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Highlights

- Should we distribute preventive *animal* health products for free or charge a positive price?
- Using a price experiment we find that demand for the product is highly sensitive to offer prices but offer prices do not affect product use
- Farmers whose animals were sick in the baseline had a higher willingness to pay
- Therefore, a highly subsidized distribution of the product is recommended
- Our findings support the human capital theory concerning demand for human health products. Individuals behave in a similar way when the decisions concern their own health or the health of an animal they rear.

ABSTRACT

Should we distribute preventive animal health products for free or charge a positive price? The decision depends on the price sensitivity of the product and the effect prices have on product use. We explore this idea through a field experiment in which we randomize the price a farmer faces for an animal health product. We find that the demand for the product is highly sensitive to offer prices; willingness to pay (WTP) decreased from 44% at ₹ 100 to 18% at ₹ 500. Further, among farmers who were willing to pay, the product usage rate was 71% and usage did not increase in offer prices (lack of screening effect). Furthermore, we find that farmers whose animals were sick in the baseline had a higher WTP. These findings support the human capital model relating to demand for human health products. We argue that individuals behave in a similar way when the decisions concern their own health or the health of an animal they rear for commercial purposes. A highly subsidized distribution of the product is recommended due to high price sensitivity, lack of screening effect, equitable distribution among poor and lesser implementation costs found in this study.

KEYWORDS Willingness to pay, price experiment, RCT, screening effect, animal health

1. INTRODUCTION

Why should we invest in health, particularly preventive products, be it for human beings or dairy animals? Because, it directly impacts how productive the subject can be, its ability to generate income in the near and distant future and is a direct component of well-being (Dupas & Miguel, 2017; Kremer et al., 2019). The human capital model argues that health is an input that determines the amount of time an individual can spend to produce commodities and income (Grossman, 2000). Similar logic applies to dairy animal health as it determines the amount of milk (and other by-products) produced and the income earnings of a dairy farmer.

Households in developing countries due to lack of cash, information or education to digest information, fail to acknowledge the potential gains to health investments (Dupas & Miguel, 2017). For instance, the demand for treatment (cure) is more than preventive products (Cohen et al., 2015). The fact that curative health investments take a large chunk (10%) of the Indian poor households' total consumption expenditure (Banerjee et al., 2015), highlights the argument made by Dupas & Miguel (2017). Households fail to take advantage of preventive health products which yield very high rates of returns (Kremer et al., 2019). The under-investment in preventive health products, as opposed to curative, can be explained with insights from behavioral economics like procrastination, projection bias, loss aversion, and failure to interpret information correctly, failure to seek and share information, limited attention and memory, etc affecting unbiased decision making (see Kremer et al., (2019) for a detailed review on behavioral development economics).

Distribution of health products is grouped into 'social marketing' category – with emphasis on retail sales (pricing) and 'public health' category – which emphasizes on free distribution (Ashraf et al., 2010). Advocates of free distribution argue that pricing leads to distribution of products only to the 'richest of poor' while their critics counter that individuals do not value or even not use the products given away for free (Ashraf et al., 2010). The critics argument points us towards two behavioral theories – sunk cost fallacy (Thaler, 1980) and screening effect of prices (Roy, 1951), both of which states that, usage increases with prices. Cost-sharing or pricing health products are needed to avoid wastage of resources by those who do not need or who will not use the product (Cohen & Dupas, 2010). Short-term subsidies can positively affect the long-run adoption of some preventive health products through channels like learning by doing and social learning (Dupas, 2014). Conversely, charging positive prices could dampen the demand (Kremer & Miguel, 2007) and also leave out people who need the product when they are cash and credit constrained (or are poor) (Cohen & Dupas, 2010), both of which leads to less adoption. Policymakers are often stuck in the dilemma of whether to subsidize the preventive health product or distribute it for free. Our study aims to assist them with evidence on demand for a preventive animal health product, namely the anionic mineral mixture (AMM), aimed at preventing the milk fever (MF) in dairy animals which causes annual losses of around US $ 137 million in Haryana, India (Cariappa et al., 2021a).

The households' demand for health products increases if the expected benefit from using the product exceeds the usage cost (both in utility and financial terms) according to the human capital model (Grossman, 2000). Meaning, demand for health products increases if any effort enhances the expected benefit or reduce the costs making expected benefits larger than costs. The theory implies that in the short-run, small costs leads to big changes in consumption behavior[1], therefore subsidies (which is a benefit) will help increase the demand for preventive products especially when some individuals who tend to benefit more from prevention, value preventive products higher than others (Kremer & Glennerster, 2011).

In this study, using randomized price variations we identify the demand for the AMM and test the sensitivity of demand. We start with the assumption that only the offer prices affect farmer's demand for the AMM and eventually determine other factors which affects demand. We work in the premise of the standard theory of demand and estimate the price elasticities of demand for the AMM. We use the Willingness to pay (WTP) at a particular price as the proxy of demand for

[1] Small costs like increased prices for the product (in financial terms) or travelling a few kilometers to buy the product and using it (in utility terms) could reduce the demand for preventive health products.

AMM. We elicit WTP using Take it or Leave it (TIOLI) approach where farmers are offered AMM at randomized TIOLI prices. If the farmers are willing to pay for AMM, they are asked to come up with the money, but ultimately the product is given for free. Several randomized evaluations have tested the effect of pricing on demand sensitivity of preventive (human) health products such as deworming pills, insecticide treated bed nets (for malaria prevention), water chlorination and hand washing soap in Kenya, Zambia and India (Ashraf et al., 2010; Cohen & Dupas, 2010; Dupas, 2014; Kremer et al., 2011; Kremer & Miguel, 2007; Spears, 2009). Dupas (2014) in an experiment found that demand for long-lasting antimalarial bed-nets was 73 per cent at \$0.60 which reduced to 6 per cent at \$3.50 (a 50% subsidy). Similarly, Cohen & Dupas (2010) found that demand for bed nets decreased from 92 per cent at 15 US cents to 39 per cent at 60 US cents. In the handbook of economic field experiments, Dupas & Miguel (2017) concluded (after reviewing such studies) that higher prices for preventive health products have resulted in many errors of exclusion; thus, providing subsidies might be justified to prevent disease transmission in the first place.Next, we move to the use of AMM once the farmer is willing to pay a particular price. We specifically test for a screening effect, which states that the product use is greater among the households which pay a higher price; because the composition of purchasers will be skewed by the higher prices towards farmers with a larger propensity to use the product (Roy, 1951). In other words, as the price increases, buyers are selected from the higher portion of the willingness to pay distribution. If dairy farmers with higher WTP for the AMM are more likely to use the product, we expect to find an increase in the use of AMM as the price increases.This theory has been tested with various products (like health, credit, insurance, etc) in different settings (Ashraf et al., 2010; Cohen & Dupas, 2010; Karlan & Zinman, 2009; Tarozzi et al., 2014). For instance, Cohen & Dupas (2010) found that usage rate of insecticide treated bed nets (measured 2 months after distribution) was 60 per cent and was independent of the price; implying that there was neither a screening nor a sunk cost effect of prices in their context. Thus, it is learnt from the experiment that the coverage (the share of pregnant women sleeping under a bed net), and hence its potential for public health outcomes, increased very rapidly as the price goes down. With this background, we test the following hypothesis regarding dairy farmers' willingness to pay and AMM use in this study.

1. *Willingness to pay for AMM*: the demand for AMM decreases in the offer price and is highly sensitive to price changes.
2. *Screening effect*: the probability of AMM use, conditional on WTP, increases with

increasing offer prices.

We make several contributions to the literature. First of all, there are no studies which evaluate the impact of preventive animal health products on animal health and farmers' welfare and also on the effect of prices on demand and product use. We, using two randomized controlled trials (RCTs[2]), try to contribute to this literature. This study will act as a primer for demand (WTP) estimation of animal health products and will add new methodological dimensions to the literature. Methodologically, we implement the first field experiment to estimate the demand for a preventive 'animal' health product and also to identify screening effect of offer prices. We also complement the literature on pricing of health products and its effect on product use (see reviews by (Dupas & Miguel, 2017; Kremer et al., 2019; Kremer & Glennerster, 2011; Null et al., 2012)). Logistically, we estimate the effect of pricing a new product, after supplementing the product well in advance so that the farmers are aware of the benefits, as the product was not available in the region. We had conducted a RCT with the same farmers to evaluate the impact of supplementing AMM before eliciting the WTP for AMM. In that RCT, the intervention (AMM) was randomly phased-in, where treatment group farmers got the product first and the control group farmers got later. Therefore, all the farmers had used the product well before the pricing experiment. Further, we provide evidence that the theories concerning demand for human health (products) are applicable to the demand for animal health product as well. Specifically, our findings support the human capital theory concerning demand for human health given by Grossman (2000). We find that individuals behave in a similar way when the decisions concern their own health or the health of an animal reared for commercial purposes. This finding will help in devising effective policy solutions based on the generalizations drawn from randomized evaluations from different contexts.

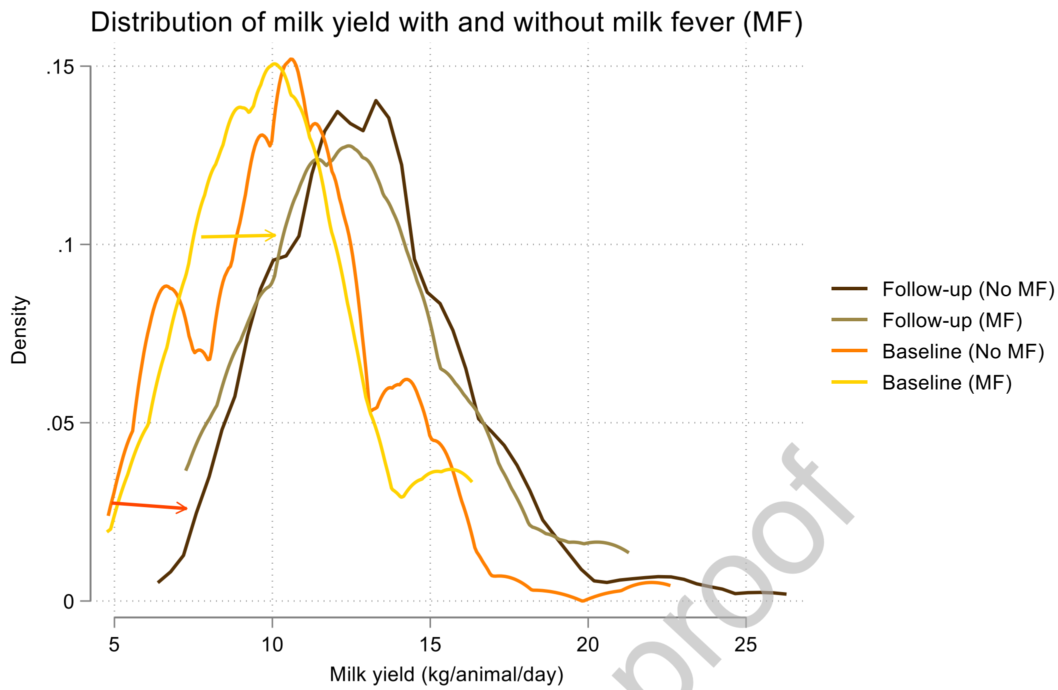
In the next section we describe our experimental setup, surveys and outcomes, followed by description of the data and estimation framework. In the following sections we discuss our results before summarizing and concluding the study.

2. EXPERIMENTAL SETTING AND DESIGN

[2] The first RCT was carried out to evaluate the impact of feeding AMM (Cariappa et al., 2021a) and the second to test the effect of prices on WTP and product use.

AMM is a preventive feed against the milk fever (MF)[3] in lactating dairy animals. It is in the powder form and has to be fed to the lactating dairy animals before 3-4 weeks of calving at 100 grams/day (totaling a dose of 2-3 kg per animal). The AMM contains 7640 mEq and 5080 mEq anionic value of sulphur and chloride, respectively; 1340 mEq cationic value of potassium with a total negative dietary cationic anionic difference (DCAD) of 11,380 mEq[4] and 10,000 IU/kg of Vitamin E. AMM decreases the probability of MF occurrence by 13 percentage points with high significant positive effects on milk yield (14%) and farmer's profit (35%); it benefits all the animals, not only those animals which has milk fever (Figure 1) (Cariappa et al., 2021a). AMM is marketed by *Kamdhenu feeds* at ₹ 180/kg (equivalent to ~US$3/kg). During the experiment, AMM was not available in the villages or any urban centers nearby. A complete course requires about 3 kg of AMM for a month which costs a total of ₹ 540[5] (around US $ 7). It amounts to around 1% of the yearly average variable costs of dairying in our sample. Alternative methods used traditionally by farmers to prevent MF are use of jaggery or calcium liquid after calving. Due to the non-availability, only 1 sample farmer had used it earlier.

[3] Milk fever is a calcium deficiency disorder in dairy animals seen immediately after parturition (calving). It causes huge economic losses to dairy farmers in the form of loss in milk production, treatment costs, mortality losses and loss in reproductive performance of animals.
[4] Due to the higher anionic value of sulphur and chloride, the product is named Anionic mineral mixture
[5] ₹ is the symbol of Indian National Rupee (INR)



Note: The figure is drawn from the results of an RCT conducted to evaluate the effect of AMM (see (Cariappa et al., 2021a) for results of the study). The yellow and orange lines depict the milk yield distribution of animals with and without MF, respectively at the baseline and the black and brown lines depict the same at the follow-up (after feeding AMM). The clear shift of the distribution to the right indicates that AMM leads to increases in milk yield of all the animals (in both MF affected and unaffected animals).

Figure 1 Distribution of milk yield in MF affected and unaffected dairy animals at the baseline and follow-up

2.1. Experimental and survey design

2.1.1. Sample selection, baseline survey and the intervention

The timeline of the experiments from sample selection to the final follow-up survey to the door-to-door marketing experiment is presented in Figure 2. This (door to door marketing) experiment was conducted after a separate RCT, in which households were given AMM during September 2020-January 2021. The sampling frame was the same for both the experiments (see (Cariappa et al., 2020, 2021a) for the pre-analysis plan and the findings from the first RCT).

The AMM is aimed at reducing the milk fever in high yielding dairy animals. For this reason, we needed to work in areas where milk yield was high and the population of high yielding animals was large. The funding agency of the study has adopted 5 villages namely *Samora*, *Garhi Gujran*, *Churni*, *Kamalpur Roran* and *Nagla Roran* in the Karnal district of Haryana state in India. As Karnal is home for around 2.8 lakh high yielding female bovines (1.1 lakh exotic/crossbred cows and 1.8 lakh buffaloes) (Government of Haryana, 2020), these villages were ideal for conducting the experiment. The AMM was not supplemented to the animals in these villages before the experiment; also, both the project staff and villagers were unaware of the product. The animals with high risk of MF, *i.e*., animals in the second parity[6] or above with peak milk yield higher than 10 kg/day and which were not fed any kind of AMM, was selected to the study[7]. Through the baseline survey we collected information on A) Household characteristics such as experience, education, household size, training received and land holding, B) Animal characteristics such as breed, parity, herd size, milk yield *etc*., C) Dairy farming costs and returns, D) Animal health history, E) Awareness (of MF and AMM) and prevention against MF, and F) Access to information like contact with extension agencies. We randomly phased-in the treatment (AMM) to 200 dairy farmers (100 cow and 100 buffalo rearers); first to 100 animals in the treatment group and eventually to 100 control animals. After the first round of intervention, we did a follow-up survey after three months of treatment to treated group to measure the effect of AMM supplementation. As AMM was a new product, the random phase-in design ensured that all the farmers (in treated and control groups) had prior experience in using and realizing the benefits of the product which is a pre-cursor to elicit the true demand for the product.

2.1.2. Pricing experiment

After all the control animals were fed the AMM and the farmers realized its benefits, we randomly assigned the farmers into 5 groups. The prices were decided based on a hypothetical subsidy policy with subsidy rates of 0%, 20%, 40%, 60% and 80% of the market price (₹ 180/kg of AMM). The

[6] Parity refers to number of times an animal has given birth to a young one. Second parity means that the animal expecting its second offspring. Literature suggests that the animals above second parity or older animals are at high risk of milk fever.

[7] Because of these strict inclusion criterions, it was difficult to find the required 200+ animals for the study. We ended up scouting the whole of 5 villages at least twice to find eligible animals.

randomized prices (rounded off) were therefore ₹ 500, ₹ 400, ₹ 300, ₹ 200 and ₹ 100, respectively for the whole course of 30 days (3 kg of AMM at the rate of 100 g per day). The sample was re-randomized until the null hypothesis of the joint test of orthogonality (Wald test) from the multinomial probit model was accepted; in short, till the balance was achieved on observables[8].

2.1.3. Door-to-door selling and the WTP

WTP (demand at each price point) can be elicited using contingent valuation, discrete choice experiment, and experimental approaches (Null et al., 2012). The first two methods use data generated from stated WTP by individuals while the experimental approach from actual purchase decisions. Further, there are two main experimental methods used to estimate WTP, namely, take-it-or-leave-it (TIOLI) and Becker, DeGroot, and Marschak (BDM). We use TIOLI method which is a straightforward revealed preference mechanism that allows us to estimate the true demand for the product at different price points (Dupas & Miguel, 2017). It does so by observing whether an individual purchases the product at a randomized price that the individual faces. Also because the BDM mechanism is hard to explain to the farmers (BDM was not fully understood by American college students (Cason & Plott, 2014)) seem to under predict the WTP compared to TIOLI (Berry et al., 2020)[9] (for a detailed account of advantages and disadvantages of each method see reviews by Dupas & Miguel, (2017) and Null et al., (2012)).

The dairy farmers were asked if they wanted to purchase a dose (3 kg) of AMM at the randomized offer prices which ranged from 0% to 80% of the retail price. If the farmer agreed to buy at the offer price and was able to come up with the cash for the transaction, they were considered 'willing to pay'[10] and then, the product was given to them for free. Therefore, the actual transaction price was nil. As the number of farmers to be covered from a village was less (around 40), it was made sure that the WTP elicitation of a village was completed in a single day. This was done to avoid any kind of biased responses. Single day coverage of a village ensured that all the farmers in the

[8] Randomization was done only twice as the omnibus Wald test indicated balance between the groups, the second time.

[9] See https://www.sciencedirect.com/science/article/abs/pii/S0167268120300275, which fails to replicate the under prediction of Berry et al., 2020)

[10] The observation of farmers getting the cash to pay for the product was made by the first author. If the farmers came up with real cash to pay the offered price immediately, we noted the farmer as "willing to pay". The whole process was very quick and we didn't spend more than 10-15 minutes with one farmer. The acquaintance with the farmer through the baseline survey and the intervention helped as we needed no introduction.

village were not aware that the product was eventually given away for free. Also, no known contact was established between the farmers of different villages. There was no change in the propensity to say "YES" to the TIOLI offer over time as evident in no significant difference of WTP across different villages (the WTP in the 5 villages were 0.24, 0.31, 0.23, 0.28, 0.18 and the Kruskal-Wallis equality-of-populations rank test *p value* = 0.9 without ties and 0.7 with ties). For analytical purposes, farmers who were WTP were coded 1 and 0 otherwise.

2.1.4. Follow-up survey and the AMM use

After seven weeks of the door-to-door selling, we called the dairy farmers who were willing to pay and asked whether they were using the product. If the farmer 'self-report' that he/she was using the product/has used the product in the telephonic survey, we consider that the farmer has used the AMM. We measure the AMM use with code 1 for users and 0 for non-users.

2.2. DATA AND DESCRIPTIVE STATISTICS

Dairy farms in our sample have on average, 5-6 animals, yielding fat-corrected milk of 10-11 kg/day with the farmer owning around 2-3 hectares of agricultural land (See Appendix A for a detailed description of sample characteristics). Table 1 presents the results of the balance test. All variables, except, experience in dairying and herd size in ₹ 500 and ₹ 200 groups respectively, does not have significant association with the treatment status implying that the randomization has created statistically similar groups. An omnibus joint test of orthogonality (Wald test) as suggested by McKenzie (2015), also suggests that random assignment is successful in achieving covariate balance. This means that the (randomly assigned) price variation across groups can be used to identify the demand for AMM.

2.3. ESTIMATION FRAMEWORK

2.3.1. Estimation strategy

Willingness to pay

$$WTP\ (1/0) = b_0 + b_1{*}Price + b_2{*}X_i + u_i \ \ldots\ (1)$$

We estimate the above equation using a linear probability model. WTP (1/0) is the dichotomous dependent variable indicating whether a farmer is willing to pay. It takes a value of '1' for farmers who are willing to pay and '0' otherwise. Price is our treatment variable, coefficient of which indicates the sensitivity of the demand to price change. We have 5 groups and hence it takes values 100, 200, 300, 400 and 500. X_i includes control covariates which might influence farmers' WTP decision such as MF in baseline ('1' if animal had milk fever and '0' otherwise), income from dairying, a group variable indicating whether the farmer received AMM at the beginning of the experiment or more recently ('1' if farmers were in the treatment group in the first RCT and '0' otherwise); farmer characteristics like years of experience in dairying, training received in dairying (1/0), contact with extension agencies (access to information); and animal characteristics like type of animal ('1' for cow and '0' for buffalo), herd size (number of animals), lactation order of animals (indicator of the age of animals) and usage of other mineral mixtures ('1' if using mineral mixture and '0' otherwise).

Screening effect of prices

Usage (1/0) = $b_0 + b_1$*Price + b_2*$X_i + u_i$ … (2)

Similar equation as WTP is used with a dichotomous product use (1/0) as the dependent variable to estimate the screening effect of prices. It takes a value of '1' if the farmers were using the product and '0' otherwise. The sample for screening effect model includes only those farmers who were willing to pay. Price is the offer price as defined above. Xi includes control covariates such as education of the farmers, MF in baseline ('1' if animal had milk fever and '0' otherwise), type of animal ('1' for cow and '0' for buffalo), lactation order of animals (indicator of the age of animals), health score of the animals (indicator of the health of animals based on vaccination and deworming status) and usage of other mineral mixtures ('1' if using mineral mixture and '0' otherwise).

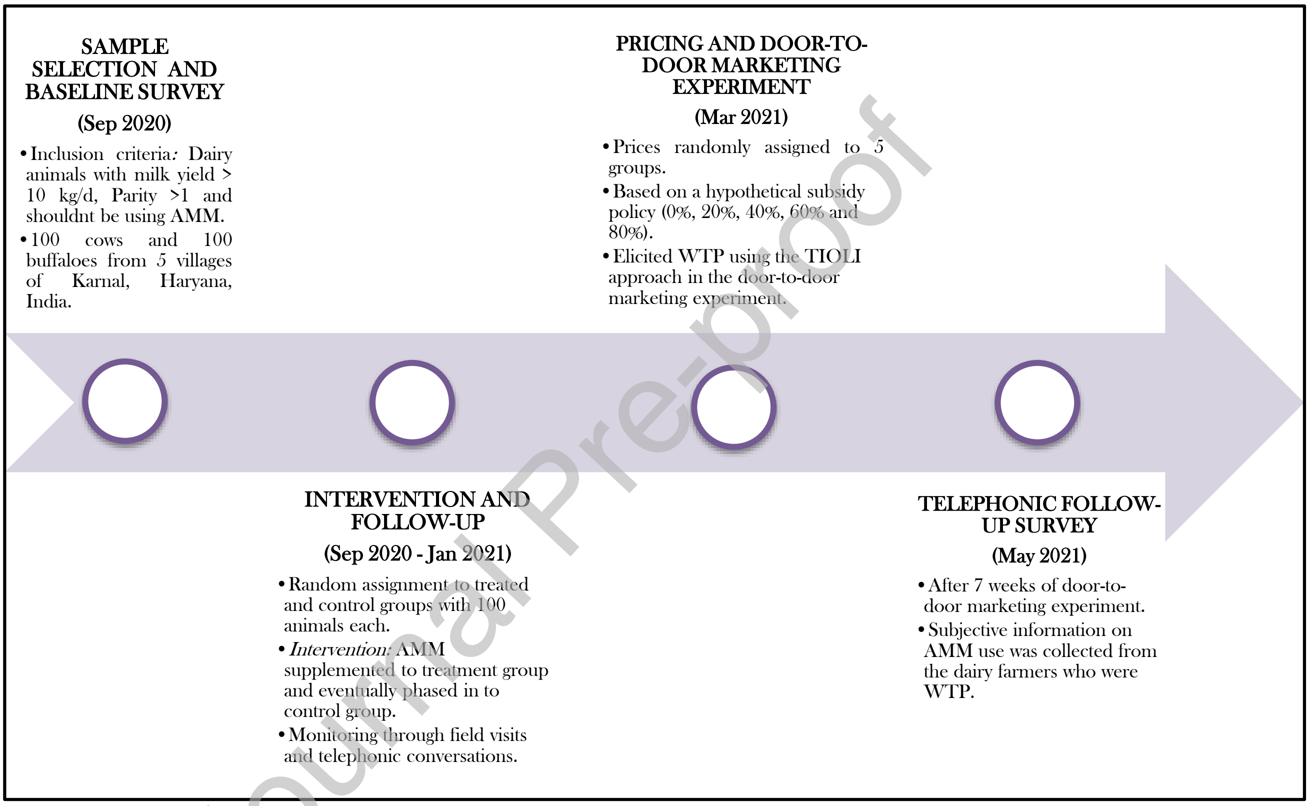


Figure 2 Experimental and survey design: Timeline

Table 1 Balance test: Independent multinomial probit estimates

Base: ₹ 100	(1) ₹ 200	(2) ₹ 300	(3) ₹ 400	(4) ₹ 500
Treated (1/0)	-0.300 (0.315)	0.127 (0.316)	-0.0297 (0.314)	-0.576 (0.387)
Experience in dairying (years)	-0.00737 (0.0171)	-0.00516 (0.0165)	0.000559 (0.0172)	-0.0666** (0.0268)
Training in dairying (1/0)	0.167 (0.353)	-0.517 (0.336)	0.215 (0.325)	0.219 (0.461)
Principal income from dairying (1/0)	0.542 (0.378)	-0.0553 (0.368)	-0.0283 (0.383)	-0.179 (0.480)
Parity (nos.)	0.163 (0.233)	0.0713 (0.226)	0.0706 (0.218)	-0.0819 (0.275)
Green fodder fed (kg/animal/d)	0.0151 (0.0266)	-0.00487 (0.0260)	0.00359 (0.0292)	-0.00299 (0.0319)
Dry fodder fed (kg/animal/d)	0.00848 (0.0350)	-0.00748 (0.0328)	-0.0314 (0.0378)	0.0204 (0.0597)
Concentrates fed (kg/animal/d)	-0.0417 (0.108)	-0.126 (0.109)	-0.0333 (0.110)	-0.0693 (0.144)
Herd size (nos.)	-0.123** (0.0572)	-0.0301 (0.0595)	-0.0289 (0.0571)	-0.00282 (0.0763)
Land holding (acres)	0.0207 (0.0335)	0.0323 (0.0303)	0.0573 (0.0301)	0.0378 (0.0407)
Incidence if MF (1/0)	0.188 (0.420)	0.0592 (0.395)	-0.605 (0.431)	-0.328 (0.424)
Income from dairying (₹/lactation)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Animal (1 if cow and 0 if buffalo)	-0.498 (0.337)	0.172 (0.325)	-0.211 (0.325)	0.189 (0.406)
Constant term	0.437 (1.262)	1.096 (1.233)	1.469 (1.202)	1.126 (1.436)

Note: Standard errors in parentheses. ** $p < 0.05$
Probit model: $Price_i = \alpha + \beta_i \times X_i + \mu_i$
Null hypothesis for Joint test of orthogonality: $\beta_1 = \beta_2 = \cdots \beta_i = 0$ (McKenzie, 2015)Joint test of orthogonality: Wald chi^2 = 61.22, p-value = 0.18 (Accept null hypothesis)

2.3.2. Identification strategy

Random assignment of prices and the confirmation from balance test that groups are similar across observable covariates enables us to causally identify the impact of prices on demand for AMM and the usage of AMM.

3. RESULTS AND DISCUSSION

3.1. Willingness to pay for AMM

In this section, we estimate farmers' WTP for AMM. Table 2 presents the results of price sensitivity of AMM demand from the linear probability model. Column 1 and 2 depicts point elasticities of AMM demand at different prices and Column 3 and 4 depicts the slope of the demand curve. Results indicate a negative relationship between price and WTP (demand) for AMM. For every marginal (₹ 100) increase in price, there is an additional fall in WTP of farmers for AMM. The relationship between the prices and WTP can be clearly visualized in Figure 3 (See Appendix B for marginal effects at each price point). The demand for AMM sharply decreases as the price increases. At ₹ 100, 200, 300, 400 and 500, the predicted willingness to pay are 44%, 25%, 18%, 19% and 18%, respectively. If we assume that all the farmers use AMM when distributed for free (which they did when we monitored and reminded them physically and over phone during the first RCT), a ₹ 100 increase in price leads to a huge (56%) fall in demand. At ₹ 100, only 44-45% of the farmers were WTP. In other words, when the farmers are asked to share the costs of the product, the demand for the product decreases from 100% at zero prices to 45% at ₹ 100 (an 80% subsidized price). It further falls to 18-19% at ₹ 500. Columns 3 and 4 depict the overall sensitivity of the WTP for changing price. The results indicate that a 1% increase in prices leads to 18% fall in demand for AMM. This result is in line with the findings from the demand for human health products in developing countries. For instance, the WTP for insecticide treated bed nets in Kenya fell from 73%to 6% when the prices increased from $ 0.6 to $ 3.5 (Dupas, 2014). Similarly, the demand for the long lasting anti-malarial bed nets fell from 92% at 15 US Cents to 39% at 60 US cents (Cohen & Dupas, 2010).

Perusal of Table 2 and Figure 3 also suggests that the relationship between price and WTP is robust to different estimators like logit, probit and Poisson (not shown). Our findings are in line with the general findings from the human health literature as summarized in reviews by Kremer et al. (2019); Kremer & Glennerster (2011); Null et al. (2012), that the WTP is lower than the cost of the product and the demand is sensitive to prices. Also, the finding of price sensitivity is in line with the human capital model (Grossman, 2000). Human capital theory implies that when the product is given for free, the disutility of buying the product and feeding it to dairy animals is offset by the benefits of AMM but the benefits do not offset the disutility when the product is positively priced.

It should be noted that, with the addition of covariates, the demand curve turns slightly inelastic at higher prices and the slope of the demand curve decreases from -0.25 to -0.18. The major reason for this is the addition of the variable ‘incidence of MF at the baseline’. The demand for the preventive health product against MF is highly correlated with the incidence of MF at the baseline. In other words, the probability of buying AMM increases significantly if the dairy farmer has experienced losses due to MF beforehand. The changes in the coefficient values due to the inclusion of observable covariates raise concerns about the validity of our randomization. The results of balance test and a separate correlation analysis of prices and MF suggests that the relationship is not significant at 0.05 levels, indicating that the randomization was successful. Moreover, controlling for MF and other covariates do not reverse or drastically change our key conclusions. Note that controlling for MF, the drop in demand is now significantly higher for a small change in price (from ₹ 100 to ₹ 200) and turns slightly inelastic at higher prices.

Although the demand curve is sloping downwards, the farmers who have dealt with MF earlier have a minimum 80% probability of buying AMM (Figure 4). In case of farmers who have dealt with MF before, the demand curve turns upward sloping at the highest price. Animals which yield more milk and are older, are more likely to get milk fever than others. Therefore, when the animals in the herd gets older and give birth to more young ones (multiparous cows) it becomes more likely to get milk fever. Also, if farmers have the experience of dealing with MF, they will know the damage MF could do their animals (animals affected with milk fever are more susceptible to mastitis, metritis, etc and many other reproductive disorders). Therefore, to prevent all these, farmers are more likely to pay more and buy the preventive health product. Also, when the non-buyers are asked why they are not willing to pay, around one-third of them responded that the animals do not have MF or that they would treat their animals when it gets sick and would buy the product when they require (Appendix C). Insights from behavioral economics and these responses highlight that the farmers are present biased and are naïve regarding the present bias in future, meaning they procrastinate (Kremer et al., 2019). This is because farmers delay purchasing the AMM now which yields high returns with small short-run utility costs (buying and feeding AMM) because they wrongly anticipate buying AMM later when required. These responses support the argument of Dupas & Miguel (2017) that the households fail to acknowledge the potential gains to health investments. For instance, around 25% of the sample farmers are willing to pay for the product while around 33% of the non-buyers (who are not willing to pay) think that they will cure the animal if and when the animal gets MF or buy the product when they require (Table 2 and Appendix C).

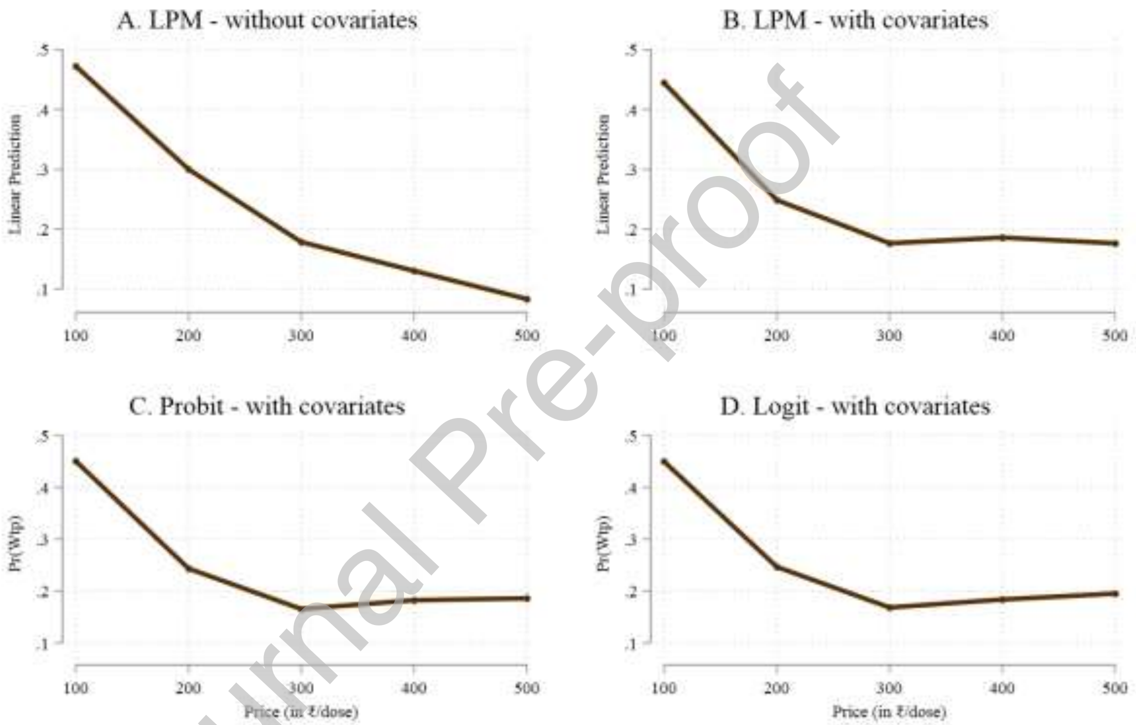
Other reasons as to why farmers are not willing to pay are that 13% are planning to sell the animal, health inputs (like mineral mixtures) are provided to them (at discounted prices or for free) either by the private buyers of milk, state government or the ICAR-NDRI (21.5%) and that 8.5% are using other preventive strategies like feeding jaggery or calcium solutions (Appendix C).

Table 1 Price sensitivity: Linear probability estimates

Dependent variable: WTP (1/0)	(1)	(2)	(3)	(4)	(5)	(6)
Natural log of price	-	-	-	**-0.250*** (0.062) [0.000]**	**-0.175*** (0.048) [0.000]**	**-0.184*** (0.052) [0.001]**
Price (Base: ₹ 100)						
₹ 200	**-0.172 (0.107) [0.108]**	**-0.196** (0.079) [0.014]**	**-0.196** (0.081) [0.016]**			
₹ 300	**-0.294*** (0.099) [0.003]**	**-0.265*** (0.072) [0.000]**	**-0.268*** (0.076) [0.001]**			
₹ 400	**-0.342*** (0.0981) [0.001]**	**-0.247*** (0.076) [0.001]**	**-0.259*** (0.0798) [0.001]**			
₹ 500	**-0.389*** (0.117) [0.001]**	**-0.257*** (0.073) [0.001]**	**-0.268*** (0.081) [0.001]**			
Income from dairying (ln)			0.099 (0.098)			0.096 (0.099)
Incidence of MF in baseline (1/0)		0.788*** (0.056)	0.788*** (0.061)		0.779*** (0.057)	0.779*** (0.062)
Treated (1/0)			-0.009 (0.035)			-0.010 (0.036)
Experience in dairying (years)			0.002 (0.002)			0.002 (0.002)
Training in dairying (1/0)			0.014 (0.032)			0.023 (0.033)
Extension score			0.007 (0.023)			0.008 (0.023)
Animal (1 if cow and 0 if buffalo)			0.026 (0.042)			0.028 (0.041)
Parity (Base: 2nd Parity)						
3rd			0.024 (0.043)			0.021 (0.041)
4th			-0.111 (0.068)			-0.116 (0.068)
5th			0.074 (0.081)			0.056 (0.073)
Herd size (nos.)			0.009 (0.006)			0.010 (0.006)
Mineral mixture fed (IHS)			-0.597 (0.445)			-0.692 (0.442)
Constant term	0.472*** (0.084)	0.275*** (0.073)	-0.953 (1.156)	1.621*** (0.351)	1.046*** (0.286)	-0.103 (1.202)

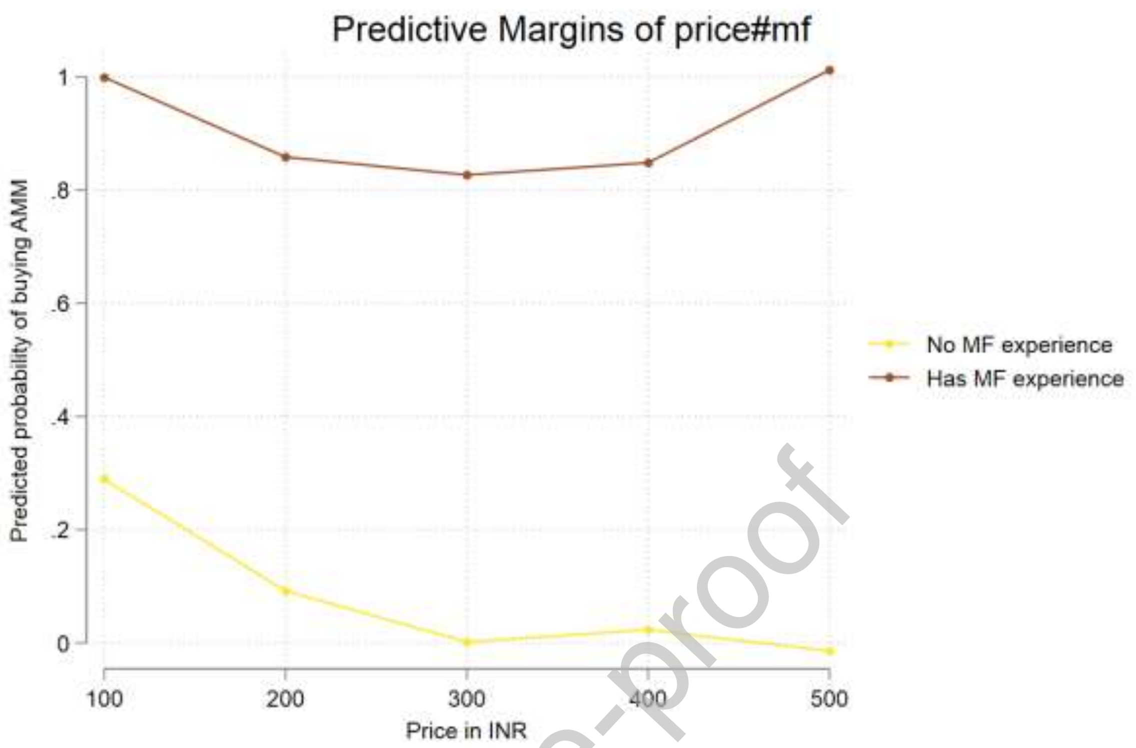
	[0.000]	[0.000]	[0.411]	[0.000]	[0.000]	[0.932]
Mean of dependent variable	0.245	0.245	0.245	0.245	0.245	0.245
N	200	200	200	200	200	200
R^2	0.086	0.630	0.644	0.085	0.623	0.638
adj. R^2	0.067	0.621	0.613	0.081	0.619	0.613
F	4.219	76.04	37.14	16.23	177.57	44.59

Note: Standard errors in parentheses. ** $p < 0.05$,* ** $p < 0.01$. *p* values are reported in square brackets.
Columns (1) (2) and (3) displays the point elasticity of demand (at different price points) while columns (3) (4) and (5) displays the slope of the demand curve.



Note: Each point on the graph is the predictive margin at different prices derived from the linear probability, probit and logit models with WTP (1/0) as the dependent variable.

Figure 3 Demand curve of AMM



Note: Each point is the predicted margin from the linear probability model.

Figure 4 Heterogeneous effects of prices on demand for AMM

Therefore, implications of the results beseech discussion in two parts. To begin, the results indicate that the demand is highly sensitive to prices; share of farmers who are willing to pay decline from 100% when distributed for free to 19% at market price (₹ 500)[11]. Market failures (like information, credit and lack of access to AMM) are plausible reasons for lower demand for AMM, even at lower prices. For instance, only 3% of the farmers knew about AMM and only 1 farmer in the sample had used it before (Cariappa et al, 2021a). During the survey, AMM was not available in any of near urban/peri-urban centers. The second part is that the farmers who tend to benefit more from the product (farmers with prior experience of dealing with MF) are willing to pay more than others. Even at higher prices, the farmers who are willing to pay for AMM are >80% and also, the demand curve turns inelastic at higher prices. Farmers who have prior experience are willing to pay more because there is a correlation of MF incidence across time on a given farm. Animals which yield more milk and are older, are more likely to get milk fever than others. Therefore, when the animals in the herd gets older and give birth to more young ones (multiparous cows) it becomes more likely

[11] The offered market price (₹ 500) is less than the actual market price of AMM (₹ 540).

to get milk fever. Also, if farmers have the experience of dealing with MF, they will know the damage MF could do to their animals (animals affected with milk fever are more susceptible to mastitis, metritis, *etc* and many other reproductive disorders (see Cariappa et al. (2021a) for a detailed review). Therefore, to prevent all these, farmers are more likely to pay more. This implies that prices of AMM have a lesser say in farmers (who have experienced economic losses due to MF) decision to buy and that positive prices could be used to target the needy population. This finding, therefore, calls for a targeted distribution policy of AMM at positive prices (small subsidy). The costs associated with procuring and distributing AMM and additional costs in the targeting affected farmers will be very crucial in selecting the best way forward. The policy (targeting and no subsidy) seems less feasible because to identify 20 beneficiaries to this programme, the government will have to survey 100 dairy farmers (incidence of MF at baseline was on average 20%). This numbers keeps changing every year, there will be new additions and deletions which requires dynamic updating of the database. To get a ballpark estimate of this cost, we use the costs incurred by us during the baseline survey. Accounting only for transportation and labor charges, the cost of selecting 1 MF affected animal was around ₹ 4100 (US $ 56). Including the AMM costs, the latter policy costs around 5 times the free distribution policy (tracking costs is included only for the targeted policy). Note that our study sample had strict inclusion criterions and animals with high risk of MF were selected. Generally, however, the MF incidence (in the whole population) will be lesser than our estimate[12] and hence the cost of tracking will be on a much higher side. Another dimension to think about before deciding on the optimal policy is the product usage rates by who buy the product. In the next section we discuss about the product use and the effect of prices in detail.

3.2. Screening effect in the use of AMM

In this section we present and discuss the results of effect of prices on the usage of AMM, specifically the screening effect. It states that the propensity to use AMM as a preventive strategy against MF increases with increased offer prices among those who buy. Columns 1 and 2 of Table 3 show the overall effect of offer prices on the use of AMM. The results indicate that the relationship is positive and significant. However, including control covariates decreases the

[12] The milk fever incidence in different states of India varied from 10% to 14% (Paul et al., 2013; Thakur et al., 2017; Thirunavukkarasu et al., 2010).

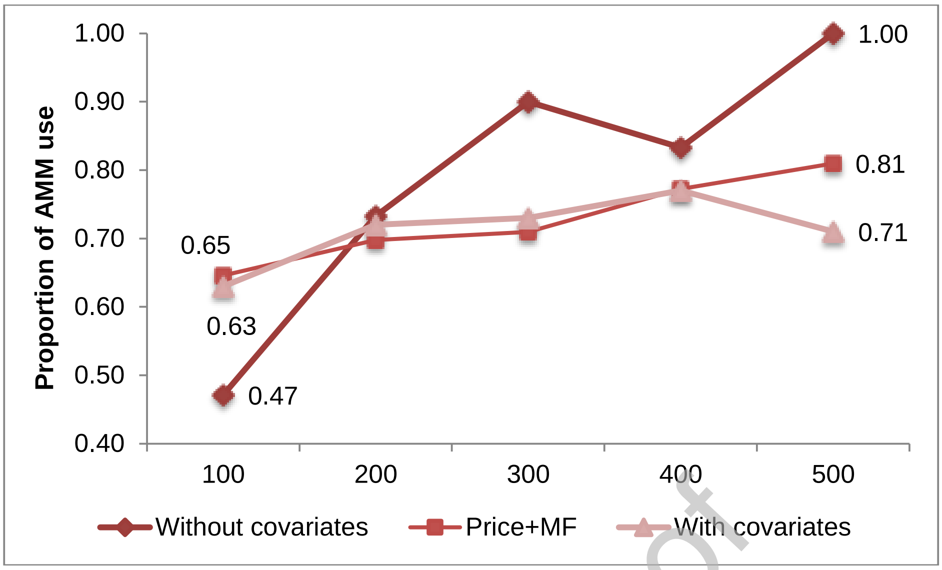
coefficient and also the effect turns non-significant. Unlike Table 2, this (change in the coefficient value due to the addition of controls) is not a test of validity of the randomization because the sample for screening effect test is selected based on the endogenous decision to buy AMM (Ashraf et al., 2010). We also test for screening effect at individual offer prices (Columns 3 and 4 of Table 3). Although the incremental increase is lesser and insignificant when controls are added, the results indicate that as the offer price increases, the propensity to use AMM also increases slightly. The evidence can be clearly visualized in Figure 5; the propensity to use AMM increases marginally with offer prices. We find high screening effects when the model is estimated without controls while we find no significant effect as we add control covariates. Therefore, we find no evidence of screening effect of offer prices. At ₹ 100, 63% of the farmers who bought AMM use it while at ₹ 500, 71% of the farmers use it implying that offer price does not play a significant role in product use decisions. Note that the usage curves with MF at baseline as control and with other additional controls are very similar. This implies that the farmer's willingness to pay along with observed MF at baseline predicts the propensity to use AMM better than what is available in other household and animal characteristics such as education, type of animal, parity or the use of other health products and mineral mixtures. Therefore, our findings imply that the offer prices have little role to play in the usage decisions of farmers relative to the influence of MF experience at baseline implying that higher offer prices do not ensure reduction in AMM wastage. This finding of absence of screening effect is in contrast to the findings of Ashraf et al. (2010), where they find significant increased use of chlorine (to prevent water borne diseases) with increasing offer prices. A 100 Kw increase in offer price led to a significant increase in Chlorine use among buyers of 6 to 7 per cent of mean usage (Ashraf et al., 2010). Also, the finding of high use propensity among farmers who have experienced milk fever before is also in contrast to the finding of (Cohen & Dupas, 2010). They find no evidence that pricing of preventive products (insecticide treated bed nets to prevent malaria in this case) induces selection of households who need the net more: those who paid higher prices did not appear sicker than the average prenatal client (Cohen & Dupas, 2010). Evidence of screening effect of offer prices is not sensitive to the estimator used. Estimates remain nearly identically when logit, probit or Poisson model is used (Appendix D). Note that the average AMM usage rate is 71%.

Additionally, there are concerns in the literature that pricing often leads to distribution of products to the "richest of the poor" (Ashraf et al., 2010). In order to test this, we study how the observable characteristics of AMM buyers, specifically proxies for wealth like income, land holding, herd size and education, change with the offer prices (Appendix E). Our results indicate that the AMM buyers at higher offer prices are not more educated or wealthier than buyers at lower offer prices. Hence, pricing doesn't lead to skewed distribution of AMM to wealthier dairy farmers.

Table 2 Effect of prices on AMM use: Linear Probability estimates

Item	(1)	(2)	(3)	(4)
Price (₹)	0.001** (0.000) [0.011]	0.0004 (0.000) [0.293]		
Base: ₹ 100				
₹ 200			0.263 (0.176) [0.142]	0.087 (0.145) [0.548]
₹ 300			0.429** (0.162) [0.011]	0.096 (0.155) [0.538]
₹ 400			0.363* (0.205) [0.084]	0.142 (0.118) [0.233]
₹ 500			0.529*** (0.128) [0.000]	0.080 (0.119) [0.507]
Baseline controls?	No	Yes	No	Yes
Number of observations	49	49	49	49

Note: The number of observations is 49; estimation only on dairy farmers who bought AMM (were willing to pay at the endline).
Standard errors in parentheses. * $p < 0.10$** $p < 0.05$,* ** $p < 0.01$. *p* values are reported in square brackets.
Controls used – MF incidence at baseline, type of animal (cow/buffalo), parity, use of health services like artificial insemination, vaccination and deworming, use of mineral mixture and farmers' education level.
Only 'MF incidence at baseline' had a statistically significant association with AMM use.



Note: Each point is the predicted margin from the linear probability model.
Model - AMM use (1/0) = f(Price, MF incidence, type of animal, parity, use of health services, use of mineral mixture and farmers' education level).

Figure 5 Effect of offer prices on AMM use: Linear probability estimates

To summarize, the demand for the preventive animal health product is highly sensitive to prices. The demand for AMM decreases significantly at each of the marginal price points. Also, farmers who have experienced losses due to MF at baseline (who stand to gain from prevention) are more likely to buy AMM. When this confound is controlled for, the demand remains highly elastic at lower prices (< ₹ 300) but turns inelastic at higher prices (> ₹ 300). Further, among farmers who were willing to pay for AMM, the product usage rate was 71% and usage did not increase significantly in offer prices. Furthermore, incidence of MF at baseline was again the important predictor of product use than offer price implying that the prior losses influence farmers buying and usage decision more than price. These findings of ours is in line with the human capital model (Grossman, 2000). It states that the households' demand for health products increases if the discounted expected benefit exceeds the cost in utility or/and financial terms. Human capital theory implies that in the short run, small costs leads to big effects in consumption behavior and therefore subsidies will help increase the demand for preventive products especially when some individuals who tend to benefit more from prevention value preventive products higher than others (Kremer & Glennerster, 2011). Note the congruence of human capital theory, which was based on the demand for human health, with demand for animal health products by the dairy farmers. Our results therefore hint that the theories that concern a household's demand and usage decisions of health products also apply to the demand for and usage of preventive animal health products. Individuals behave in a similar way when the decisions concern their own health or the health of an animal they domesticate (especially for commercial purposes). When we think of learning from and generalizing the results of randomized evaluations at different locations in different contexts, these findings will help to frame relevant strategies and policy framework for pricing and distributing preventive health products.

4. CONCLUSION

Preventive health products have huge benefits but are seldom used by the households. There are advocates of free distribution of preventive health products because of the benefits it presents and critics who argue that the products given away for free will not be valued and hence will not be used calling for pricing of the products. In this study, we report evidence from a randomized controlled trial designed to estimate the effect of prices on the willingness to pay and use of a preventive animal health product. Controlling for the covariate which also affects farmers' WTP - MF at baseline, we find that the demand for AMM dampens significantly when the price increases. Also, we find no evidence of screening effect of prices; the product usage does not significantly increase in offer prices. This implies that higher offer prices do not change the mix of buyers, in other words, prices do not screen buyers based on their propensity to use. Therefore, charging positive prices to farmers might lead to decreased buying of AMM (due to high price sensitivity) and doesn't affect usage rates to a large extent (lack of screening effect). Therefore, decreasing the prices (subsidizing) leads to significant increase in adoption of AMM.

Our findings support the human capital theory concerning demand for human health products. We find that individuals behave in a similar way when the decisions concern their own health or the health of an animal reared for commercial purposes. This finding will help in devising effective policy solutions based on the generalizations drawn from randomized evaluations from different contexts. Any kind of policy implications, however, can only be drawn after a large-scale study about the presence of MF and scaling up of our successful pilot in major milk producing tracts of India. Thus, our study acts as a primer on which a scale up could be designed. Future research could focus on evaluating the long-term effect of prices on demand and use of animal health products. Also, future research could focus on using real world marketing strategies like vouchers for buying AMM. We had a targeted sample of animals which are more susceptible to MF. Thus, researchers can use a sample with no inclusion restrictions and run a similar price experiment in multiple locations to achieve external validity.

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Declarations

Declarations of interest: none.

APPENDICES

Variables	**Price = ₹100**		**Price = ₹200**		**Price = ₹300**		**Price = ₹400**		**Price = ₹500**		**p-value***
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
a. Dependent variables											
Proportion of MF affected animals	0.25	0.44	0.28	0.45	0.21	0.41	0.13	0.34	0.08	0.29	0.32
Average milk yield (kg/animal/d)	9.54	3.05	9.32	3.67	9.28	3.39	8.57	2.46	8.80	2.02	0.60
Fat corrected milk yield (kg/animal/d)	10.91	2.86	10.81	3.16	10.25	3.08	10.12	3.12	10.14	2.16	0.75
Income from dairying (000 ₹/lactation)	105.47	27.02	104.23	30.97	99.63	29.80	97.32	28.31	97.90	19.07	0.65
b. Farmer characteristics											
Experience (years)	14.61	10.55	14.54	8.51	15.00	10.16	14.74	9.67	8.42	6.39	0.17
Proportion of trained	0.33	0.48	0.34	0.48	0.20	0.40	0.35	0.48	0.33	0.49	0.41

farmers											
Land holding (acres)	5.57	4.33	5.22	4.65	6.06	5.84	7.64	6.69	7.08	7.16	0.56
c. Animal characteristics											
Proportion of cows	0.50	0.51	0.44	0.50	0.57	0.50	0.48	0.51	0.50	0.52	0.75
Parity (nos.)	2.75	0.73	2.84	0.82	2.77	0.74	2.74	0.68	2.50	0.67	0.69
Peak milk yield (kg/animal/d)	14.54	4.66	14.21	5.60	14.14	5.17	13.07	3.76	13.42	3.09	0.60
Herd size (nos.)	5.92	2.81	5.12	2.43	5.34	3.31	5.80	3.19	6.42	3.03	0.46
d. Feed and inputs used											
Green fodder fed (kg/animal/d)	19.53	5.70	20.37	6.67	19.47	5.00	20.24	7.28	21.79	5.36	0.68
Dry fodder fed (kg/animal/d)	11.92	4.42	12.02	4.94	11.96	4.44	11.71	4.54	13.08	4.67	0.90
Concentrates fed (kg/animal/d)	3.92	1.81	3.68	1.51	3.37	1.40	3.64	1.49	3.72	1.32	0.51
Labor (nos.)	2.44	0.88	2.30	0.95	2.23	0.91	2.46	0.94	2.17	0.83	0.47
No. of animals (n)	36		50		56		46		12		N=200

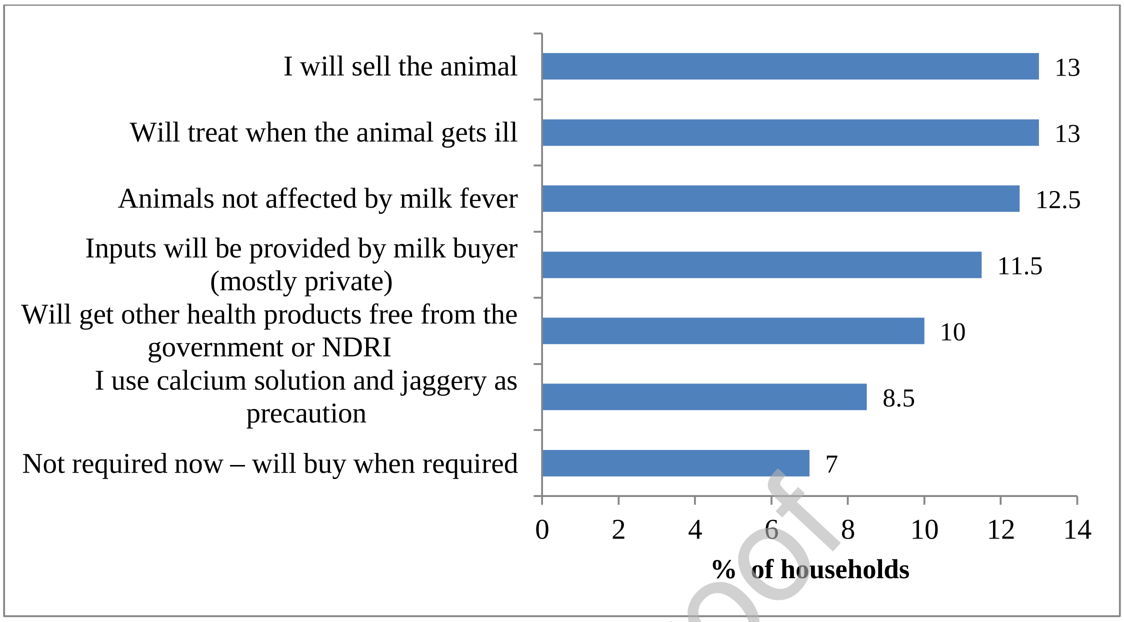
* Kruskal-Wallis equality-of-populations rank test (chi-squared with ties)

Appendix A Sample characteristics by price group

Dependent variable: Proportion of farmers WTP	**OLS**	**Probit**	**Logit**
₹ 100	0.444*** (0.071)	0.452*** (0.067)	0.452*** (0.068)
₹ 200	0.249*** (0.045)	0.245*** (0.036)	0.249*** (0.047)
₹ 300	0.176*** (0.023)	0.166*** (0.024)	0.170*** (0.027)
₹ 400	0.186*** (0.031)	0.183*** (0.029)	0.185*** (0.035)
₹ 500	0.176*** (0.035)	0.187*** (0.034)	0.196*** (0.033)

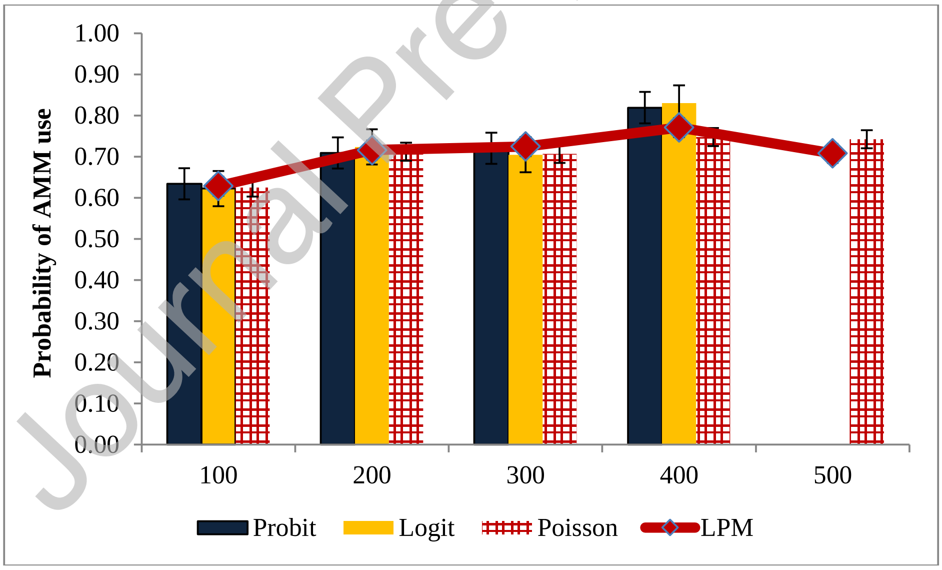
Note: Delta method standard errors in parentheses.
*** $p < 0.01$

Appendix B Robustness of WTP: Predictive margins from different estimators



Note: The share of households not buying AMM adds up to 75.5% (not 100%) as 24.5% were willing to pay (buy) for the product

Appendix C Reasons for not buying the AMM



Appendix D Robustness test: Predictive margins of AMM use from different estimators

Price (₹)	Education score	Annual gross income (₹/animal)	Herd size (nos.)	Land holding (acres)
100	4.53	101904.35	6.35	5.26
200	3.87	109460.75	5.07	4.03
300	4.00	101993.31	7.00	6.35
400	4.00	102667.22	5.50	5.33

500	5.00	72010.50	4.00	5.00
Total	4.16	103719.02	5.94	5.11
Kruskal-Wallis equality-of-populations rank test *p* value	0.49	0.51	0.46	0.56

Appendix E Education and wealth indicators of buyers by randomized price groups