The Impact of a Smartphone Marketing Application on Smallholder Livestock Producers in Nepal: Pre-Analysis Plan

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Abstract

Can smartphone applications be harnessed to raise the incomes of smallholder farmers? Although previous literature has shown that access to mobile phones and mobile phone-based interventions can positively affect smallholder farmers, little is known about the effects of introducing smartphone applications (apps) designed to solve market problems and increase economic activity. In this pre-analysis plan, we propose to evaluate the effects of a smartphone-based, information-sharing app for livestock producers known as the "Virtual Collection Center". Our population of interest consists of smallholder goat producers in rural Nepal, all of whom are women and are members of producer cooperatives. We will estimate average and heterogeneous treatment effects of the app in four domains: information sharing, animals sold, prices received and cooperative-level management outcomes. Our study will contribute to two areas of interest where little evidence currently exists: the potential of smartphone apps as a tool for agricultural development, and business development for agricultural cooperatives in developing countries.

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1 Introduction

Can smartphone applications be harnessed to raise the incomes of smallholder farmers? Although previous literature has shown that access to mobile phones and mobile phone-based interventions can positively affect smallholder farmers (Aker 2010; Cole and Fernando 2012; Curtois and Subervie 2014; Jensen 2007; Nakasone 2013), little is known about the effects of introducing smartphone applications (apps) designed to solve market problems and increase economic activity. Prior research on the effects of apps has been limited by low rates of smartphone ownership in the developing world, but the gap between rich and poor countries has substantially narrowed over the last decade (World Bank 2016). In particular, the rate of smartphone ownership in the developing world grew from 18% in 2013 to 47% by 2018, with much higher rates of ownership among individuals 35 years of age and younger (Pew Research Center 2018).

In this pre-analysis plan, we propose to evaluate the effects of a smartphone-based information-sharing app for livestock producers known as the "Virtual Collection Center" (VCC). Our population of interest consists of smallholder goat producers in rural Nepal, all of whom are women and members of producer cooperatives. The VCC allows rank-and-file cooperative members to regularly update leadership on available goat inventory. Cooperative leaders use this inventory information to negotiate bulk sales with traders, and then invite cooperative members to sales events through the app. By lowering barriers to communication in an environment characterized by rugged terrain and long travel times between population centers, the VCC has the potential to encourage market participation by cooperative members, thereby raising incomes.

We will evaluate the effects of the VCC using a cluster-randomized control trial where treatment is assigned at the cooperative level. Cooperative members in the treatment group receive access to the VCC app as well as training on how to use it through our implementing partner, Heifer Project International Nepal (HPIN). At the completion of the study in spring 2020, we will (i) estimate average intent-to-treat (ITT) effects of the intervention on cooperative and individual level economic performance and (ii) assess treatment effect heterogeneity.

By facilitating communication and the flow of information, mobile technology has the potential to help alleviate poverty around the world (Aker, Ghosh, et al. 2016). Mobile technology could be particularly helpful for rural households who depend on agriculture for their livelihoods.

Smallholder agricultural producers sometimes struggle to access information, communicate with market actors, and arrange sales, resulting in high transaction costs, weak bargaining power and price dispersion that limit income growth and investment in productive assets (Staal et al. 1997). The existing literature shows that mobile-phone adoption and mobile phone-based interventions can positively affect smallholder bargaining power, production and prices received (Cole and Fernando 2012; Curtois and Subervie 2014; Muto and Yamano 2009; Nakasone 2013; Shimamoto et al. 2015), while also improving producer and consumer welfare and reducing waste by eliminating price dispersion across markets (Aker 2010; Jensen 2007). However, mobile technology for agricultural development has not been universally effective. In some cases, access to mobile phones or mobile phone-based information services has increased farmer knowledge without affecting prices received (Aker and Ksoll 2016; Camacho and Conover 2011), and in others impacts have been limited by low adoption (Fafchamps and Minten 2012; Muto and Yamano 2009).

While there is a rich literature on the impact of mobile phone coverage and related interventions, smartphones are a fairly recent development in low-income countries. Existing studies of smartphone apps for agriculture tend to consist of small pilots rather than large randomized trials. Examples include Eitzinger et al. (2019), who discuss GeoFarmer, a cloud-based smartphone app that allows farmers to share information with other producers and experts, and Saito et al. (2015), who develop a decision-support application that helps farmers in Senegal improve fungicide applications.

This study will contribute to two areas of interest where little evidence currently exists. First, we will provide evidence on the impact of a smartphone app designed to increase economic activity in a rural area of a developing country. In addition, we add to the evidence on business development for woman entrepreneurs, smallholder livestock producers, and agricultural cooperatives.

2 Background

In Nepal, where 68 percent of the population depends on agriculture for their livelihood (International Labor Organization 2016), goats are an essential source of income and animal source foods. Goats are commonly referred to as the "poor person's cow," and nearly every rural Nepali household owns at least a few (Upreti 2009). Recently, rising urban incomes have translated into higher demand for goat meat, but a poorly functioning value chain has left poor smallholders, most of whom are women, unable to benefit (Ashby et al. 2009; Choudhary et al. 2011; Gurung et al. 2015). Producers face the twin obstacles of weak bargaining power and a lack of communication infrastructure, limiting their ability to access and gain from formal output markets (Ashby et al. 2009; Kristjanson et al. 2014).

By increasing bargaining power, decreasing transaction costs, and helping achieve scale economies in marketing, cooperatives may promote agricultural development by reducing constraints that limit the success of smallholders (Bernard and Spielman 2009; Collion and Rondot 2001; Fischer and Qaim 2012; Poole and De Frece 2010; World Bank 2003). Many agricultural policy and rural development plans in Nepal have promoted agricultural cooperatives as a means of supporting smallholder producers (Agricultural Development Strategy 2015), and HPIN programming includes organizing its beneficiaries into cooperatives. The process of organizing HPIN beneficiaries begins with extensive training followed by livestock transfers and organization into self-help groups (SHGs) of around 20-30 female members. Once SHGs in a given area are sufficiently organized, they are combined into larger producer cooperatives.

In Nepal, the majority of goats are consumed locally after sale to a local collector who pools animals from small producers, or to a local butcher (Heifer International Nepal 2012). For goats that are marketed outside their original communities, the commercial value chain links producers, local collectors, regional traders who pool animals purchased from collectors, processors and retailers, and finally consumers who are primarily located in urban markets like the Kathmandu Valley (Heifer International Nepal 2012). A collector looking to buy goats from smallholder producers who are not affiliated with a cooperative would likely have to conduct individual negotiations, sometimes making multiple visits per home (Heifer International Nepal 2012; Staal et al. 1997). After agreeing to terms with producers, the collector would still have to coordinate transportation. If the collector does not want to transport goats from each individual home, then he or she would have to coordinate with producers so that the latter bring their animals to a collection point at a specific date and time. Bargaining with many small producers and managing logistics may inflate transaction costs and dissuade collectors from dealing with smallholders. From the perspective of producers, one-on-one bargaining may be disadvantageous if collectors have little competition within communities. A study on the goat value chain in Nepal suggests that competition between collectors is low and that they may coordinate with one another (Heifer International Nepal 2012).

In contrast, a collector purchasing through a cooperative need only negotiate with a single entity and can leave sales coordination to cooperative managers. But rather than eliminating the source of high transaction costs, the burden is shifted to the cooperatives themselves. The effectiveness of cooperatives in raising smallholder market engagement will depend on how well cooperative management meets the coordination challenge. The cooperatives included in our evaluation appear to struggle with coordinating goat sales in a way that is broadly inclusive of members. Although officers from 90 of the 92 cooperatives included in our study stated in baseline interviews that their organizations coordinated group sales, 43% of households who had sold at least one goat in the 12 months prior to baseline data collection indicated that their cooperatives did not perform this service.

Despite growth in mobile phone ownership, our baseline data suggest that the cooperatives studied here largely communicate in person. Less than 30% of households in our sample received any information about sales organized through the cooperative in the 6 months prior to data collection. Among the households that did receive price and sales information, half indicate that they did so by word of mouth, nearly 75% indicate receiving this information through SHG meetings, while only 19% have received this information by phone call and less than 1% via short message service (SMS). The responses of rank-and-file cooperative members regarding use of mobile phones are reinforced by a survey of cooperative officers, who indicate that they contacted SHGs by SMS less than once and by phone call only three times in the month prior to data collection, on average.

The failure to transmit information about sales could be the result of meeting infrequently, as nearly all households state that SHG meetings happen monthly or less while nearly two-thirds indicate that cooperative meetings take place every two months or less. Distance to meetings points could be a barrier to more frequent interactions, as cooperative members state that it takes approximately 75 minutes to travel to and from cooperative meetings, on average. Road quality, access to transportation, and distance between cooperative members were identified by 90%, 93%, and 83% of cooperative leaders, respectively, as limiting communication. Cooperatives may be responding slowly to market demand and potentially losing sales in the time it takes to communicate with members, while also failing to consider the entire inventory of animals at their disposal.

The necessary conditions for an effective smartphone-based marketing intervention appear to be in place in rural Nepal. Survey data collected from a representative sample of HPIN beneficiaries for a prior project show that at least 47% of members in every SHG own a mobile phone (Janzen et al. 2016). More recent data from the Nepal Telecommunications Authority (2019) show that the mobile phone penetration rate (the number of SIM cards in use) exceeds 132% of the total Nepali population. Smartphone ownership in Nepal has grown by roughly 10 percentage points each year since the start of the decade and surpassed 50% in 2018 (NepaliTelecom 2019). Virtually all of the country except for mountainous areas has 2G or better network coverage, allowing for voice, SMS, and basic internet usage through mobile phones.[1]

The difficulties associated with word-of-mouth communication beg the question of why mobile phones do not play a larger role in cooperative marketing. One barrier may be the lack of specialized communication tools that reduce the time and cost of making calls and sending text messages. Given that cooperatives average about 500 members each, calling all members or confirming that all receive a text message may seem more onerous than holding a meeting. Network quality is also an issue, with 89% of cooperative leaders in our baseline data indicating that mobile network coverage limits communication within the cooperative. But mobile network coverage and smartphone ownership are likely to continue increasing in Nepal at rapid rates, while infrastructure improvements and other investments needed to make face-to-face communication in rural areas easier may not be forthcoming. These circumstances might accurately describe many rural areas reliant upon agriculture, making the effectiveness of smartphone marketing tools in rural Nepal an important development question.

3 Research Design

3.1 Intervention

The VCC app was designed by the research team and HPIN, and programmed by Pathway Technology and Services, a Nepali software firm that also shared responsibility for training cooperatives in the use of the app with HPIN. The VCC app was completed and piloted in 2018. After initial technical difficulties, the app was rolled out in earnest to the treatment group in December 2018.

[1] For example, see the coverage map for major carrier Ncell.

The app, which requires an Android smartphone, was designed to be easy to use by producers who have basic literacy and are familiar with smartphones, but probably not able to use a complicated program. The intervention was designed so that only one member of each SHG needs to have the VCC app installed on her smartphone, while a single cooperative officer manages the data compiled from all SHGs. The person responsible for the app at the SHG level is known as the "SHG manager" while the cooperative officer managing the app at a higher level is known as the "cooperative VCC manager" (as opposed to the regular cooperative manager, which is a separate position in the cooperative leadership hierarchy). As of June 2019 all SHG managers and cooperative VCC managers had the app installed on a smartphone.

Figure 1 provides a description of how the VCC platform is used to organize sales within a given cooperative. In step 1, SHG members report the quantity of small, medium and large goats available for sale to the SHG manager. Goat weight classifications and their associated cutoffs are commonly known. The SHG manager enters inventory information into the VCC app, and the app automatically sends the information to a server managed by HPIN in step 2. Sending and receiving information through the app requires cell service. Information sent through the application is done so in SMS format. Information cannot be sent or received without cell service and is delayed until service is restored.

In step 3, the server compiles the data sent by each SHG into a database and a summary table is automatically created for each cooperative and sent to the cooperative VCC manager. The summary table lists the quantity of small, medium, and large goats available for sale in each SHG. In steps 4 and 5, cooperative leaders use inventory information to coordinate sales with local buyers. Once a sale has been arranged, the cooperative leaders select specific SHGs to participate in the sale based on the inventory data in the VCC app. Using the VCC app, the cooperative VCC manager notifies the SHG managers of the date, location, trader, number of animals by weight category, and price per animal for the arranged sale in step 6. In step 7, the SHG manager confers with her fellow SHG members, and then lets the cooperative VCC manager know through the app how many members will attend the sale and the quantity of animals each will bring. If necessary, the cooperative VCC manager can invite additional SHGs until the buyer's order is filled. At the conclusion of the sale, the SHG manager enters updated information on the number of goats available into the VCC app, and the process begins again. In addition to inventory and sales coordination, the VCC app has a general-purpose messaging tool.

Figure 2 displays select images of the VCC interface that SHG managers see on their mobile device. The left-most image depicts the home screen, where users can navigate the various functions of the app. The center image displays the screen where SHG managers update the quantity of available goats within the SHG. The right-most image depicts sale information that is sent to an SHG manager if her SHG is invited to a sale.

Figure 1: VCC Network Diagram

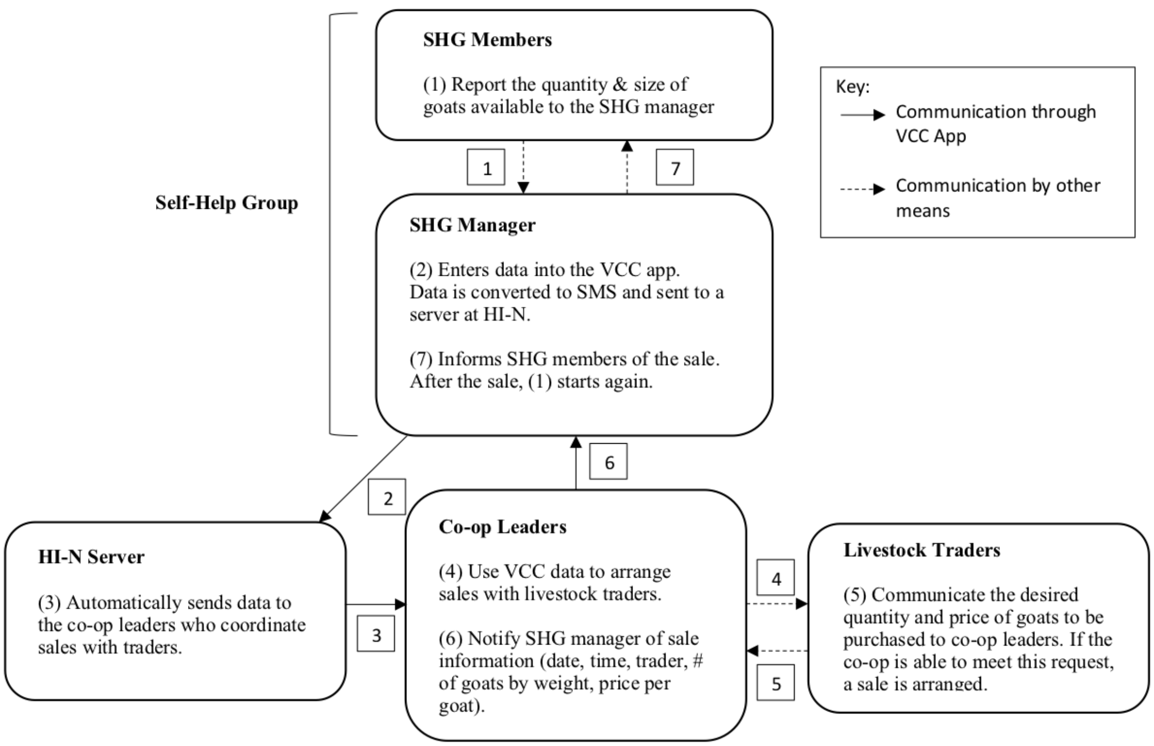
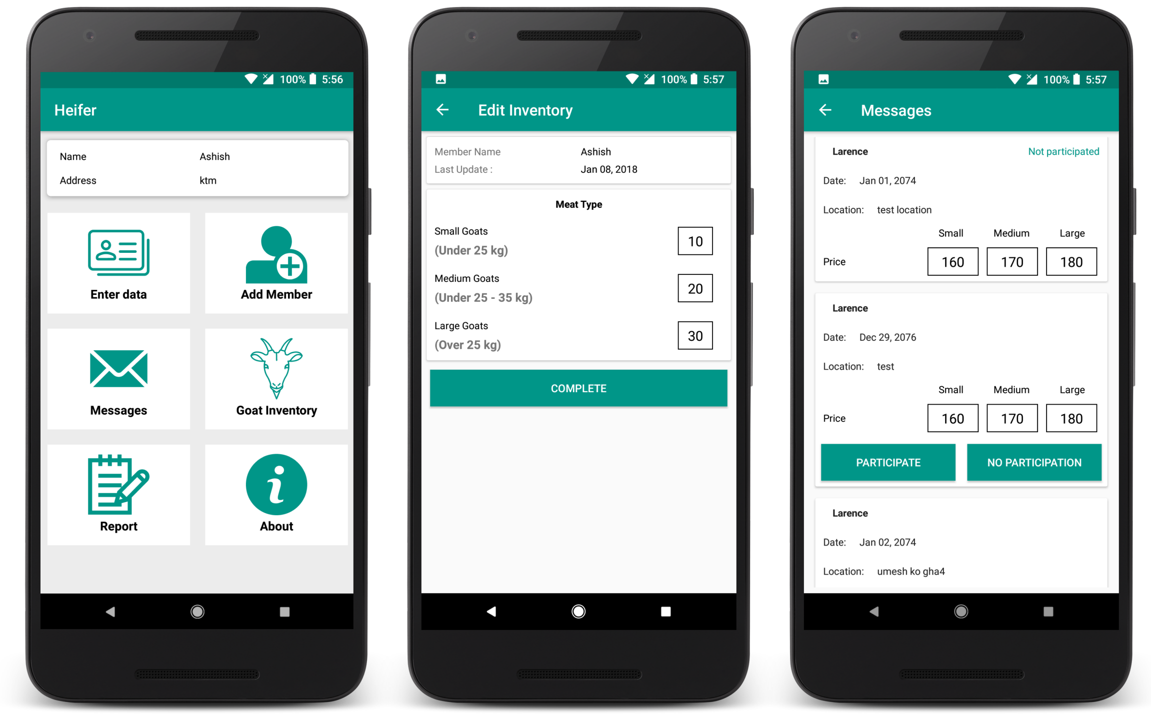


Figure 2: VCC Application Interface



3.2 Experimental design

The impact of the VCC platform will be evaluated using a cluster RCT spanning 92 cooperatives in Nepal. Treatment was assigned at the cooperative level through a stratified randomization design as described in detail in section 4.2. Treatment effects will be estimated at both the household and cooperative levels.

The cooperatives in our study cover a wide geographic area. Based on conversations with HPIN, we understand cooperatives largely sell to local markets and buyers, such that broader macroeconomic price impacts (extending beyond the geographic borders within which the cooperative operates) are not anticipated. Cooperatives are geographically based, and members of a cooperative are only able to sell through their cooperative. Because cooperative membership comes through SHG membership, and SHG membership is extremely local (tole, or neighborhood), non-members would only be able to join their local cooperative and not a cooperative in a different treatment group.

3.3 Research questions

Our study will answer the following questions: (i) across a range of dimensions of cooperative performance (measured at the cooperative and household levels), what are the overall impacts of access to the VCC, (ii) are the effects of the VCC heterogeneous, and if so, (iii) how do the households and cooperatives most and least affected by the intervention compare in terms of their observed characteristics?

If effective, the VCC app could transform households and cooperatives in our study area as follows. By improving access to market information and reducing the costs of coordination within cooperatives for group marketing, we hypothesize that the VCC application will increase the proportion of cooperative members made aware of cooperative-organized sales. More generally, the improved flow of communication stimulated by the VCC app may make cooperatives more transparent, where transparency is measured by how closely aligned management and rank-and-file members are in their responses to questions about the services offered by their cooperative. Improved awareness of group sales will raise the quantity of goats sold through cooperatives and the total number of goats sold overall. Raising the number of goats sold through cooperatives may have two impacts on prices received: first, by selling more goats through cooperatives, households may receive higher prices, and second, selling more goats through cooperatives may increase cooperative bargaining power by limiting side selling, leading to higher prices received for goats sold through cooperatives. The VCC app may also transform cooperative management. As demonstrated by Lajaaj (2017) using randomized assignment of input subsidies and matched savings to rural households in Mozambique, poverty shortens planning time horizons. Similarly, we hypothesize that improved cooperative performance will translate into longer planning time horizons for cooperative leaders, as well as higher expectations for future goats sold and revenue.

Below we organize our hypothesized effects of the VCC app into four research questions. Each research question has a corresponding family of hypothesis tests where we will test the null of no effect on the outcomes listed below each question. For a given research question, we will answer in the affirmative if we reject the null hypothesis of no effect for at least one associated outcome while adjusting for multiple hypothesis testing. We discuss our approach to adjusting for multiple hypothesis testing in section 5.2.

- **Question 1:** Does access to the VCC application improve communication within cooperatives?

  1a) Household is aware of whether or not their cooperative organizes goat sales with traders (0/1)

  1b) Household was contacted at least once about cooperative goat sale in past 12 months (0/1)

  1c) Administrative transparency index (continuous)

  1d) Economic services transparency index (continuous)

- **Question 2:** Does access to the VCC application increase goat sales?

  2a) Number of goats sold by the household through the cooperative (count)

  2b) Number of goats sold by the household (count)

- **Question 3:** Does the VCC application increase prices received for goats?

  3a) Revenue per goat sold through the cooperative (USD)

  3b) Revenue per goat sold (USD)

- **Question 4:** Does access to the VCC application improve the planning horizon and expectations of cooperative leaders?

  4a) Planning time horizon (years)

  4b) Number of goats expected to be sold through cooperative in next six months (count)

  4c) Total revenue expected to be earned by cooperative in next six months (USD)

Most outcomes are self-explanatory, with the exception of the "administrative transparency index" and the "economic services transparency index." Our data set contains several variables that were collected by asking cooperative leaders and member households identical questions. For the administrative index, we have seven binary variables that indicate whether cooperative leaders and member households stated that the cooperative makes certain information available to its members. For the economic services index, we have sixteen binary variables that indicate whether cooperative leaders and member households stated that the cooperative provides certain services to its members. Each index is created by coding disagreements between the cooperative manager and member households as zeroes and agreements as ones. The resulting administrative and economic service variables are then combined into separate inverse covariance weighted indices as described in Anderson (2008), respectively. We offer detailed descriptions of each outcome indicator in section A.3 of the appendix.

3.4 Heterogeneous effects

We hypothesize that the impact of our intervention will vary across cooperatives and individuals. To answer questions (ii) and (iii) above, we will estimate differing treatment effects for each identified group and analyze the average characteristics of those most and least affected by the intervention. We hypothesize heterogeneity of impacts across the following dimensions:

1. Mobile network seriously limits cooperative communication (0/1)
2. Household sold goats at baseline but not through the cooperative (0/1)
3. Household sold goats through the cooperative at baseline (0/1)
4. Round-trip travel time between the household and the cooperative meeting place (minutes - Inverse hyperbolic sine transformation)

Details of how this analysis will be conducted are discussed in section 5.3.

4 Data

4.1 Sample and data collection

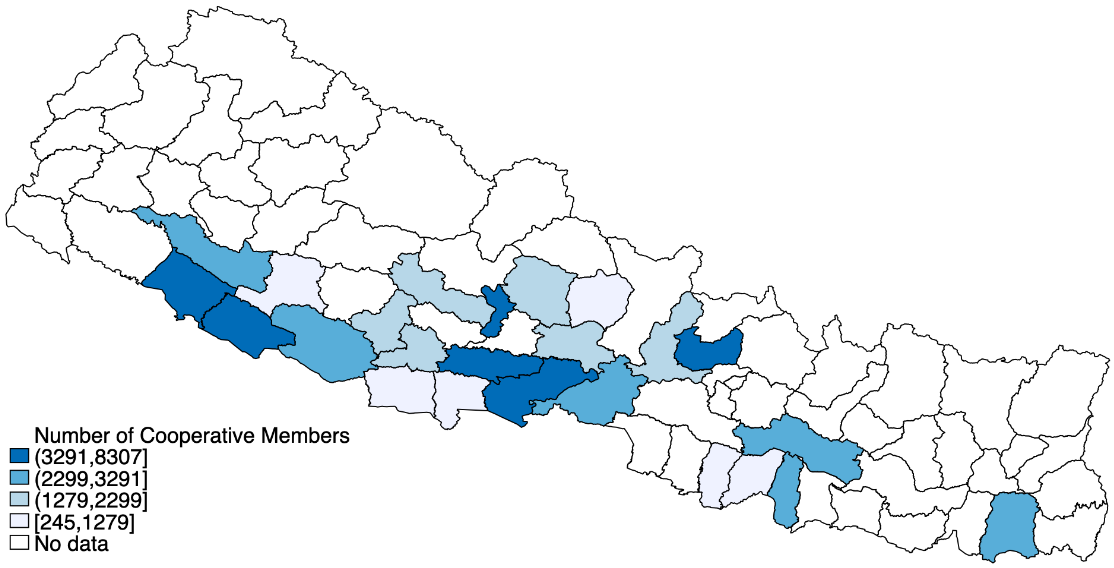
Our sample frame is a list of 108 cooperatives spread across four of five development regions in Nepal, specifically the East, Central, West and Mid-Western Development regions. All cooperatives operate in either the low-land Terai or mid-Hills. Figure 3 shows the study area covered in our sample, which includes cooperatives from 20 of 77 districts across Nepal. The cooperatives included in the study were selected by HPIN and include all existing livestock marketing cooperatives the organization helped form prior to 2017.

Because we are interested in impacts at the cooperative and household level, we conduct two separate surveys - one with cooperative leaders and another with general members. We refer to these surveys as the cooperative leader and household survey, respectively.

In each cooperative we select 3 officers to participate in the cooperative leader survey. By interviewing multiple officers for each cooperative we use triangulation to validate data. For some questions, we can also triangulate across the household and cooperative leaders survey.

To obtain a representative sample of household likely to be affected by the interventions for the household survey, we worked with HPIN and cooperative leaders to obtain complete cooperative

Figure 3: Study Area



rosters. From these comprehensive lists, we drew a random sample of 2,856 households across 108 cooperatives to participate in the household survey.

Baseline data were collected from the sample in January 2018 using Android tablets and Open Data Kit. Endline data will be collected in mid 2020, when treatment group households will have been exposed to the app for about a year and a half.

4.2 Assignment to treatment

To form strata prior to randomization, we first used the baseline data from both the household and cooperative leader survey to identify what we expect to be strong predictors of our outcomes of interest, including region (Terai and Mid-Hills), household goat revenue over the past 12 months, number of cooperative members, and cooperative revenue. Household goat revenue was top coded, replacing obvious outliers with reported number of goats sold multiplied by the median revenue per goat sold. The strata were then created using the following steps:

1. Dropping a single cooperative that was used in a pilot of the VCC app, leaving 107 cooperatives in total.

2. Sorting cooperatives within each region by average household-level goat revenue.

3. Splitting each region at its 33rd and 66th percentiles of average household goat revenue,

yielding six bins.

4. Sorting cooperatives in each of the six bins by number of cooperative members.

5. Splitting each bin at the median number of cooperative members, yielding a total of 12 bins.

6. Sorting each of the 12 bins by cooperative revenue.

7. Splitting each bin at the median of cooperative-level revenue (from any source), yielding a total of 24 bins ranging in size from four to six cooperatives.

Within each cooperative, we generated a uniform random variable and assigned the two (in the case of strata with four or five members) or three (in the case of strata with six members) cooperatives with the greatest value of the random variable to treatment. For strata with five members, the odd-numbered cooperative was assigned to treatment with 50% probability using a uniform random variable.

Two complications arose around the time of treatment assignment. First, HPIN informed the research team that cooperatives in a single district could not be part of the randomization because the cooperatives work together to market goats. At that point, the randomization was complete and cooperatives had already been contacted to coordinate VCC app training. Therefore it would have been problematic to perform the randomization again. Instead, we verified that balance for our chosen indicators was maintained after dropping the cooperatives from the aforementioned district.[2] The final treatment assignment includes 92 cooperatives in total, with 45 assigned to treatment and 47 assigned to control.

Second, a coding error occurred during the randomization that resulted in 39 of 92 cooperatives being assigned to strata using the wrong value of total cooperative revenue. Fortunately, the damage caused by the error was minimal. Total cooperative revenue was used at the lowest level of stratification, and no household-level variables were affected. Total cooperative revenue is almost identical on average in treatment and control cooperatives. In section A.1 of the appendix, we describe how the error arose in detail.

[2]Cooperatives in this district union were removed from the research design but were allowed to proceed using the app.

4.3 Summary statistics and balance

The summary statistics displayed in table 1 demonstrate that cooperatives in our sample vary in both size and economic activity. The average cooperative has over 500 members and revenue of nearly $3,800 USD. Total membership ranges from 11 to 2,600 while cooperative revenue ranges from $0 to over $65,700 USD. We observe similar variation across cooperative members. The average household sold one goat in the past year, and received $42 USD in revenue per goat sold. Note that revenue per goat was set to zero for households not selling any goats, making revenue per animal (especially for sales through cooperatives) appear artificially low. Goats sold through the cooperative range from zero to 5, while the total number of goats sold range from zero to 12.

Table 1: Summary Statistics

Cooperative-Level Variables	N	Mean	sd	Min	Max
Members (count)	92.00	553.36	376.42	11.00	2,600.00
Revenue (USD)	92.00	3,775.21	8,014.47	0.00	65,709.51
Costs (USD)	92.00	377.52	1,639.07	0.00	10,964.25
Net revenue (USD)	90.00	3,473.19	8,245.85	-7,935.00	65,554.27
Revenue per member (USD)	92.00	7.20	10.55	0.00	63.53
Net revenue per member (USD)	90.00	6.80	10.95	-13.22	63.53
Coordinates goat sales (0/1)	92.00	0.85	0.36	0.00	1.00
Goat revenue (USD)	90.00	111.86	203.73	0.00	1,029.40
Planning time horizon (years)	92.00	1.26	0.98	0.00	5.00
Expected goats sold (count)	92.00	269.09	359.69	0.00	2,500.00
Expected revenue (USD)	92.00	1,011.83	2,136.93	0.00	14,850.00
Number of ICT assets (count)	92.00	0.57	0.74	0.00	3.00
Number of non-ICT assets (count)	92.00	2.79	2.47	0.00	15.00
Mobile network limits communication (0/1)	92.00	0.33	0.47	0.00	1.00
Household-Level Variables	**N**	**Mean**	**sd**	**Min**	**Max**
Household has dirt floors (0/1)	2,448.00	0.56	0.50	0.00	1.00
Household has more than one floor (0/1)	2,448.00	0.58	0.49	0.00	1.00
Age (years)	2,448.00	42.80	11.69	6.00	83.00
Literacy (0/1)	2,446.00	0.79	0.36	0.00	1.00
Number of SHG meetings attended (count)	2,448.00	1.84	2.49	0.00	24.00
Log travel time to cooperative (minutes)	2,323.00	4.65	1.01	0.00	8.88
Aware of cooperative goat sales (0/1)	2,448.00	0.64	0.48	0.00	1.00
Received Sale Information (0/1)	2,448.00	0.29	0.45	0.00	1.00
Goats sold through cooperative (count)	2,448.00	0.22	0.75	0.00	5.00
Total goats sold (count)	2,448.00	1.14	1.75	0.00	12.00
Revenue per goat (USD)	2,448.00	42.13	50.01	0.00	187.27
Revenue per goat through cooperative (USD)	2,448.00	9.44	29.10	0.00	132.00
Administrative transparency index	2,448.00	-0.00	0.97	-1.31	1.63
Economic services transparency index	2,448.00	0.05	0.96	-4.16	1.69

Notes: Several variables have missing values replaced with zero for analysis. Log travel time to cooperative is generated using the inverse hyperbolic sine transformation (see section A.3 for more details). Among the household-level variables, dwelling characteristics (dirt floors and number of floors) and goat marketing variables (number sold, number sold through cooperative, revenue per goat, revenue per goat through the cooperative, and net goat income) are measured at the household level. Remaining variables are at the level of the cooperative member.

Tables 2 and 3 display balance across the treatment and control groups in the cooperative and household-level data. All outcomes of interest are balanced across treatment and control groups at baseline. More extensive balance tables can be found in section A.2 of the appendix.

Table 2: Cooperative Level Balance Table

	(1)		(2)		
	Control		Treatment		Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Cooperative coordinates goat sales (0/1)	47	0.809	45	0.889	-0.080
		(0.058)		(0.047)	
Cooperative revenue (USD)	47	3791.017	45	3758.693	32.323
		(1419.881)		(866.417)	
Planning time horizon (years)	47	1.092	45	1.426	-0.334
		(0.129)		(0.158)	
Expected goats sold over next 6 months (count)	47	233.082	45	306.700	-73.618
		(55.623)		(50.049)	
Expected revenue over next 6 months (USD)	47	663.426	45	1375.729	-712.303
		(205.460)		(397.352)	

Notes: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. The value displayed for t-tests are for tests of differences in means by treatment status, controlling for the strata dummies used to assign treatment.

Table 3: Household Level Balance Table

	(1)		(2)		
	Control		Treatment		Difference
Variable	N/[Clusters]	Mean/SE	N/[Clusters]	Mean/SE	(1)-(2)
Household is aware of cooperative goat sales (0/1)	1200	0.603	1248	0.683	-0.080
	[47]	(0.059)	[45]	(0.048)	
Received sale information (0/1)	1200	0.259	1248	0.317	-0.057
	[47]	(0.045)	[45]	(0.040)	
Administrative transparency index (continuous)	1200	0.000	1248	-0.005	0.005
	[47]	(0.091)	[45]	(0.094)	
Economic services transparency index (continuous)	1200	0.000	1248	0.093	-0.093
	[47]	(0.119)	[45]	(0.091)	
Goats sold through cooperative (count)	1200	0.189	1248	0.258	-0.069
	[47]	(0.040)	[45]	(0.057)	
Goats sold (count)	1200	1.068	1248	1.208	-0.139
	[47]	(0.068)	[45]	(0.093)	
Revenue per goat sold (USD)	1200	41.441	1248	42.786	-1.345
	[47]	(2.721)	[45]	(2.145)	
Revenue per cooperative goat sold (USD)	1200	8.065	1248	10.758	-2.693
	[47]	(1.616)	[45]	(2.068)	

Notes: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. The value displayed for t-tests are for tests of differences in means by treatment status, controlling for the strata dummies used to assign treatment. Standard errors are clustered at the cooperative level.

4.4 Statistical power

Below we present minimum detectable effects (MDEs) estimated using our baseline data set. To guard against data mining, we base our MDEs on a new permutation of treatment assignment as suggested in Olken (2015), following our stratified randomization scheme (including dropping cooperatives that market goats together post-randomization and the coding error as described in section 3.2). We set $1 - \beta$ (statistical power) to 0.80, and α (the significance level) to 0.05. To estimate MDEs, we use the baseline sample of either the household-level or cooperative-level data to estimate the following equations respectively:

$$y_{ij} = \beta_0 + \beta_1 T_j + \gamma \boldsymbol{S}_{ij} + \varepsilon_{ij} \tag{1}$$

$$y_j = \beta_0 + \beta_1 T_j + \gamma \boldsymbol{S}_j + \varepsilon_j \tag{2}$$

In equation 1, y_{ij} is the outcome of interest for household i from cooperative j. The indicator T_j equals one for households in cooperatives assigned to the treatment groups and zero for households in the control group. The vector $\boldsymbol{S}_{ij}$ contains indicator variables for the strata created by our randomization. The parameter β_1 is the average intent-to-treat (ITT) effect, i.e. the average impact of being given access to the VCC app as well as training on how to use it. Terms in equation 2 are defined similarly, but are for outcomes measured at the cooperative level.

We then estimate the MDE for outcome y_{ij}, as follows:

$$MDE_{y_{ij}} = (t_{a/2} + t_{1-\beta}) se_{\hat{\beta}_1} \tag{3}$$

where $se_{\hat{\beta}_1}$ is the standard error of the estimated average ITT effect. For household-level outcomes we use cluster-robust standard errors while for cooperative outcomes we use "HC1" robust standard errors (MacKinnon and White 1985), where the latter are the standard errors invoked by the "robust" option with linear regression in Stata. The terms $t_{a/2}$ and $t_{1-\beta}$ are set equal to critical values from a t-distribution with the appropriate degrees of freedom (the number of cooperatives minus one for household level outcomes, which is the default Stata adjustment when using cluster-robust standard errors, and $G - k$ for cooperative-level outcomes, where G is the number of cooperatives and k is the number of parameters to be estimated).

Our estimated MDEs are summarized in table 4. For household-level outcomes, the estimated MDEs are generally small, ranging from .14 to .35 standard deviations with a median of .26 standard deviations. Cooperative-level MDEs are much larger, as we would expect given the smaller number of observations involved. We conclude that we have adequate power to detect small effects for most household-level outcomes, but that a high probability of finding a non-zero impact on cooperative planning and expectations would require large true effects at the cooperative level. When estimating ITTs using our follow-up data, we will include lagged outcomes, a vector of covariates as well as the interaction between each covariate and the treatment indicator on the right-hand side (see section 5). Our estimated MDEs are therefore likely to understate the statistical power of our experimental design.

Table 4: Minimum Detectable Effects

Category	Variable	MDE	Standard Deviations
Communication	Aware of cooperative goat sales (0/1)	0.1632	0.3406
	Received sale information (0/1)	0.1356	0.2992
	Administrative transparency index (continuous)	0.2810	0.2872
	Economic services transparency index (continuous)	0.3457	0.3519
Goat Sales	Household goats sold through cooperative (count)	0.1707	0.2270
	Household goats sold (count)	0.2426	0.1436
Prices Received	Household revenue per goat sold (USD)	7.2217	0.1443
	Household revenue per cooperative goat sold (USD)	6.6429	0.2277
Planning & Expectations	Planning time horizon (years)	0.5675	0.5778
	Expected goats sold (count)	170.6262	0.4744
	Expected revenue (USD)	1,208.6133	0.5656

5 Empirical strategy

5.1 Average intent-to-treat effects

To measure intervention impacts, we will estimate average intent-to-treat (ITT) effects for each outcome of interest. Our main estimating equations for household and cooperative-level outcomes are given below:

$$y_{ijt} = \rho y_{ijt-1} + \beta_0 + \beta_1 T_j + \beta_2 \dot{\boldsymbol{X}}_{ijt-1} + \beta_3 (T_j \times \dot{\boldsymbol{X}}_{ijt-1}) + \gamma \boldsymbol{S}_{ij} + \varepsilon_{ijt} \tag{4}$$

$$y_{jt} = \rho y_{jt-1} + \beta_0 + \beta_1 T_j + \beta_2 \dot{\boldsymbol{X}}_{jt-1} + \beta_3 (T_j \times \dot{\boldsymbol{X}}_{jt-1}) + \gamma \boldsymbol{S}_j + \varepsilon_{jt} \tag{5}$$

Equations 4-5 are similar to the equation used to estimate our MDEs, but now includes lagged (baseline) outcomes on the right-hand side, a vector of controls variables and an interaction between the control variables and the treatment indicator. The vector $\dot{\boldsymbol{X}}_{ij} (= \boldsymbol{X}_{ij} - \bar{\boldsymbol{X}})$ consists of the demeaned variables specified in section 3.4, all dimensions across which we hypothesize treatment effect heterogeneity.[3]

5.2 Inference for average intent-to-treat effects

As in our power calculations, we will use cluster-robust standard errors for household outcomes and HC1 robust standard errors for cooperative-level outcomes. But as discussed in section 3.3, our answer to a given research question will hinge on whether we reject one or more hypotheses in the relevant family of tests. We will account for the fact that we have multiple tests for each research question by controlling the false discovery rate (FDR) at level 0.10, where the FDR is the proportion of rejected nulls within a given family of hypotheses that are Type 1 errors in repeated samples.

We apply the two-step procedure described in Benjamini et al. (2006):

1. Generate p-values for each null hypothesis within each research question.

[3] For outcomes 1c and 1d, we will also control for the total number of services provided by the cooperative. Due to the design of each index, members of cooperatives that provide a large number of services are more likely to be unaware of a few. Members of cooperatives that only provide a small number of services are more likely to be aware of the few that are provided. Controlling for the number of services offered, as reported by the cooperative leader, will control for these differences.

2. Order the p-values from smallest to largest.

3. Let p_r be the r^{th} p-value when all p-values in the family of tests are ranked from smallest ($r = 1$) to largest ($r = h$), where h is equal to the number of outcomes within a given research question. Reject the null hypothesis associated with the r^{th} p-value if the following condition holds: $p_r < (0.10/(1.10)) \times (r/h)$.

4. If no hypotheses are rejected or all hypotheses are rejected, stop. Otherwise, continue.

5. Let k be the number of rejected hypotheses. Test all three hypotheses in the family and reject any hypothesis for which $p_r < q^* \times (r/h)$, where $q^* = (0.10/(1.10)) \times (h/(h-k))$.

The procedure just described controls the FDR at 0.10 for independent p-values and is likely to be conservative for positively dependent p-values (Benjamini et al. 2006). When calculating q-values for each family of hypotheses, the total number of tests in a given family will include primary effects of interest (details on our primary effects of interest are found in the next subsection).

5.3 Heterogeneous effects

To study how the effects of the VCC app vary with household and cooperative characteristics, we will interact treatment status with each of the variables specified in section 3.4, represented by the vector $\dot{\boldsymbol{X}}_{(i)jt-1}$ below. We estimate equations 4-5 separately for each outcome of interest, reporting both the average ITT as well as the heterogeneity of impacts across each dimension of $\dot{\boldsymbol{X}}_{(i)jt-1}$. Although we will report both sets of estimates for each outcome, the ITT is not the primary effect of interest for outcomes 1a and 1b. Given that these are binary indicators, individuals who have a value of one for each indicator at baseline cannot improve for these measures. Therefore, the primary effect of interest for these outcomes will be among the subsample of individuals who reported a value of zero for each indicator at baseline. We will calculate q-values for our heterogeneous ITT effects just as described for our main effects of interest in the previous subsection. multiplying each p-value by four (because we have four subgroup effects for each outcome) and adjusting in a second step based on how many nulls are rejected in the firs step.

6 Additional considerations

This research was approved by the University of Florida's Institutional Review Board and has protocol number IRB201602316. The project was also approved by the Social Welfare Council of the Government of Nepal.

We will seed the random number generator used to estimate our results using the closing value of the Dow Jones Industrial Average from December 2, 2019.

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A Appendix

A.1 Randomization error

Prior to randomization, the baseline data were stored in several files, some at the cooperative level and others at the household level. The cooperative-level data files were merged by sorting the cooperatives alphabetically by name, generating a numeric identifier for each cooperative, and then merging using the new identifier. Unfortunately, not all cooperatives were present in every cooperative-level data file, resulting in multiple identifiers being assigned to individual cooperatives in 39 cases, and errors in matching across data files. The stratification variable affected by the error is total cooperative revenue, which was used in the lowest level of stratification. Despite the error, treatment and control cooperatives and households are very similar, as shown in table 2 and appendix tables A.1 and A.2.

A.2 Treatment Balance

Table A.1: Cooperative Level Balance Table

Variable	N	(1) Control Mean/SE	N	(2) Treatment Mean/SE	Difference (1)-(2)
Cooperative coordinates goat sales (0/1)	47	0.809 (0.058)	45	0.889 (0.047)	-0.080
Cooperative revenue (USD)	47	3791.017 (1419.881)	45	3758.693 (866.417)	32.323
Planning time horizon (years)	47	1.092 (0.129)	45	1.426 (0.158)	-0.334
Expected goats sold over next 6 months (count)	47	233.082 (55.623)	45	306.700 (50.049)	-73.618
Expected revenue over next 6 months (USD)	47	663.426 (205.460)	45	1375.729 (397.352)	-712.303
Mandate is made available to members (0/1)	45	0.819 (0.056)	45	0.804 (0.058)	0.015
Annual report is made available to members (0/1)	45	0.859 (0.051)	45	0.826 (0.055)	0.033
Annual budget is made available to members (0/1)	45	0.852 (0.052)	45	0.785 (0.060)	0.067
Financial report is made available to members (0/1)	45	0.796 (0.059)	45	0.819 (0.055)	-0.022
Meeting minutes are made available to members (0/1)	45	0.807 (0.058)	45	0.759 (0.063)	0.048
Election results are made available to members (0/1)	45	0.596 (0.072)	45	0.511 (0.074)	0.085
Sale records are made available to members (0/1)	45	0.711 (0.067)	45	0.800 (0.060)	-0.089
Mobile network seriously limits communication	45	0.289 (0.068)	45	0.378 (0.073)	-0.089
Distance between members seriously limits communication	45	0.267 (0.067)	45	0.378 (0.073)	-0.111
Members (count)	47	521.475 (49.566)	45	586.652 (61.482)	-65.177
Total number of ICT assets (count)	47	0.553 (0.100)	45	0.585 (0.119)	-0.032
Total number of non-ICT assets (count)	47	2.564 (0.388)	45	3.018 (0.335)	-0.454

Notes: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. The value displayed for t-tests are for tests of differences in means by treatment status, controlling for the strata dummies used to assign treatment.

Table A.2: Household Level Balance Table

Variable	(1) Control N/[Clusters]	(1) Control Mean/SE	(2) Treatment N/[Clusters]	(2) Treatment Mean/SE	Difference (1)-(2)
Age (years)	1200	42.400	1248	43.188	-0.787
	[47]	(0.519)	[45]	(0.561)	
Literacy (0/1)	1199	0.778	1247	0.803	-0.025
	[47]	(0.020)	[45]	(0.018)	
SHG Meetings Attended in Past 6 Months (count)	1200	1.754	1248	1.931	-0.177*
	[47]	(0.151)	[45]	(0.150)	
Household has dirt floors (0/1)	1200	0.560	1248	0.554	0.006
	[47]	(0.034)	[45]	(0.027)	
Household has more than one floor (0/1)	1200	0.558	1248	0.592	-0.034
	[47]	(0.045)	[45]	(0.038)	
Household is aware of cooperative goat sales (0/1)	1200	0.603	1248	0.683	-0.080
	[47]	(0.059)	[45]	(0.048)	
Received sale information (0/1)	1200	0.259	1248	0.317	-0.057
	[47]	(0.045)	[45]	(0.040)	
Administrative transparency index (continuous)	1200	0.000	1248	-0.005	0.005
	[47]	(0.091)	[45]	(0.094)	
Economic services transparency index (continuous)	1200	0.000	1248	0.093	-0.093
	[47]	(0.119)	[45]	(0.091)	
Goats sold through cooperative (count)	1200	0.189	1248	0.258	-0.069
	[47]	(0.040)	[45]	(0.057)	
Goats sold (count)	1200	1.068	1248	1.208	-0.139
	[47]	(0.068)	[45]	(0.093)	
Revenue per goat sold (USD)	1200	41.441	1248	42.786	-1.345
	[47]	(2.721)	[45]	(2.145)	
Revenue per cooperative goat sold (USD)	1200	8.065	1248	10.758	-2.693
	[47]	(1.616)	[45]	(2.068)	
Net Goat Income (USD)	1200	55.296	1248	63.964	-8.668
	[47]	(5.859)	[45]	(7.594)	
Goat revenue (USD)	1200	8949.372	1248	10837.065	-1887.693
	[47]	(629.555)	[45]	(1111.971)	
Goat revenue through cooperative (USD)	1200	1843.787	1248	2614.268	-770.481
	[47]	(394.008)	[45]	(550.331)	
Log round-trip travel time to cooperative (minutes)	1140	4.555	1183	4.740	-0.185
	[47]	(0.078)	[45]	(0.073)	
Co-op makes its mandate available to its members (0/1)	1200	0.353	1248	0.362	-0.009
	[47]	(0.033)	[45]	(0.040)	
Co-op makes its annual report available to its members (0/1)	1200	0.403	1248	0.426	-0.023
	[47]	(0.036)	[45]	(0.045)	
Co-op makes its annual budget available to its members (0/1)	1200	0.427	1248	0.438	-0.012
	[47]	(0.036)	[45]	(0.043)	
Co-op makes its financial report available to its members (0/1)	1200	0.446	1248	0.446	0.000
	[47]	(0.033)	[45]	(0.041)	
Co-op makes its meeting minutes available to its members (0/1)	1200	0.427	1248	0.450	-0.024
	[47]	(0.039)	[45]	(0.040)	
Co-op makes its election results available to its members (0/1)	1200	0.226	1248	0.255	-0.029
	[47]	(0.025)	[45]	(0.030)	
Co-op makes its sale records available to its members (0/1)	1200	0.350	1248	0.400	-0.050
	[47]	(0.038)	[45]	(0.037)	

Notes: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. The value displayed for t-tests are for tests of differences in means by treatment status, controlling for the strata dummies used to assign treatment. Standard errors are clustered at the cooperative level.

A.3 Indicators

In this section we discuss how each indicator is defined across the five research questions discussed in section 3.3. All variables listed in USD were converted from Nepalese Rupees using the official exchange rate as of January 1st, 2018 to coincide with the timing of data collection.

Question 1: Does access to the VCC application improve communication within cooperatives?

Outcome 1a:

1a) Household is aware of whether or not their cooperative organizes goat sales with traders (0/1).

Outcome 1b:

1b) Household was contacted at least once about cooperative goat sale in past 12 months (0/1).

Outcome 1c:

We collect data on administrative transparency by asking identical questions to both cooperative general managers and individual members. Our data contains seven binary variables that indicate whether the general manager and individual member state that the cooperative makes certain information available to its members. For each of the seven administrative transparency questions, we calculate a binary discrepancy variable equal to 1 when the cooperative general manager and individual member agree, and zero when they disagree.

i. Cooperative general manager and individual member agree that the cooperative makes its mandate available to members (0/1).

ii. Cooperative general manager and individual member agree that the cooperative makes its annual report available to members (0/1).

iii. Cooperative general manager and individual member agree that the cooperative makes its annual budget available to members (0/1).

iv. Cooperative general manager and individual member agree that the cooperative makes its financial report available to members (0/1).

v. Cooperative general manager and individual member agree that the cooperative makes its meeting minutes available to members (0/1).

vi. Cooperative general manager and individual member agree that the cooperative makes its election results available to members (0/1).

vii. Cooperative general manager and individual member agree that the cooperative makes its sale records available to members (0/1).

1c) weighted standardized average of variables: (i), (ii), (iii), (iv), (v), (vi), (vii).

Outcome 1d:

We collect data on economic services transparency by asking identical questions to both cooperative general managers and individual members. Our data contains sixteen binary variables that indicate whether the general manager and individual member state that the cooperative makes certain information available to its members. For each of the seven transparency questions, we calculate a binary discrepancy variable equal to 1 when the cooperative general manager and individual member agree, and zero when they disagree.

i. Cooperative general manager and individual member agree that the cooperative accepts savings deposits (0/1).

ii. Cooperative general manager and individual member agree that the cooperative offers loans (0/1).

iii. Cooperative general manager and individual member agree that the cooperative helps members access bank loans (0/1).

iv. Cooperative general manager and individual member agree that the cooperative sells or helps members access livestock insurance (0/1).

v. Cooperative general manager and individual member agree that the cooperative sells animal feed (0/1).

vi. Cooperative general manager and individual member agree that the cooperative sells seed (0/1).

vii. Cooperative general manager and individual member agree that the cooperative sells fertilizer (0/1).

viii. Cooperative general manager and individual member agree that the cooperative offers pesticide or other agrochemicals for sale (0/1).

ix. Cooperative general manager and individual member agree that the cooperative sells or rents agricultural or livestock tools (0/1).

x. Cooperative general manager and individual member agree that the cooperative sells consumer goods, such as food (0/1).

xi. Cooperative general manager and individual member agree that the cooperative provides access to veterinary services (0/1).

xii. Cooperative general manager and individual member agree that the cooperative provides assistance with business planning (0/1).

xii. Cooperative general manager and individual member agree that the cooperative provides assistance with animal husbandry (0/1).

xiv. Cooperative general manager and individual member agree that the cooperative coordinate sales of goats to traders (0/1).

xv. Cooperative general manager and individual member agree that the cooperative gives dividend payments to owners of cooperative shares (0/1).

xvi. Cooperative general manager and individual member agree that the cooperative provides goat price information (0/1).

1d) weighted standardized average of variables: (i), (ii), (iii), (iv), (v), (vi), (vii), (viii), (ix), (x), (xi), (xii), (xiii), (xiv), (xv), (xvi).

Question 2: Does access to the VCC application increase goat sales?

Outcomes:

2a) Number of goats sold by the household through the cooperative (count).

- *Winsorized at the 1st and 99th percentiles.*

2b) Number of goats sold by the household (count).

- *Missing values replaced with zero.*
- *Winsorized at the 1st and 99th percentiles.*

Question 3: Does the VCC application increase prices received for goats?

Outcomes:

3a) Revenue per goat sold through the cooperative (USD).

- *Missing values replaced with zero.*
- *Converted to USD.*
- *Winsorized at the 1st and 99th percentiles.*

3b) Revenue per goat sold (USD).

- *Missing values replaced with zero.*

- *Converted to USD.*
- *Winsorized at the 1^{st} and 99^{th} percentiles.*

Question 4: Does access to the VCC application improve the planning horizon and expectations of cooperative leaders?

<u>Outcomes:</u>

4a) Planning time horizon (years).

4b) Number of goats expected to be sold through cooperative in next six months (count).

- *Missing values replaced with zero.*
- *Winsorized at the 1^{st} and 99^{th} percentiles.*

4c) Total revenue expected to be earned by cooperative in next six months (USD).

- *Missing values replaced with zero.*
- *Converted to USD.*
- *Winsorized at the 1^{st} and 99^{th} percentiles.*