−.0125 (.0194)
Has a bank account (1/0)	.82 (.39)	.86 (.35)	.84 (.37)	−.0410 (.0298)
Frequently interact with peers (1/0)	.75 (.44)	.74 (.44)	.74 (.44)	.00492 (.0354)
Frequently watches the agriculture related program on TV (1/0)	.58 (.49)	.65 (.48)	.61 (.49)	−.0655* (.0392)
Frequently seeks advice of agriculture extension office (1/0)	.35 (.48)	.34 (.48)	.35 (.48)	.00746 (.0384)
Willing to take risk (1/0)	.26 (.44)	.26 (.44)	.26 (.44)	−.00492 (.0354)
Rented land (1/0)	.20 (.40)	.19 (.39)	.19 (.40)	.005 (.03)
Time preference; i.e., willing to wait to gain more in future (1/0)	.31 (.46)	.31 (.46)	.31 (.46)	−.00201 (.0373)
Net-seller of rice (1/0)	.49 (.50)	.51 (.50)	.50 (.50)	−.0162 (.0403)
Used tractor/mini-tiller (1/0)	.96 (.19)	.98 (.15)	.97 (.17)	−.0128 (.0135)
Used saved seeds (1/0)	.34 (.47)	.36 (.48)	.35 (.48)	−.0249 (.0384)
Has access to irrigation in 2021 (1/0)	.81 (.39)	.81 (.39)	.81 (.39)	−.00201 (.0316)
Land owned (kattha) ^a	18.92 (19.42)	23.32 (26.16)	21.11 (23.12)	−4.404** (1.853)
Rice cultivated area (kattha)! in 2021 ^a	21.68 (24.03)	22.05 (23.74)	21.86 (23.87)	−.367 (1.922)

(Continues)

TABLE 1 (Continued)

Variables	Treatment group	Control group	Pooled	Mean difference ¹
Applied animal manure in 2021 (1/0)	.80 (.40)	.80 (.40)	.80 (.40)	−.0045 (.03)
Purchase fertilizer and store to be used later (1/0)	.14 (.34)	.19 (.39)	.16* (.37)	−.0528* (.0296)
Covid-19 affected fertilizer availability and purchase in 2020 (1/0)	.62 (.49)	.62 (.49)	.62 (.49)	.00247 (.0392)
Covid-19 affected fertilizer availability and purchase in 2021 (1/0)	.21 (.41)	.19 (.39)	.20 (.40)	.0181 (.0323)
The fertilizer retail shop was closed due to Covid-19 in 2020 (1/0)	.56 (.50)	.57 (.50)	.57 (.50)	−.0166 (.0399)
Fertilizer retail shop closed due to Covid-19 in 2021(1/0)	.14 (.35)	.14 (.35)	.14 (.35)	−.000922 (.0282)
Visited the fertilizer retail store few times to purchase fertilizers in 2020 (1/))	.34 (.47)	.35 (.48)	.34 (.48)	−.00869 (.0383)
Visited the fertilizer retail store few times to purchase fertilizers in 2021 (1/))	.09 (.29)	.07 (.26)	.08 (.28)	.0156 (.0222)
Rural areas (1/0)	.79 (.41)	.79 (.41)	.79 (.41)	−.00511 (.0328)
Community has access to gravel road (1/0)	.36 (.48)	.33 (.47)	.35 (.48)	.0333 (.0384)
Community has access to blacktop road (1/0)	.38 (.49)	.55 (.50)	.46 (.50)	−.162*** (.0397)
Time to reach nearest market (minutes)	7.22 (7.09)	7.72 (7.73)	7.47 (7.41)	−.505 (.596)
Time to reach nearest farm credit organization (minutes)	9.68 (12.16)	11.16 (15.62)	1.42 (14.00)	−1.486 (1.126)
Altitude of surveyed household (meters above sea level)	158.97 (144.57)	166.29 (154.99)	162.61 (149.78)	−7.322 (12.06)
Bara (1/0)	.17 (.38)	.17 (.37)	.17 (.37)	−.00538 (.0301)
Chitwan (1/0)	.17 (.37)	.17 (.37)	.17 (.37)	−.00216 (.0300)
Jhapa (1/0)	.16 (.37)	.16 (.37)	.16 (.37)	.00105 (.0297)
Kailali (1/0)	.16 (.37)	.17 (.37)	.17 (.37)	.00107 (.0299)
Nawalpur (1/0)	.16 (.37)	.17 (.38)	.17 (.37)	.00756 (.0301)
Tanahun (1/0)	.17 (.38)	.17 (.38)	.17 (.38)	−.00214 (.0303)
Observations	310	308	618	618

Note: ¹ indicates the mean difference between the treatment and control groups. Standard error in parentheses * $p < .1$, ** $p < .05$, *** $p < .01$. Treatment group denotes the farmers served by the agrodealers while the control group denotes the farmers being served by the cooperatives.

^a(1 ha = 30 kathha).

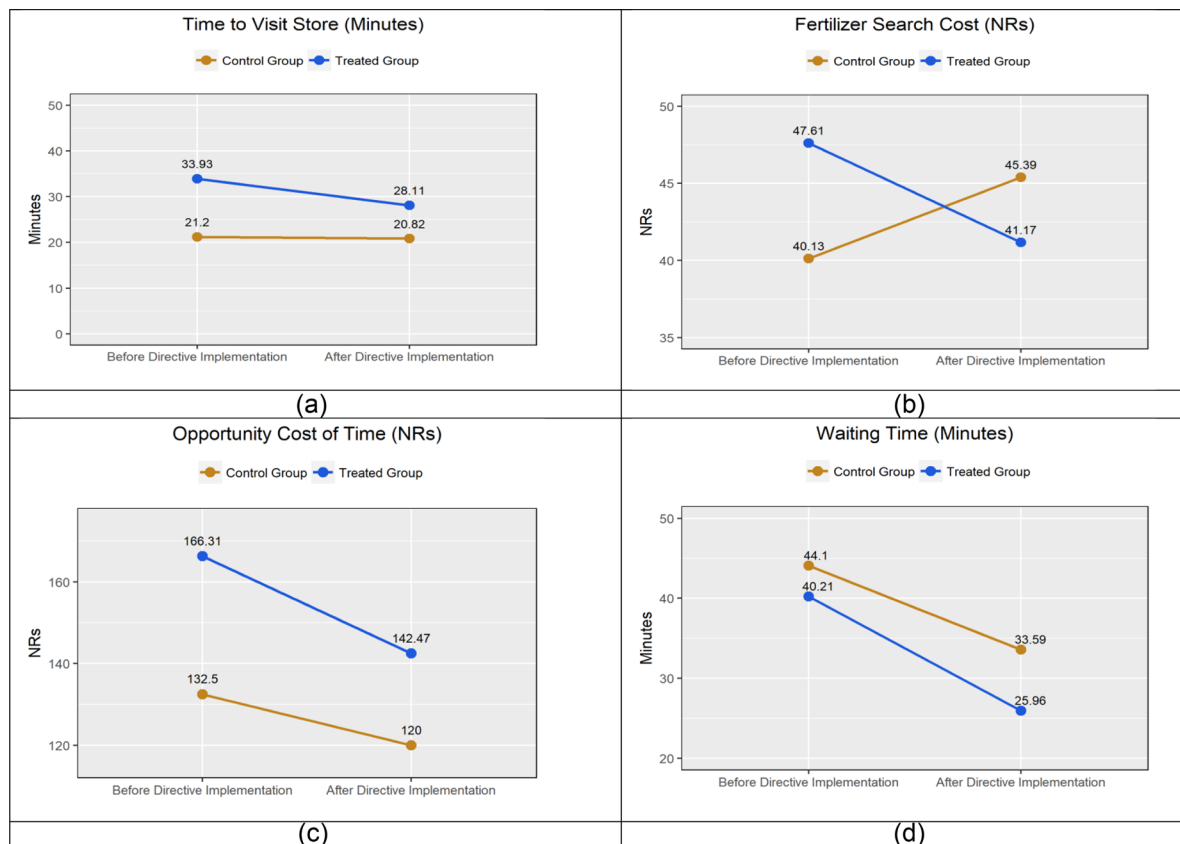


FIGURE 3 Time and cost of accessing subsidized fertilizer among treatment and control groups before and after FDD 2020.

group than those from the treatment group, most of whom live in remote areas where cooperatives had not provided services in the past.

4.2 | Effects of directive implementation on market transaction costs

In general, FDD 2020 has increased farmers' access to fertilizer, reduced the opportunity cost of time spent purchasing fertilizer and waiting in the store, as well as reduced travel time and fertilizer search costs (transaction cost, only for the treatment group) and travel costs (Figure 3).

The opportunity cost of time spent to purchase subsidized fertilizer was reduced from NPR 166 to NPR 143 per transaction for the treatment group and from NPR 132 to NPR 120 per transaction for the control group (Table 2). FDD 2020 reduced the opportunity cost of time spent purchasing subsidized fertilizer for the treatment group, but the difference is statistically insignificant (Table 3). For the DiD estimate to be statistically significant, there should not be significant changes for the control group compared to the treatment group.

The in-store waiting time (one-time purchase) to purchase fertilizer diminished from an average of 40–26 min for the treatment group (Table 2). However, the DiD estimate for this is insignificant, as the control group also experienced a significant reduction in waiting time because some farmers who previously purchased fertilizer from cooperatives but now belong to the treatment wards are buying fertilizer at the agrovets, resulting in less crowding and expedited transactions at the cooperative store.

Similarly, fertilizer search costs were reduced from NPR 48 to NPR 41 for the treatment group but increased for the control group from NPR 40 to NPR 45 (Table 2). This is because cooperatives' fertilizer allotments were reduced by the redistribution to agrovets under FDD 2020 and are now less than the demand. Results from the main regression show that the 2020 directive significantly reduced the fertilizer search cost (Table 3), which led to a decrease by an average of NPR 20 in a season.

Implementation of the directive reduced the travel time (single visit) to the fertilizer retailer by 6 min (from 34–28 min) for the treatment group (Table 2, Figure 3), a significant effect, according to the main regression. On average, FDD 2020 reduced travel time by 10 min per visit

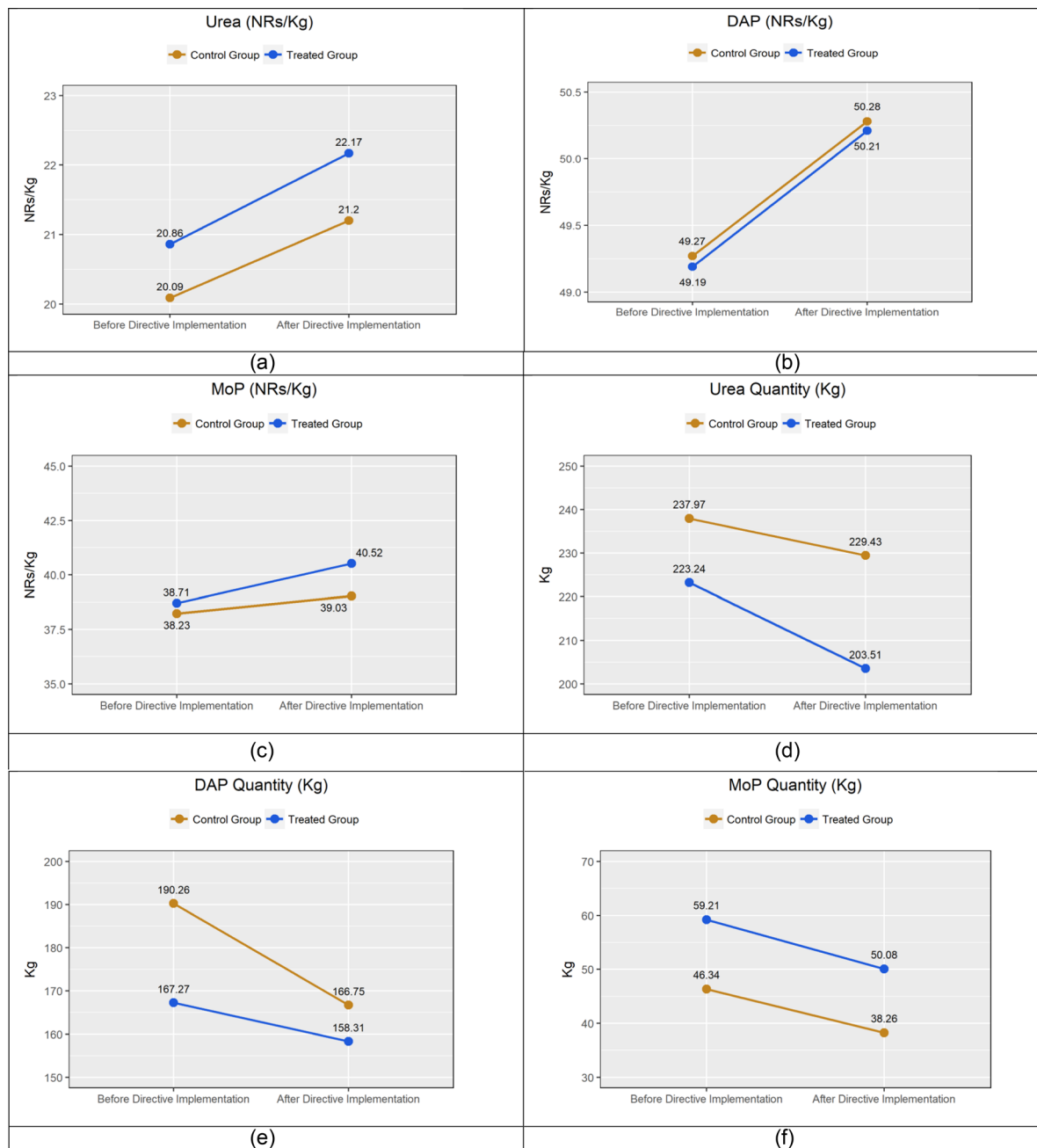


FIGURE 4 Amount purchased, and the price paid for subsidized fertilizer among treatment and control groups before and after FDD 2020.

(Table 3) due to farmers in places far from cooperative services gaining access to fertilizer through retail shops.

For both groups, private sector involvement significantly reduced travel costs (by about NPR 5) for visits to retail shops and phone costs (by NPR 7, at a <10% level of significance) to confirm fertilizer availability (Table 2), with both effects being important to promote fertilizer use. Winter-Nelson and Temu (2005) found that a 1% reduction in travel time to input markets led to a .3% increase in chemical fertilizer and agrochemical use in Tanzania. In Ethiopia, lower household agriculture production was due to high

transaction costs in obtaining modern inputs (Stifel & Minten, 2017). Our findings suggest that FDD 2020 lowered market transaction costs and improved farmers' access to subsidized fertilizer.

4.3 | Effects of FDD 2020 on price paid and quantity purchased

Private sector involvement did not significantly affect the amount of fertilizer purchased by the treatment group

TABLE 2 Status of fertilizer accessibility before and after FDD 2020

Outcomes	Treatment group			Control group			DiD estimates
	Before DI	After DI	MD	Before DI	After DI	MD	
Time spent in a single visit to purchase fertilizer (minutes)	33.93	28.11	−5.82***	21.20	20.82	−.39	−5.44***
Opportunity cost of time spent to purchase subsidized fertilizers (NPRs)	166.31	142.47	−23.85***	132.5	120.0	−12.50*	−11.83
Fertilizer search cost (NPRs)	47.61	41.17	−6.45*	40.13	45.39	5.26	−11.70**
Waiting time in the store during purchase of subsidized fertilizer (minutes)	40.21	25.96	−14.25***	44.10	33.59	−10.51***	−3.73
Travel cost to visit the store (including return cost) (NPRs)	30.59	26.48	−4.11*	20.06	20.88	.81	−4.92*
Total phone cost to confirm fertilizer availability (NPRs)	17.01	14.68	−2.32	20.06	24.51	4.45	−6.78*
Quantity/Price							
Urea price (NPRs/kg)	20.86	22.17	1.31***	20.09	21.20	1.10***	.27
DAP price (NPRs/kg)	49.19	50.21	1.02***	49.27	50.28	1.01***	.01
MOP price (NPRs/kg)	38.71	40.52	1.81***	38.23	39.03	.80***	1.38**
Urea quantity (kg)	223.24	203.51	−19.72***	237.97	229.43	−8.53**	−4.43
DAP quantity (kg)	167.27	158.31	−8.95*	190.26	166.75	−23.50*	−19.69
MOP quantity (kg)	59.21	50.08	−9.14***	46.34	38.26	−8.08***	−3.46

Treatment group denotes the farmers served by the agrodealers while control group denotes the farmers being served by the cooperatives.

Abbreviations: DAP, diammonium phosphate; DI, directive implementation; DiD, difference in difference; MD, mean difference standard error in parentheses; MOP, muriate of potash; NPRs, Nepalese rupees.

* $p < .1$. ** $p < .05$. *** $p < .01$.

(Figure 4, Table 4), which is not surprising, as the directive aimed to make distribution more effective rather than to increase the size of purchases. Further, we found that the 2020 directive did not significantly influence the price of urea, DAP, and MOP (Table 4).

4.4 | Role of FDD 2020 on the equitable distribution of subsidized fertilizer to farmers

The directive aimed to combat discriminatory practices by cooperatives favoring members in fertilizer sales. We tested empirically if cooperatives were biased towards members before and after FDD 2020. Model 1 (Equation (3)) estimates the parsimonious model, while Model 2 (Equation (4)) estimates the full model (Table 5). The interaction terms (product of binary indicator of whether a household belongs to a cooperative that sells subsidized fertilizer and whether or not that household has purchased fertilizer from the cooperative) capture the bias effect and is statistically significant at <5% for subsidized urea and <1% for MOP. We found that cooperatives were biased in urea and MOP sales before FDD 2020, with cooperative members purchasing 25.4 kg more subsidized urea and 2 kg

more subsidized MOP than non-member farmers. Because cooperatives were the sole providers of subsidized fertilizer to both the cooperative members and non-cooperative farmers prior to FDD 2020, their members likely benefited from quick information regarding fertilizer availability and priority access for purchases when supplies were limited. The World Bank (2016) found that about 14% of non-member small farmers and about 17% of non-member large farmers in Nepal were not able to purchase subsidized fertilizer, whereas all farmers with membership had access to this product.

We also estimated Models 1 and 2 after the implementation of the directive (Table 5). We interpreted the interaction term for the full model (Model 2), given it control for several other confounding variables, and found the interaction term insignificant, suggesting that the bias had been eliminated through FDD 2020. We did not find significant bias effects for agrovets toward cooperative members or large- and medium-scale farmers in sales of subsidized fertilizer except for MOP, where agrovets likely privileged sales to large-scale farmers (Table 6). The directive includes a provision that requires equal access to subsidized fertilizer for all farmers in retailers' service areas, under the possible penalty of retailers having their fertilizer sales license revoked. Overall, these are significant

TABLE 3 Impact of fertilizer distribution directive on travel time, fertilizer search cost and opportunity cost of time spent in fertilizer purchases for farmers served by agrodealers

Variables	Travel time to visit store (minutes)		Fertilizer search cost (NPRs)		Opportunity cost of time spent in fertilizer purchase (NPRs)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
DiD estimates (Treated#Post directive implementation period)	−9.911*** (3.190)	−10.233*** (3.248)	−19.987* (10.690)	−19.766* (10.065)	−25.477 (17.347)	−26.196 (17.691)
Post fertilizer distribution directive implementation period (1/0)	1.669 (1.739)	4.500* (2.379)	9.942 (7.857)	12.438 (8.574)	−7.835 (11.852)	8.124 (14.889)
Covid-19 affected the fertilizer availability and purchase (1/0)		9.571 (6.743)		22.436 (23.223)		41.558** (19.340)
If farmer agrees that he could not purchase fertilizers as the store was closed		−6.236 (6.447)		−11.725 (29.530)		−9.045 (19.470)
Rice cultivated area (kattha)		−.207 (.277)		−1.493 (1.775)		−1.199 (1.015)
Quantity of fertilizer (urea, dap, mop) purchased (kg)		.005 (.003)		−.031* (.018)		.033 (.021)
Mode of transportation used to purchase fertilizer is bicycle (1/0)		3.831 (6.728)		−5.472 (24.197)		21.903 (41.072)
Average time (minutes) taken to wait in line while purchasing fertilizer		.054* (.031)				
Household has rented land (1/0)		5.364 (7.090)		24.545 (26.674)		−24.899 (25.648)
Household has applied animal manure (1/0)		4.933 (6.125)		16.708 (15.373)		6.085 (38.089)
Constant	29.326*** (.796)	20.994* (10.986)	56.806*** (2.673)	101.304 (71.022)	169.841*** (4.336)	156.473*** (56.691)
Observations	614	614	614	614	614	614
R-squared	.044	.079	.011	.044	.025	.045
Number of groups	307	307	307	307	307	307

Robust standard errors in parentheses.

*** $p < .01$. ** $p < .05$. * $p < .1$.

achievements of the directive in promoting the equitable distribution of subsidized fertilizer.

5 | ROBUSTNESS CHECK

We used the fixed effects regression estimation technique, controlling for households' unobserved and time-invariant characteristics, to assess the robustness of the main results. Only those outcomes (fertilizer search cost, travel time to reach the store, and MOP price) that are statistically significant at <10% are considered. Although there is a slight change in the magnitude of the coefficients, their significance levels did not change, and the results are highly robust to the main results (Table A3).

We also assessed whether farmer cooperatives favored farmers whose land holdings exceeded 1 ha in sales of subsidized fertilizer compared to marginal/small-scale farmers (less than .5 ha of land holdings) and medium-scale farmers (between .5 and 1 ha). We found that, prior to FDD 2020, cooperatives favored members, who were generally medium- and large-scale farmers, in urea sales (Table A4) but not in sales of MOP (Table A5). Urea is Nepal's most popular and extensively used fertilizers and farmers likely exert greater effort to obtain it. We did not find significant bias after the implementation of the 2020 directive. Although the DiD model requires to conduct a parallel test, we were not able to conduct such test due to lack of more than one pre-intervention observation. We acknowledge this as a shortcoming of the study.

TABLE 4 Impact of fertilizer distribution directive on prices paid and quantity purchased for farmers served by agrodealers

Variables	Urea price (NRS/kg)		DAP price (NRS/kg)		MOP price (NRS/kg)		Urea quantity (kg)		DAP quantity(kg)		MOP quantity (kg)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Did estimates (Treated#Post directive implementation period)	.488 (.520)	.466 (.497)	.416 (.475)	.352 (.465)	.973 (.712)	.733 (.683)	-23.358 (18.153)	1.430 (19.176)	31.497 (37.337)	39.831 (37.300)	-9.20 (4.413)	-7.192 (6.056)
Post fertilizer distribution directive implementation period (1/0)	1.351*** (.260)	1.922*** (.342)	1.046*** (.244)	1.614*** (.356)	1.107*** (.385)	1.487*** (.476)	-7.812 (8.340)	-29.843** (13.411)	-42.948 (35.660)	-7.378 (52.127)	-8.747*** (3.232)	-4.041 (4.518)
Covid-19 affected the fertilizer availability and purchase(1/0)		1.557*** (.424)		1.341*** (.434)		1.309 (.857)		-41.590** (18.929)		-51.463 (33.602)		-8.877 (5.812)
Owner of the cooperatives/agrodealer is close friend/relatives (1/0)		-.840 (.737)		.133 (.394)		.581 (1.164)		-2.333 (14.730)		11.801 (15.727)		-3.209 (5.522)
Rice cultivated area (kattha)		-.052** (.025)		-.028 (.046)		-.094 (.060)		-.245 (6.451)		-2.297 (4.502)		2.497** (1.266)
Quantity of urea purchased (kg)		-.002 (.001)										
Has access to irrigation in 2078 (1/0)		.224 (.985)		1.096 (.783)		-2.584 (2.315)		-5.946* (29.743)		-65.518 (46.898)		-54.572 (41.970)
Household has applied animal manure (1/0)		-1.097 (1.240)		-.144 (.390)		-.907 (1.107)		-116.771* (61.964)		-37.262 (26.185)		9.094 (11.584)
Quantity of DAP purchased (kg)				.001 (.000)								
Quantity of MOP purchased (kg)				-.010 (.012)								
Price of urea (Rs/kg) in 2021								-1.879 (1.168)				
Search cost (NRS)										-437* (.228)		-1.06 (.065)
Time (minutes) spent to visit the store (time taken to visit and return) in 2021								.506 (.313)		.399 (.331)		.087 (.167)
Price of DAP in NRS/kg										4.404 (3.121)		
Price of mop (Rs/kg) in 2021												-821 (.847)
Constant	19.74*** (.128)	22.007*** (1.613)	48.573*** (.118)	47.521*** (1.750)	38.016*** (.158)	43.444*** (3.245)	35.371*** (4.530)	552.470** (217.907)	268.003*** (9.359)	262.989 (184.637)	53.782*** (1.103)	85.697 (68.959)
Observations	606	606	601	601	423	423	614	606	614	601	614	423
R ²	.115	.160	.089	.118	.105	.153	.020	.076	.009	.035	.054	.218
Number of groups	306	306	303	303	232	232	307	306	307	303	307	232

Robust standard errors in parentheses.

Abbreviations: DAP, diammonium phosphate; MOP, muriate of potash.

 *** $p < .01$. ** $p < .05$. * $p < .1$.

TABLE 5 Regression results assessing if cooperatives are biased towards their members in selling subsidized urea

Variables	Before directive implementation						After directive implementation					
	Urea		DAP		MOP		Urea		DAP		MOP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Member of cooperative that sells subsidized fertilizers	114.358** (49.960)	94.947** (39.030)	51.818* (25.843)	25.393 (37.909)	19.009* (9.470)	3.752*** (8.676)	-106.494 (101.432)	-65.003 (58.067)	-43.894 (5.826)	-8.734 (22.273)	-26.589 (15.870)	-15.802 (11.091)
# Purchase fertilizers from cooperatives												
Purchased subsidized fertilizer from cooperative	-4.426 (29.927)	-39.167* (2.259)	-19.824 (25.550)	-21.752 (19.954)	-16.507 (12.310)	-14.656* (8.328)	2.625 (38.837)	-7.996 (27.338)	-4.374 (3.933)	-1.143 (21.409)	-16.622 (1.970)	-8.251 (7.947)
A household is a member of cooperative that sells subsidized fertilizer (1/0)	-18.876 (23.859)	-69.578** (28.167)	-9.739 (2.349)	-55.33** (23.443)	-6.818 (8.558)	-28.72** (1.790)	174.213* (91.726)	74.826 (55.115)	76.386* (41.916)	-9.183 (21.771)	36.605** (14.464)	14.385 (11.999)
Price of urea (Rs/kg)		-5.083** (1.960)					-1.135 (1.347)					
Price of dap (Rs/kg)				1.483 (2.543)						3.200* (1.815)		
Price of mop (Rs/kg)						-0.842 (.932)						.633* (.361)
Highest year of education by household head		-7.531*** (2.235)		-2.707 (2.304)		.218 (.892)		-7.579*** (2.603)		-4.086** (1.645)		.560 (.825)
Male headed household (1/0)		18.927 (27.090)		9.855 (15.692)		-9.83 (7.802)		21.896 (27.010)		11.039 (16.489)		3.171 (6.025)
Age of the household head in years		-2.983*** (.990)		-3.048** (1.141)		-7.57* (.383)		-2.995*** (1.018)		-2.088** (.838)		-4.04 (.351)
Rate economic condition as good (1/0)		54.379 (32.478)		13.726 (33.407)		2.704*** (6.192)		36.495 (36.016)		37.373* (2.252)		15.825** (6.557)
Has a bank account (1/0)		-31.382 (32.490)		-18.316 (24.409)		-12.474 (13.130)		-32.141 (24.765)		-13.045 (23.147)		-15.843 (17.755)
Frequently interact with peers (1/0)		21.541 (19.818)		44.498** (18.776)		1.896 (9.629)		18.912 (16.961)		27.468* (15.410)		11.319 (8.151)
Willing to take risk (1/0)		42.541 (31.614)		26.918 (24.927)		11.022 (1.481)		4.215 (32.106)		19.346 (27.098)		3.397 (9.980)

(Continues)

TABLE 5 (Continued)

Variables	Before directive implementation						After directive implementation					
	Urea		DAP		MOP		Urea		DAP		MOP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Time preference, i.e., willing to wait to gain more in future (1/0)	4.285 (26.492)	-6.772 (26.865)			13.219 (8.103)	21.411 (25.578)	19.103 (2.449)	15.864** (6.888)				
Frequently seeks the advice of agriculture extension (1/0)	25.773 (2.960)	21.673 (13.686)			1.072** (4.855)	29.816 (22.906)	39.064** (13.942)	3.167 (5.214)				
Used saved seeds (1/0)	-12.564 (18.807)	1.356 (26.843)			-1.181 (7.851)	-17.185 (21.650)	-18.615 (17.782)	-9.463 (6.703)				
Access to irrigation (1/0)	1.974 (25.384)	-4.204 (16.492)			.482 (4.958)	8.094 (27.534)	9.801 (24.795)	1.372 (5.023)				
Level of fertilizer shortage faced by farmers (1 = readily available, 5 acute shortage)	9.797 (1.866)	28.537 (19.125)			4.410 (4.539)	8.831 (13.014)	9.477 (9.972)	2.810 (3.774)				
Land owned (kattha)	7.994*** (.816)	8.200*** (1.845)			1.383*** (.451)	8.551*** (1.007)	6.855*** (1.326)	1.069*** (.373)				
Rural areas (1/0)	61.467** (27.121)	53.102** (2.917)			16.916** (7.374)	62.364* (33.571)	46.989* (22.926)	16.050** (6.907)				
If condition of road is gravel in your village, then 1, otherwise 0	1.653 (37.976)	-9.145 (39.938)			32.831* (16.150)	-1.463 (33.615)	.735 (23.727)	31.122* (15.722)				
Time to reach nearest farm credit organization (in minutes)	.277 (.670)	-.006 (.404)			-.027 (.148)	-.006 (.452)	.240 (.363)	-.176 (.160)				
Constant	348.525*** (45.934)	28.717*** (86.639)	30.223*** (58.783)	-25.748 (21.567)	94.163*** (24.140)	316.459*** (46.931)	281.087*** (111.906)	8.758*** (18.522)	4.190 (29.970)			
Observations	616	614	605	604	432	606	597	387	385			
R-squared	.273	.571	.155	.399	.159	.255	.210	.176	.358			
District FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses.
 *** $p < .01$. ** $p < .05$. * $p < .1$.

TABLE 6 Regression results assessing the bias effects of agrodealers in selling subsidized fertilizer

Variables	Urea		DAP		MOP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Member of cooperative that sells subsidized fertilizers # Purchase	82.817 (88.294)	48.768 (6.609)	3.743 (49.542)	-7.859 (39.838)	-7.562 (16.617)	4.011 (1.038)
Large farmers # Purchase fertilizers from agrodealers	-103.260 (99.862)	47.826 (77.453)	-28.299 (104.683)	92.349 (86.357)	45.870* (25.845)	93.610*** (19.182)
Medium # Purchase fertilizers from agrodealers	9.613 (18.707)	1.827 (25.175)	-4.468 (17.680)	-5.466 (23.130)	6.592 (1.710)	5.065 (8.843)
A household is a member of cooperative that sells subsidized fertilizer (1/0)	45.627 (31.642)	14.313 (19.154)	14.844 (26.595)	-15.462 (24.463)	6.828 (6.142)	2.663 (5.103)
Large farmers (household owns land size of > 1 ha)	515.726*** (85.822)	201.852** (78.034)	357.467*** (61.711)	105.597 (64.676)	46.537*** (13.507)	25.944 (16.111)
Medium farmers (household owns land size between 0.5 to 1 ha)	49.776*** (15.838)	-18.920 (26.072)	53.161*** (12.995)	-9.463 (25.130)	12.594** (5.355)	1.957 (7.405)
Farmer purchased subsidized fertilizer from agrovot (0/1)	4.374 (17.722)	-7.419 (13.671)	2.376 (16.032)	-8.134 (13.681)	-.995 (4.246)	-8.438 (5.065)
Price of urea (Rs/kg) in 2021		-1.122 (1.645)				
Price of DAP in NPRS/kg				3.877** (1.766)		
Price of mop (Rs/kg) in 2021						-.660 (.392)
Highest years of education		-7.571** (2.784)		-4.187* (2.402)		.014 (.545)
Male headed household (0/1)		12.182 (28.895)		5.680 (16.075)		-2.288 (4.714)
Age of household head (year)		-2.647*** (.929)		-1.808** (.850)		-.371 (.271)
Household consider their economic condition as good (0/1)		39.957 (33.944)		4.475 (23.818)		22.054*** (7.829)
Household has a bank account (0/1)		-15.862 (17.700)		1.720 (2.171)		-8.429 (13.355)
Household interacts with their peers (0/1)		18.974 (2.447)		26.895* (15.224)		7.023 (7.145)
Willing to take risk (0/1)		52.899** (23.517)		27.881 (22.260)		5.922 (9.052)
Willing to wait to gain more in future (0/1)		3.470 (23.508)		8.859 (18.259)		1.614 (7.549)
Frequently seek the advice of agriculture extension office (1/0)		2.315 (2.458)		34.949** (16.553)		6.724 (6.184)
Used saved seeds (1/0)		-2.167 (2.544)		-22.212 (14.158)		-11.971** (5.822)
Has access to irrigation in 2021 (1/0)		-3.533 (27.388)		1.016 (18.090)		-3.934 (5.729)
Intensity of fertilizer shortage faced (1 = readily available, 5 = rarely available)		9.109 (14.047)		8.885 (11.555)		5.054 (3.665)

(Continues)

TABLE 6 (Continued)

Variables	Urea		DAP		MOP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Land owned (kattha)		6.703*** (1.495)		5.654*** (1.581)		.511* (.269)
Household resides in rural region (0/1)		53.277** (23.101)		39.245** (16.392)		9.426* (4.694)
Household has access to dirt road in a community (0/1)		-3.613 (27.024)		3.841 (18.908)		3.931** (12.714)
Time to reach nearest farm credit organization (in minutes)		-.117 (.461)		.172 (.352)		-.175 (.156)
Constant	183.742*** (4.331)	165.480 (105.120)	175.781*** (47.108)	-118.546 (119.176)	46.774*** (12.611)	53.198 (36.016)
Observations	618	605	618	596	618	381
R-squared	.454	.603	.372	.561	.272	.498
District FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses.

*** $p < .01$. ** $p < .05$. * $p < .1$.

6 | CONCLUSION AND POLICY IMPLICATIONS

Any policy that promotes the effective and efficient distribution of fertilizer is important to boost agricultural productivity, increase household welfare, and improve food security in developing countries. Our results indicate that FDD 2020 has increased farmers' access to fertilizer, reduced travel time and fertilizer search costs and eliminated prior biases in fertilizer sales.

These results carry useful policy implications for Nepal. Private sector engagement in sales of subsidized fertilizer should be expanded and include importation. Policies, in this regard, should include precautions regarding overcharging to farmers, particularly during periods of scarcity and peak demand, and enforceable quality standards for unsubsidized fertilizer. We recommend rigorous official monitoring and regulation of private sector sales and behavior in fertilizer markets. Future studies can assess the impact of FDD 2020 on the profitability of fertilizer use and its effects on agricultural productivity.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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