Continued Existence of Cows Disproves Central Tenets of Capitalism?

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> "In theory, the market should have done away with Edible Arrangements long ago," said American Economic Association president Orley Ashenfelter, who added that one of the crucial assumptions of capitalism is the idea that businesses producing undesired goods or services will fail. "That's how it's supposed to work." (*The Onion* [a satirical newspaper], March 31, 2011)

I. Introduction

Despite the importance of livestock as an asset class in developing countries, we know less than we should about their economic returns. Stylized facts have circulated for years regarding low, often negative, economic returns from assets (de Janvry, Fafchamps, and Sadoulet 1991). Yet this stylized fact, to our knowledge, does not remain well documented or well understood. Using detailed data from cows and buffaloes in India, we attempt to document carefully the returns in a given year. We then discuss a myriad of reasons why observed returns may be negative and discuss some evidence on each, including measurement error leading to underestimates of returns, preference for illiquid savings, insurance and variation over years (unobserved in our data), labor market failures, milk market failures, and social, cultural, and religious value.

Understanding the profitability of common household investments is important for several reasons. First, if these types of investments are profitable, then it suggests that low take-up of formal financial savings products may be

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driven in part by profitable risk-adjusted returns to informal assets. If this is the case, then programs that encourage households to use formal sector savings are unlikely to succeed unless they provide higher, safer, or more flexible returns than those available on livestock assets.

Second, estimates of the returns to livestock can inform lenders about whether there are profitable projects for them to finance. As pointed out in de Mel, McKenzie, and Woodruff (2009b), while the (albeit limited) demand for high–interest rate loans suggests that some proportion of households earn high returns on investments such as dairy animals, much heterogeneity likely exists, and evidence suggests that nonborrowers may have quite low or nil returns to capital (Beaman et al. 2014).

Third, understanding the returns to livestock can help us learn more about labor market failures. Households will choose to spend time caring for livestock only if the returns on livestock are greater than their opportunity cost of labor; low returns on livestock may be masking even lower labor market opportunities (whether formal, informal, or via household production).

Fourth, to the extent that some development organizations provide grants of livestock to alleviate poverty, this analysis provides plausible estimates of potential impact, or at least lower bounds (many such grant programs provide services alongside the grant).[1] Randomized trials evaluating the impact of asset transfers on income and consumption have found considerable success in several instances (Bandiera et al. 2013; Banerjee et al. 2015), but these studies are evaluating bundled interventions that include the training, ongoing coaching, savings accounts, health trainings, and consumption support as well as the livestock grants, rendering it difficult to isolate the returns to livestock specifically.

We use newly collected animal-level survey data from northern India to estimate the returns to owning dairy cows and buffaloes. We study dairy animals in India because of their importance as an asset among India's rural poor. India holds more than a sixth of the world's population and over one-quarter of the world's estimated cattle population. The Rural Economic and Demographic Survey, a nationally representative survey of rural India, found that 45% of rural Indian households owned at least one cow or buffalo in 1999, and on average, those who have a cow or buffalo have an adult female. Our survey data provide information on all the major inputs in the milk production function including the value of the animal, fodder costs, veterinary costs, and lactation periods, as

[1] Organizations that provide livestock grants, sometimes alongside a holistic set of training, coaching, and consumption support (often referred to as "graduate" or "ultrapoor" livelihood programs when employing a more holistic intervention), include Bandhan, BRAC, Fonkoze, Heifer, and TrickleUp, among others.

well as detailed data on animal outputs including milk, calves, and dung. We estimate annual returns to owning a dairy animal based on estimates of accounting profits (excluding the opportunity cost of labor) and economic profits (including the opportunity cost of labor, but not including the opportunity cost of capital).

Our main finding is the preponderance of negative returns from investments in cows and buffaloes. We begin our analysis by calculating rates of return under two conservative (potentially upwardly biasing) assumptions. First, we assume that household labor is valued at zero. Second, we use our lowest estimates of fodder costs, which come from independent sources on the prices and quantities of fodder animals eat (these independent estimates of fodder costs are substantially lower than the self-reported fodder costs in our survey). Even under these conservative assumptions, we find that the median return on cows is −7% per year, and the median return on buffaloes is +17% per year.[2] We show that rates of return are even lower if fodder is valued at households' self-reported values or if we value household labor at market wages. In terms of the distribution, with the conservative assumptions of zero value for labor and lowest fodder costs, we find that 51% and 45% of households earn negative returns on cows and buffaloes, respectively.

We caveat our results by noting that there are a number of important measurement challenges in estimating the returns to dairy animals. For example, households may report that their home-produced milk is worth the price that they could sell it for on the market but in reality value it much higher because they are assured that it is high quality. As another example, we find particularly low returns for adult animals that have not yet given milk; even though these animals produce no revenue, they should appreciate in value as they get closer to giving milk (in equilibrium). One potential explanation for our low estimated returns is that our self-reported measures of animal appreciation are biased downward.[3] We discuss how these and other measurement issues may contribute to our low estimated returns.

Estimates of low or negative returns present a puzzle similar to the "Edible Arrangements" satirical quote at the opening of this article: if cows and buffaloes earn such low, even negative, economic returns, why would rural Indian households continue to invest in them? Naturally this is not meant to be taken

[2] It is important to note that there is wide dispersion in our estimates, in particular for cows; the 95% confidence intervals on our main estimates of the returns to cows and buffaloes are [−43, 32] and [3.5, 25.7], respectively. Pooling the cow and buffalo samples, we get a median return estimate of 11% with a 95% confidence interval of [−8, 23].

[3] When we include labor costs, we find low returns even when we look only at the subsample of milking animals.

literally, but to make a point that we need to understand why these data generate these estimates and, likewise, why the anecdotal evidence suggests similar low returns from other livelihoods and investments, such as smallholder farming (Duflo, Kremer, and Robinson 2008; Beaman et al. 2013; Karlan et al. 2014). The second part of our article puts forward theories as to why households might persist in investing in cows and buffaloes despite their low returns. While the data at hand do not allow us to distinguish conclusively between these various explanations, we present some evidence to suggest that some explanations appear more plausible than others.

We also contribute to a prominent literature in anthropology that tries to understand the cultural and economic underpinnings of cattle ownership in India. One strand of this literature argues that the Indian stock of cows is too large relative to its productivity, that is, that cows consume more societal resources than they produce. This strand explains the prevalence of these "surplus cattle" by arguing that cultural factors, such as the sanctity of cows in Hinduism, provide noneconomic benefits to society that can explain the holding of unproductive animals.[4] A second strand of this literature, starting with Harris (1966), argues that a broader consideration of the benefits of cattle owning could justify the large level of cattle ownership in India on economic grounds and that the sanctity of cows in Hinduism is a consequence of the economic productivity of cows.

We contribute to this debate in anthropology by adding some useful facts on individual cow rates of return from detailed animal-level input and output data for a reasonably large sample of rural cow- and buffalo-owning households.[5] Our results corroborate the idea that the widespread ownership of low-productivity cows and buffaloes cannot be explained by the simple economic factors Harris (1966) described (i.e., benefits of milk, calves, and dung); instead, there must be more subtle economic or cultural forces influencing the

[4] The literature focused on the fact that in Hinduism cows are considered sacred, cow slaughter is prohibited, and eating beef is considered taboo. See Pal (1996) for a recent review of the literature on "surplus cattle," which he terms the "classical" view. There is also a literature in anthropology, mainly focused on African pastoral herders, that provides evidence that cattle play a broader role in society beyond that of economic assets. A key feature in most (though not all) African contexts is the reluctance of households to trade cattle for money and also the special role cattle play in exchange for brides. See Comaroff and Comaroff (1990) and Hutchinson (1992) for detailed discussions. The anthropological literature on Indian cows cited above does not specifically discuss a role for cattle as a special medium of exchange (and we also have not heard of anecdotal evidence of this), so we suspect this is not an important explanation for the ownership of low-return cows and buffaloes in India.

[5] Rao (1969) attempted to estimate cow-level production functions using input data on feed and labor and output data on milk and dung. He does not report results on the profitability of cows and also does not have information on calves born. See Dandekar (1970) for criticisms of Rao's methodology.

ownership of cows. Our analysis is not entirely consistent with the idea that cultural factors, such as religion, explain household cow ownership and low productivity because (1) buffaloes are not considered sacred in Hinduism, and yet we find low returns for them as well, and (2) it is possible that economic factors in the form of milk or savings market failures could convey benefits to households that are difficult to measure in our setting.

The article proceeds as follows. Section II describes the data and methods for calculating the returns to cows and buffaloes. Section III presents the estimates. Section IV discusses potential explanations for why so many estimates are zero or negative, and Section V discusses further research questions and policy implications.

II. Data and Methods

A. Data

The data were collected from the 2007 Uttar Pradesh Household Survey, also used in Anagol (2010) and implemented by the Center for Financial Design at the Institute for Financial Management and Research in Chennai. The data were collected for a sample of households in two districts in the state of Uttar Pradesh in northern India: Lakhimpur Kheri and Sitapur.

The districts were split into two geographic regions, a smaller region called the "Ajbapur" area and a larger region called the "non-Ajbapur area." The distinction was relevant for this survey as Ajbapur is the location of a large sugarcane mill, and the survey collected detailed data on water trading among sugarcane farmers. A complete list of villages in the two districts was obtained from the Indian census of 2000, and 70 villages were randomly selected (with probability proportional to size), including 20 from the Ajbapur area and 50 from the non-Ajbapur area. Within each village in Ajbapur, we randomly sampled 10 households from the full village and an additional 20 households among all households that were identified as selling water in the village in a household listing survey.[6] In non-Ajbapur villages we sampled 20 households randomly from the full village and two households that were identified as jointly owning a bore well in the village.[7] All households in the survey, including the water

[6] We sampled a greater number of households that traded water within the Ajbapur area because the survey was also used to study the water trading behavior of households that lived near the sugarcane mill in Ajbapur.

[7] Because of unsatisfactory performance by the initially hired data entry firm, we switched data entry firms and reentered all of the data. In the process of transferring the hard copies of surveys from the first data entry firm to the second, 11% of the original surveys were lost. Among the non-Ajbapur villages, we received 967 of the expected 1,100 surveys. Three villages in the original non-Ajbapur sample frame were lost. Among the Ajbapur villages, we received 546 of the expected 585 surveys. We received

seller respondents, were asked the same set of questions regarding their dairying behavior.

The survey asked detailed questions about livestock, farming practices, landholdings, assets, household consumption and income history, savings, borrowing, and shocks. The "animal details" section of the questionnaire (sec. E) focused on one randomly chosen dairy animal owned by the household, asking if the animal was a cow or buffalo and other details about the animal.[8] For an adult female dairy animal, the survey asked how many liters of milk were given at different stages of the lactation period, including immediately after giving birth to a calf, 3 months after giving birth, 6 months after giving birth, and 9 months after giving birth. The survey also asked about the number of insemination attempts it would take to impregnate the animal, the number and value of male and female calves born to the animal, the number of dung cakes the animal produces per day, the number of times the animal had visited the veterinarian in the 12 months preceding the survey, the costs associated with these visits, and the costs of feeding the animal (including both purchased and home-produced fodder).

B. Estimating the Rate of Return

Our equation for the annual rate of return on a cow or buffalo is

$$\text{Rate of return} = \frac{P_t - P_{t-1} + \text{Profit}_t}{P_{t-1}},$$

where P_t is the price at the end of the year, P_{t-1} is the price at the beginning of the year, and Profit_t is the profit generated by the animal over the year. We estimate the term P_{t-1} from the owner's perception of the animal's value, and we measure P_t on the basis of a regression model of the price appreciation for animals 1 year older. We estimate the flow profits (Profit_t) as the revenues from milk, calves, and dung minus fodder, veterinary, and insemination costs.

surveys from all of the villages that were originally included in the Ajbapur sample frame. Overall, we are missing data from 11% of households in the original sample frame. The survey collected a larger number of observations from water sellers in Ajbapur to study water trading among those living close to a sugarcane mill. In the non-Ajbapur area, the survey collected information on two households that jointly owned bore wells as baseline information for a potential field experiment on joint ownership of bore wells.

[8] The dairy section of the questionnaire (sec. D) asked if the household owned any female cows/buffaloes and, if so, how many cows/buffaloes the household owned. For each cow or buffalo owned, households were asked to record, beginning with the most valuable cow/buffalo and then proceeding in order of declining value, the animal's breed and what its selling price would be if the household wanted to sell the animal. The enumerator was then instructed to administer the detailed animal questions (sec. E) regarding the animal in this list whose identification number appeared first on a sticker (unique to each survey), which contained a randomized ordering of all animal IDs.

We first need to estimate the average number of lactations per dairy animal per year. There are two types of cows to consider in this calculation: cows that have not attained reproductive age and cows that have attained reproductive age. Our survey asked households whether the sample dairy animal had given birth yet in its life. If the animal had not yet given birth, we count that animal's milk yield as zero for the year. Of our total of 302 cows, 106 have not given birth and thus have milk revenues of zero. Of our total of 383 buffaloes, 143 have not given birth and thus have milk revenues of zero.

For cows that had given birth at least once before in their lives, we estimate the number of calves expected per year as follows. Our survey asked households how many calves they expected the sampled dairy animal to have in the rest of its life (having a calf is a necessary and sufficient condition for having a lactation). We take this number and divide it by an estimate of the number of years we expect the sampled animal to live.[9] For cows, the average number of calves expected per year is 0.89, and for buffaloes the average number of calves expected per year is 0.97. For simplicity, we assume that cows and buffaloes that have had at least one calf in the past will produce one calf, and thus have one lactation period, per year.[10] The annual input and output variables used in the calculations are as follows.

C. *Inputs*

Fodder costs. Our survey asked households to report the daily value, in rupees, of 12 different types of food for the selected dairy animal. For each of these types of fodder we asked for the value that was home produced and for the value that was purchased. We also asked for these separately for when the animal was milking as well as when the animal was dry. Online appendix tables A1 and A2 present the average value of each type of fodder given to cows and buffaloes separately for when the animal is milking and when the animal is dry (dairy animals typically eat more during the time when they are giving milk). In addition, our survey asked whether the animal was fed any wild grasses (which we assume are costless); more than 99% of the sampled dairy animals were re-

[9] We estimate a dairy animal's expected years to live as follows. We first take the observed age distribution of cows above the age of 6 years old in our sample and estimate the probability of death at each age based on the proportionate decrease in the number of cows at each age level. We also assume that cows or buffaloes that reach the age of 15 will die in that year, as this is the oldest observed animal we see in our data. Using this estimate of a mortality table for cows, we can estimate an animal's life expectancy, conditional on current age. For animals less than 6 years of age, we assume that they will make it to age 6 with probability one. We make this assumption as our data contain few observations of animals less than 6 years old, so our estimated mortality table is not accurate for the younger ages.

[10] The assumption of one calf per year is likely an overestimate, as even dairy cows in the United States typically do not give birth to more than one calf per year on average.

ported to eat some wild grasses. The additional fodder costs reported should thus be interpreted as beyond the wild grasses given to these animals.

Dairy animal fodder can be classified into three groups: (1) roughage, (2) concentrate, and (3) minerals. Roughage is typically dried crop residues that are produced as a by-product of crop production. On average, the main fodder cost for both cows and buffaloes is home-produced wheat straw, which is the primary form of roughage in our sample area. Our respondents also report feeding their animals rice paddy and straw (*puwal*/*paira*) as additional forms of roughage. *Bursin* (a protein-rich legume), *ampicheri*, maize (corn), mineral cakes, and ready-made concentrate would all fall under the concentrate type of fodder. Concentrates in general provide greater nutrients. Our households also report providing small amounts of minerals (*ghur* and salt).

Our households report that the average cost of feeding a milking cow is Rs 35 per day, and the average cost of feeding a dry cow is Rs 29 per day. For milking cows, approximately 61% of the daily feed cost comes from home-produced fodder, and for dry cows, approximately 71% comes from home-produced fodder. The value of fodder given to buffaloes is slightly higher, but the breakdown across different fodder types is very similar to that of cows (app. table A2).[11]

An important issue is how we should interpret the values households report for home-produced fodder, as it is not clear whether these values represent "buy" values or "sell" values. Households might report a high value of their home-produced fodder because that is what they would buy it for; but, in reality, they may not be able to sell home-produced fodder for that price because of frictions in the fodder market (such as adverse selection). Ideally we would like to know the price households could sell their home-produced fodder for and use these "ask" prices to estimate the value of home-produced fodder, but these data are not in our survey (nor are there easy answers to elicit accurately).

To get a sense of such potential biases in our survey-estimated fodder costs, we searched online for recommended quantities and market prices of fodder for Indian cows and buffaloes ("feeding guides"). We found eight sources that estimated the quantities of roughage and concentrate that should be given to cows and buffaloes in milking and dry phases.[12] For each source we estimate

[11] Our survey did not ask how the prices of fodder varied across seasons, so it is possible that seasonal variations affect these estimates. We have not come across any anecdotal evidence to suggest there are large swings in fodder prices.

[12] A reasonable concern is that these online feeding guides might cater to richer urban households with larger and more productive cows. These feeding guides typically give recommendations for cows and buffaloes by weight. We calibrate these recommendations by proportionally reducing the amounts recommended on the basis of the weights of rural Indian cows and buffaloes relative to

the cost of feeding the animal separately for the milking and dry phases and then take the average across all of the sources as our estimate of the average fodder cost for a milking or dry animal.[13] For milking cows, the average estimate is Rs 20.8 per day. For dry cows, the average is Rs 16.3 per day. Our online sources recommend, on average, Rs 21.2 per day of fodder for dry buffaloes and Rs 27.9 per day for milking buffaloes. We use these feeding guide estimates of fodder costs in our baseline calculations as these are our most conservative (i.e., lowest) estimates of fodder costs.[14]

We combine this information on daily dry and milking fodder costs with previous estimates on the average amount of time Indian dairy animals spend dry versus milking per year. Dry periods for cows and buffaloes in India are estimated to be approximately 160 days per year (Anagol 2010). Since we are estimating returns over a 1-year period, assuming a 365-day year implies that milking periods are 205 days per year (roughly 7 months). The survey asked how many months the animal will give milk after it gives birth. The average response was 7 months (but can go up to 10 months for some animals), which is consistent with the estimated 205 days we use to estimate annual fodder costs. For animals that gave milk during the survey year, we assume that each cow has daily dry fodder costs for 160 days per year and milking fodder costs for 205 days per year. For animals that have not yet given milk, we use the dry fodder costs for the 365-day period.

Value of adult animal. Our survey asked respondents "If you wanted to sell this cow, what would the price be?" We use the response to this question as our estimate of P_{t-1}.

Appreciation and depreciation of dairy animal value. We estimate the change in the capital value of each animal ($P_t - P_{t-1}$) dependent on its age as follows. We first regress the logarithm of the self-reported value of the dairy animal on age and age squared as a predictive model of dairy animal values as a function of age. Appendix figure A1 presents scatter plots of the relationship between animal value and age separately for cows and buffaloes. Both figures show that a quadratic model in age is a reasonably good fit for the relationship

the weights of the animals mentioned in the feeding guides. It is also worth noting that after our calibration, our estimated feeding guide costs are lower than the costs our households report themselves (see table 1). For details on these sources and the underlying feeding guide calculations, see the online appendix.

[13] Figure 2 presents our median rate of return estimates across a range of potential fodder costs as well, to give a sense of how returns would change across different assumptions on fodder costs.

[14] The feeding guide estimates are similar to the survey estimates of home-produced fodder on average (see app. table A2 for a breakdown of our survey fodder estimates by home-produced vs. purchased). Our finding of low returns would thus also be similar if we estimated it using only the value of home-produced fodder.

between dairy animal age and value: dairy animals increase in value at younger ages and then decline in value at older ages. This positive age/value relationship at younger ages is plausible since as a young dairy animal ages it gets closer to giving milk; also, there is positive selection in our sample of older animals, as lower-quality animals may die or prove to be infertile. This type of selection will likely bias upward our estimates of animal appreciation and therefore cause us to overestimate the returns to dairy animals. The figure also suggests that dairy animals decline in value in their older years, which is consistent with the fact that older animals have fewer future lactations to give.[15]

Given our estimated model of the relationship between the logarithm of dairy value and age, we estimate the average change in the log value of animals for each age in our data. For example, our model predicts that, on average, 3-year-old buffaloes gain in value by 0.2 log points per year (approximately 20%). We apply these average changes in value, conditional on age, to each of the animals in our sample to estimate their appreciation/depreciation over the year.

One potentially important issue here is that there may be a gap between the appreciation households experience, because they know their cow is high-quality, versus the appreciation in market prices (where quality may be uncertain to buyers).[16] If households have private information about cow quality and tend to keep the best animals, then the real appreciation households experience may be higher than the market price appreciation. We return to this issue when we discuss potential explanations of our finding of low returns.

Ideally we would also have estimates of the probability of death of animals at each possible age to include in our return calculation. Our survey did not contain information on cow and buffalo deaths that would allow us to estimate death probabilities, although we note that including the probability of death would naturally reduce the returns to holding cows, which would strengthen our finding of low returns.

Veterinary costs (costs of examinations and procedures during visits to a veterinarian). We have a direct survey question that asks how much the household spent on veterinary costs for the animal over the past year.

[15] Ideally we would have been able to estimate depreciation functions specifically by animal breed, as breed has been shown to be an important determinant of value in prior work. In our sample, however, there are very few buffaloes and cows reported as specific breeds; most animals are nondescript local varieties. More than 81% and 95% of the buffaloes and cows are categorized as "unknown Indian" breed. This leaves us with too small a sample size to estimate breed-specific depreciation, although this issue appears to be less relevant in our context where most households do not own pure-bred animals.

[16] We estimate appreciation on the basis of households' answers to the question "If you wanted to sell this cow, what would the price be?"

Cost of insemination. This is determined by the number of insemination attempts needed to impregnate the animal multiplied by the cost for one insemination. Where we collected detailed information, 78% of animals were inseminated using a breeding bull, 13% were inseminated using artificial insemination, and 9% were inseminated using both methods (the households tried different methods). The survey did not include a direct question on the cost of using natural insemination, so we make the conservative assumption that natural insemination is as expensive as artificial insemination.[17] Insemination services are typically provided by either a government veterinary hospital or a nongovernmental organization (NGO) in our survey villages. Our village-level survey suggests that the average cost of one insemination by a government hospital was Rs 66. For an NGO, the corresponding figure was Rs 70. As we are unable to distinguish between the services provided by the two providers, we assume the price is the average of the two, Rs 68.

Labor costs. Our survey asked about the number of hours spent caring for dairy animals per day in the household where the sampled animal lives. Appendix figure A2 plots the number of hours households reported taking care of their dairy animals against the number of dairy animals in the household separately for cows and buffaloes. Both plots show that there appear to be strong economies of scale in taking care of dairy animals; the number of labor hours used does not increase with the number of dairy animals owned in the household. To bias ourselves toward underestimating the cost per animal owned, we assume that hours spent on the sampled animal are equal to the total hours spent on dairy animals divided by the number of dairy animals in the household.

We estimate the cost per hour of this labor as follows. We observe that children and adults (both men and women) in the household are generally equally responsible for the care of the animal.[18] According to our village-level survey, the daily wage rate for an adult (man or woman) is Rs 60, and the child labor wage rate per day is Rs 25. In our baseline estimates we thus assume that adults and children equally share the burden of taking care of the animals, yielding an average cost of taking care of the dairy animal of Rs 42.5 per day. Assuming an

[17] In reality we suspect that natural insemination is cheaper than artificial insemination, as local bulls are typically maintained in villages for insemination purposes. Nonetheless, given the low price of insemination in general (median annual cost of Rs 70 relative to a median annual value of fodder costs of Rs 6,850), it is unlikely our results are driven by measurement error in insemination costs.

[18] We do not know which household members take care of these particular animals. However, the survey asks whether a household has owned any female cows or buffaloes in the past 5 years and which members of this household are responsible for dairy animals. According to the data, it is common practice for household members (adult males and females as well as children) to share the responsibility of taking care of their cows and buffaloes.

8-hour workday, this gives an hourly labor cost of approximately Rs 5.[19] We multiply this average cost of labor per hour by the total number of hours spent per year on the sample animal to estimate the total cost of labor in caring for this animal.

An important point to note is the possibility of multitasking when tending the animal. It is possible that the animal is taken out to pasture while the caretaker is doing something else (working on the farm, doing something in the neighboring plot, etc.). Our survey did not ask any questions about multitasking, so we cannot directly assess its importance. We account for the fact that multitasking might reduce the effective cost of labor by including return calculations where we assume the value of labor is zero (our "accounting" rates of return).

D. Outputs

Value of milk. For animals that had not yet given birth to a calf, the value of milk produced in the year is zero. It is important to include these animals in the analysis as our data suggest that it is common for households to own such animals (approximately 35% of the dairy cows and buffaloes held by our households had not yet given birth).

For animals that had given birth to at least one calf in the past, our survey asked the following questions to determine the value of milk produced by the animal per lactation. We asked for the number of liters of milk produced during the first 3 months after birth, from 3 to 6 months, from 6 to 9 months, and from 9 to 10 months. We asked for potentially differing amounts of milk production based on months since birthing, as cows and buffaloes typically give the most milk around 4–5 months after giving birth and then reduce milk production as the calf switches to solid foods. We multiply the liters per day estimate by the household's response to a survey question on the average price of milk produced by the household.[20] The value of milk produced by the cow/buffalo when it is dry is assumed to be zero.

Figure A3 shows histograms of the price per liters reported by households that own the cows and buffaloes in our sample. There is little variation in the milk prices that households report, with 48% and 30% of cow and buffalo owners reporting a price of Rs 10 per liter and 40% and 54% of cow and buf-

[19] According to the *Times of India* (2011), the average for the OECD nations is 8 hours a day, slightly below the figure for Indians at 8.1 hours (486 minutes).

[20] The survey did not ask for specific price per liter estimates for each animal in the household as fieldwork during piloting suggested there was not substantial variation in the price per liter of milk within households. The exact wording of the survey question was "What is the average price of this milk per liter?"

falo owners, respectively, reporting Rs 12 per liter. One potentially important source of measurement error here is that households do not have a good idea of the true value of their milk (i.e., marginal utility of consumption value) and therefore use a heuristic price of Rs 10 or Rs 12 per liter. We discuss the issue of misvaluation of milk as a potential explanation of our results later in the article.

It is important to note that our measure of milk is based on market prices and therefore does not account for the fact that cow and buffalo owners may enjoy substantial consumer surplus from home-produced milk. The fact that only 12% of households sell milk suggests that this consumer surplus could potentially be large. One particular reason consumer surplus may be larger than market prices is that households can verify the quality of home-produced milk; we elaborate on this issue when we discuss explanations for our main findings.

Value of calves. Given that we estimate that dairy cows and buffaloes have approximately one lactation per year, this implies that they would produce one calf per year (on average). For each cow and buffalo in our sample, the survey asked the respondent to estimate what a new calf of this particular animal would be worth (separately for male and female calves) at the time of birth. Given that male and female calves are equally likely to be born, we take the average value of male and female calves as the expected value of a calf during its first year.

Value of dung cakes. Our survey asked the respondent to estimate the number of dung cakes the animal produces per day.[21] We combine this information with the estimated value of a dung cake as provided in the village survey (Re 1 per dung cake) to estimate the value of dung cakes produced per year.

III. Estimates

We collected survey data on 303 cows and 384 buffaloes. Of the 303 cows, eight were missing data on the self-reported value of the cow, fodder costs, or labor costs, leaving us with an estimation sample of 295 cows. For buffaloes, 17 were missing the self-reported value or labor costs, so we are left with an estimation sample of 367 buffaloes.[22] The estimation sample is consistent through all of the results we present.

[21] Cow dung can be used in several ways. First, dung cakes are a source of domestic fuel in many rural households in India (Aggarwal and Singh 1984). Second, dung is often used as agricultural fertilizer (Aggarwal and Singh 1984). Third, because of its insect-repellent properties for some types of insects (such as mosquitoes), dung is used to line the floors and walls of buildings (Mandavgane, Pattalwar, and Kalambe 2005). Dung is therefore important, allowing households to save money that would otherwise be spent on alternatives such as firewood, fertilizer, and insecticides.

[22] One buffalo had a self-reported value of Rs 20, which is too low to be reasonable. We treat this animal as having a missing self-reported value and exclude it from the estimation sample.

Table 1 presents summary statistics of the sources of value and expenditure, focusing on variables directly from our survey that were typically collected at the daily frequency (we later present summaries of annualized revenues and costs). Panel A includes variables in which we have data for all animals in the sample, and panel B includes variables relevant only for animals that have given birth to a calf (and thus have given milk before the time of the survey).

On average, the self-reported values of cows and buffaloes are Rs 2,280 and Rs 8,700, respectively. The average ages of cows and buffaloes are similar at 5.5 and 5.7 years. Buffaloes produced 0.7 more dung cakes per day and are expected to have an additional 0.6 calves in the rest of their life. In terms of the major costs of owning dairy animals, fodder, and labor, buffaloes require approximately Rs 3–Rs 7 additional per day of fodder depending on whether the animal is milking or dry. The feeding guide estimates of fodder costs are typically Rs 10–Rs 15 lower per day relative to the survey-based estimates.[23] Our survey respondents also report spending 0.3 hour (18 minutes) longer, on average, taking care of their buffaloes.

The milking and value of calf variables (panel B) are means calculated for the 190 cows and 235 buffaloes that had given birth at least once at the time of the survey. Buffaloes, on average, give an additional 1 liter of milk per day between zero and 9 months after giving birth and an additional 0.5 liter 9–12 months after birth. Further, buffalo milk is, on average, valued at Rs 0.6 more than cow milk. On average, female cow and buffalo calves are worth Rs 470 and Rs 950, respectively. Calves are worth substantially less than the average adult animal because the calf must be fed for 3–5 years before giving milk. Male cow and buffalo calves are worth, on average, Rs 413 and Rs 639, respectively. The declining importance of male animals for farm work is likely the reason for the lower value of male versus female calves.

It is important to note that our sample comes from a relatively small set of villages in just two districts of Uttar Pradesh. The milk productivity of our sample animals seems reasonably similar to that of cows and buffaloes in Uttar Pradesh in general; statewide survey results report average milk yields of 2.46 and 4.32 liters per day (conditional on milking) for indigenous cows and buffaloes, which is similar to the reported average yields we find (Basic Animal Husbandry Statistics, 2006). Our results are also not too different from the all-India reported yields of 2.36 and 4.8 liters per day for cows and buffaloes. We suspect that our results are most relevant for indigenous (i.e., non-cross-bred) cows and buffaloes throughout the country but not applicable to states where cross-bred

[23] The standard deviations on the feeding guide estimates are zero as these are imputed from the average cost based on the feeding guides. See the online appendix for details.

TABLE 1
SUMMARY STATISTICS: MEAN AND STANDARD DEVIATION

	Cows	Buffaloes
	A. Full Sample of Dairy Animals	
Animal value (self-reported)	2,285.7	8,706.5
	(1,680.4)	(4,740.8)
Age (years)	5.5	5.7
	(2.5)	(2.7)
Dung cakes per day	4.2	4.9
	(1.7)	(2.0)
Calves expected in rest of life	4.3	4.9
	(2.0)	(2.2)
Number of vet trips in past year	.8	.9
	(.9)	(1.0)
Survey daily cost of fodder when milking (Rs)	35.2	38.2
	(26.6)	(30.1)
Feeding guide daily cost of fodder when milking (Rs)	18.7	25.1
	(.2)	(1.1)
Survey daily cost of fodder when dry (Rs)	28.8	34.3
	(18.7)	(35.2)
Feeding guide daily cost of fodder when dry (Rs)	13.6	22.2
	(2.7)	(4.2)
Daily labor hours	3.0	3.3
	(1.5)	(1.5)
Observations	295	367
	B. Subsample of Dairy Animals That Have Produced a Calf (and Thus Milk)	
Milk (liters/day):		
0–3 months after birth	2.6	3.5
	(1.0)	(1.3)
3–6 months after birth	2.7	3.6
	(1.0)	(1.2)
6–9 months after birth	1.9	2.8
	(1.0)	(1.1)
9–12 months after birth	.2	.7
	(.6)	(1.0)
Milk value (Rs per liter)	11.2	11.7
	(1.7)	(1.9)
Months milking after birth	7.2	8.2
	(1.4)	(1.7)
Value of female calf	476.9	933.6
	(531.7)	(1,323.9)
Value of male calf	418.1	650.0
	(433.0)	(744.6)
Observations (with milk data)	190	235

or high-yielding animals are common (e.g., the average milk yield per day for buffaloes in Punjab is 7.1 liters per day).

Table 2 presents our baseline estimates of rates of return for the full sample of cows (panel A) and buffaloes (panel B). To construct these tables we first calculate the rate of return earned on each animal according to equation (1) above.

TABLE 2

DISTRIBUTION OF RATES OF RETURN (ROR), VALUING LABOR AT ZERO AND FODDER AT FEEDING GUIDE VALUES

Sample Frame	RoR in Bottom 20th Percentile	RoR in 20th–40th Percentile	RoR in 40th–60th Percentile	RoR in 60th–80th Percentile	RoR above 80th Percentile	Full Sample
	A. Cows					
Animal value	1,000	2,000	2,500	2,500	2,000	2,000
Median revenues:						
Milk	0	0	5,400	7,560	9,450	5,400
Calf	0	0	200	300	350	125
Dung	1,095	1,460	1,460	1,460	1,825	1,460
Total	1,095	1,825	7,030	9,275	11,625	7,030
Median costs:						
Fodder	5,652	5,652	6,850	6,850	6,850	6,850
Depreciation	−101	−199	−46	13	−27	−62
Insemination	0	0	136	136	136	68
Veterinary	0	0	100	100	40	50
Total	5,666	5,528	7,090	7,117	7,040	6,945
Median profit	−3,676	−2,389	−182	2,339	4,627	−182
Median RoR	−385	−136	−5	90	220	−5
	B. Buffaloes					
Animal value	3,500	8,000	11,500	12,000	7,000	8,000
Median revenues:						
Milk	0	0	8,100	11,880	14,040	8,100
Calf	0	0	450	400	450	50
Dung	1,460	1,460	1,825	1,825	2,008	1,825
Total	1,460	1,460	10,615	14,090	16,523	10,690
Median costs:						
Fodder	7,738	7,738	9,078	9,078	9,078	9,078
Depreciation	−805	−1,524	−280	−459	−247	−625
Insemination	0	0	136	136	136	68
Veterinary	0	0	100	100	100	50
Total	6,991	6,432	9,233	8,855	9,086	8,432
Median profit	−5,667	−4,466	1,572	5,354	7,352	1,581
Median RoR	−153	−53	16	46	96	17

Note. Median values of all input, output, and rate of return variables for cows and buffaloes. Data are first sorted on the basis of the estimated rate of return for the animal, and then within each quintile we present the median value of the variable as indicated in the row headings. Sample sizes of cows and buffaloes are 295 and 367, respectively.

In this table we assume that the value of household labor used to take care of the animal is zero, and the value of fodder given is equal to the recommended amount from the feeding guides (see the online appendix for a full description). We then sort the animals from lowest to highest rate of return. The table presents the median for the variables indicated in the rows separately for each rate of return quintile, as well as the median values for the full sample. For example, the number 1,000 for animal value in the first column of the table indicates that among the cows in the bottom 20% of the rate of return distribution, the median animal value is Rs 1,000.

Our main result in table 2 is that the median return to cows and buffaloes, even before including labor costs, is low and that therefore there appear to be a large number of Indian dairy animals that produce negative returns. We estimate a median return to cows of −7% and a median return to buffaloes of +17%.[24] The 95% confidence intervals for the cow and buffalo median estimates are [−43, 32] and [3.5, 26], respectively; it is important to note that our rate of return estimates for cows will be particularly sensitive to mismeasurement of fodder costs; given that the median value of a cow is only Rs 2,000, an upward bias in estimated fodder costs of just Rs 5 a day (or Rs 1,825 per year) would change the rate of return estimate for a cow with a true rate of return of 0% to a negative return of −91%. This is less of an issue with buffaloes, as their median value is substantially larger relative to annual fodder cost cash flows. Pooling the cow and buffalo samples together, we find a median return of 11% with a 95% confidence interval of −7.6% to 23%.

For buffaloes, the median return of +17% per month is slightly larger than the risk-free interest rates observed in India at the time of our survey, suggesting that a large proportion of buffaloes earn returns lower than those available in risk-free savings instruments.[25] Figure 1 presents a kernel density estimate of rates of return (excluding labor costs and valuing fodder at the feeding guide levels) for cows and buffaloes separately. The densities for both cows and buffaloes show a large fraction of animals earning negative returns.[26]

There are a few things worth noting about the median values of the revenue and cost variables individually in table 2. First, animals in the bottom two rate of return quintiles for cows and buffaloes have a median milk value of zero. The reason is that households report that more than 50% of the animals in this

[24] We estimate mean returns of −84% for cows and −34% for buffaloes, with 95% confidence intervals of [−123, −43] and [−48, −20], respectively. In both cases our 95% confidence intervals do not include positive returns. Given the sensitivity of these mean return estimates to outliers, however, the analysis in our tables focuses on median returns as well as providing information about the full distribution of returns.

[25] The annual interest rate paid to saving accounts by many formal banks in India ranges between 4% and 10%. As another point of comparison, the nominal yield on 10-year Indian government bonds in 2007–8 (the year of our survey) was 8.5% (Campbell, Ramadorai, and Ranish 2012).

[26] In the online appendix we present figures on heterogeneity in returns by education, wealth, and herd size of the owner. In app. fig. A3, we find no significant difference in the distribution of returns across high- and low-education cow owners. For buffalo owners, we find that the distribution of returns for high-education owners is shifted slightly higher than the returns of low-education owners. Figure A4 shows little heterogeneity in returns across high- and low-wealth owners. In fig. A5, we explore whether there are economies of scale in cattle ownership by testing whether households with more than one dairy animal have greater returns. For cows we find no difference in the distribution of returns across households with one dairy animal vs. those with more than one dairy animal. For buffaloes we find that households with one dairy animal appear to have higher returns than those with more than one dairy animal, suggesting, if anything, diseconomies of scale.

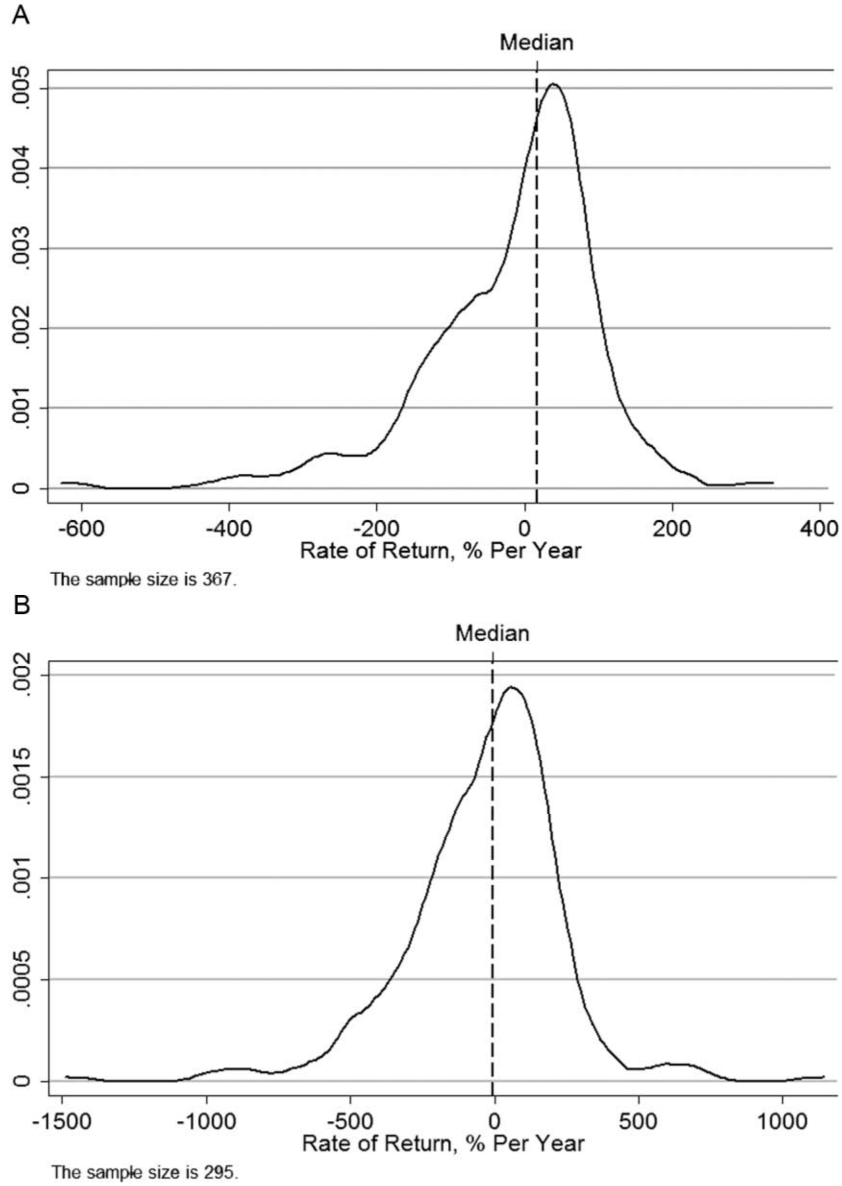

Figure 1. Distributions of rates of return, valuing labor at zero and fodder at feeding guide values

quintile had not yet given milk in their lifetime. These animals are primarily young adults (heifers) that households hold in the expectation that they will give milk in the future. As noted above, it is important to include these animals in the analysis as they are a quantitatively important part of dairy animal holdings among households in India; in our sample, 64% of cows and buffaloes have not given milk yet, and Basic Animal Husbandry Statistics (2006) reports that 65.4% of the adult female population was not "in-milk." While it is unclear what exactly the report means by in-milk (i.e., not in-milk at the time of the survey or breedable but not yet calved), the fact that these numbers are similar suggests to us that our sample is not unusual in having a large fraction of adult female animals not giving milk.[27]

Appendix figures A5 and A6 plot the returns distributions for animals below reproductive age (dry animals) and those above reproductive age (milking animals). Figure A5 values labor at zero, and figure A6 includes our estimated labor costs. Figure A5 reiterates the point that much of the negative return of the sample animals (assuming labor costs are zero) is driven by animals that did not give milk in the past year. If we believe the assumption that labor costs are zero, then the "puzzle" of low returns seems to be concentrated in these dry animals, and our results may be driven by measurement issues among this specific sample. In the absence of market failures, animals that have not given milk yet should not necessarily have negative returns because although they currently produce no revenue, they should appreciate in value over the year as they get closer to producing milk. Although we do include estimates of animal appreciation, one possibility is that our estimates of appreciation for these younger animals are biased downward because of an adverse selection problem in the market for cows (Anagol 2010). For example, households' own valuations of a cow may appreciate more than the market's value if it is difficult for a household to prove the quality of the cow on the market.

However, if we include our estimates of labor costs, figure A6 shows that even a large fraction of milking animals (50.5% and 39% of milking cows and buffaloes, respectively) earn negative returns. This result is important in the sense that it seems unlikely that households could hire labor and make strongly positive returns in cow investments, even if animals gave milk every year.

In appendix table A4 we present our estimated rates of return valuing fodder at the self-reported values in the survey (labor is still valued at zero). Using households' self-reported fodder costs, we find that the median return to cows is −238%, and the median return to buffaloes is −38% (95% confidence intervals of [−304, 194] and [−43, −23], respectively). The important thing to note in table A4 is that much of the variation in median rates of return across

[27] For example, it is theoretically possible that "in-milk" means milking at the time of the survey, and those animals not in-milk were in their dry phase and would provide milk soon. In this case our result of 36% of animals not having given milk would still be high relative to the national statistics. On the basis of our fieldwork we found adult animals that had not yet given birth as relatively common, but this is an area where improved measurement in future work would be helpful.

quintiles is being driven by variation in fodder costs. For example, the median fodder cost for cows in the bottom quintile is Rs 12,410 per year, whereas the median fodder cost for those in the top quintile is Rs 6,300 per year. One possibility is that households may be overestimating the value of home-produced inputs, in particular, fodder (which is the only quantitatively important input when we value labor at zero).[28] Given that between 60% and 70% of daily fodder costs (app. tables A1 and A2) are due to home-produced fodder, a small but systematic bias in the value of this home-produced fodder could have large effects on our estimated rates of return. For example, households may assume that their home-produced fodder is as good quality as the fodder that is traded in markets and therefore overestimate its value. Or households may not have experience selling home-produced fodder and therefore assume that there is a market for it when in reality it is difficult to sell. Given these concerns on the measurement of fodder costs, we conduct a simulation in which we estimate rates of return over a range of possible annual fodder costs. Figure 2 presents the results of this simulation. The *y*-axis plots the median rate of return across all animals in the sample if we assume that each animal has a fodder cost equal to the value on the *x*-axis (we reestimate rates of return across the sample for each fodder cost on the *x*-axis). The rates of return are plotted separately for cows and buffaloes. The larger negative slope for the cow rate of return line arises because cow rates of return are mechanically more sensitive to fodder costs since the capital value of cows is lower.

Note that the feeding guide fodder costs are substantially lower than the fodder costs reported by the households in our survey. This result is consistent with the idea that households may be overestimating the value of the home-produced fodder they feed their animals.

It is important to note that these low estimated rates of return are calculated before we include the cost of any labor spent on caring for animals or adjust for the fact that livestock investments are likely more risky than formal financial products (livestock can get sick or die or have problems getting pregnant). Taking these factors into account, the results presented so far make it seem unlikely that cows and buffaloes offer large positive returns on average.

Naturally, once we include labor costs, we find large and negative returns for both cows and buffaloes. Table 3 presents these rate of return calculations

[28] We are less concerned about households underestimating milk revenues for the following reasons. First, the main information necessary to estimate milk revenues is the number of liters the animal gives per day. Anecdotal evidence from our conversations at markets suggests that the number of liters an animal gives per day is the most salient statistic about the animal's productivity. Also, households milk their animals themselves and are likely to notice the amount of milk the animal produces.

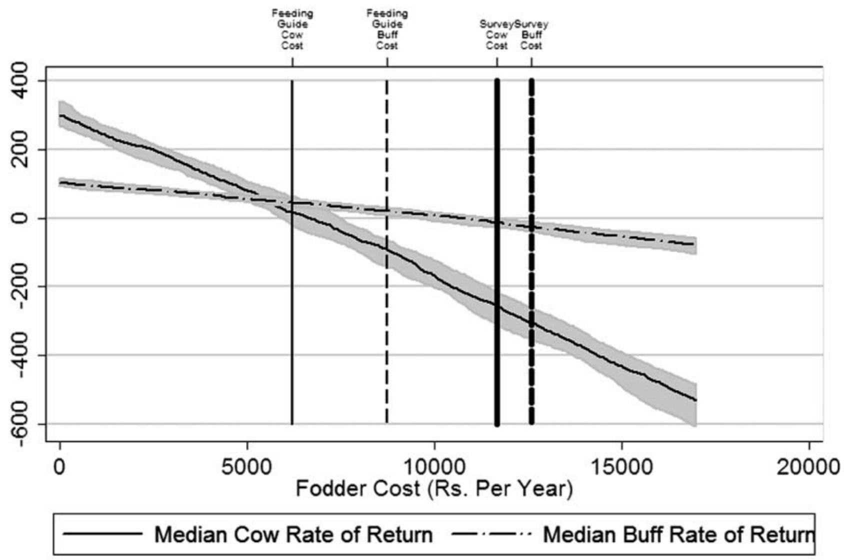

Figure 2. Rates of return and variation in fodder costs. Assumption: labor valued at zero. Figure shows how rates of return change with different values of fodder costs. Median rate of return in the sample given a per-animal annual fodder cost is on the *x*-axis (shaded regions are 95% confidence intervals). Thin solid vertical line is the cost of feeding a cow as recommended by the feeding guides. Thin dashed vertical line is the cost of feeding a buffalo as recommended by the feeding guides. Thick solid vertical line is the mean annual fodder cost for a cow in our survey data. Thick dashed vertical line is the mean annual fodder cost for a buffalo in our survey data.

in which we use our feeding guide fodder costs and include our estimated value of labor. For cows, we estimate a median rate of return of −293% (95% confidence interval [−329, −245]), and for buffaloes we find a median negative return of −65% (95% confidence interval [−79, −44]).

IV. Potential Explanations

A. Measurement Error

The first explanation of our finding is the simplest: our data or assumptions on production of cows are wrong and lead to systematic underestimates of the returns. We have attempted to deal with mismeasurement in fodder costs, which from appendix table A4 appeared to be the most noisily measured input or output in our data. We believe it is less likely that there would be a major measurement problem with the value of milk, as households milk their own animals and the number of liters an animal gives per day is anecdotally used as a summary statistic of an animal's quality. Nonetheless, it is possible that other variables are systematically mismeasured. Indeed, in Sri Lanka, de Mel et al. (2009b) find that firms systematically underreport revenues by about 30% and overreport costs. They conclude that simply asking firms how much profit

TABLE 3

DISTRIBUTION OF RATES OF RETURN, INCLUDING LABOR COSTS AND VALUING FODDER AT FEEDING GUIDE VALUES

Sample Frame	RoR in Bottom 20th Percentile	RoR in 20th–40th Percentile	RoR in 40th–60th Percentile	RoR in 60th–80th Percentile	RoR above 80th Percentile	Full Sample
			A. Cows			
Animal value	1,000	1,500	2,000	3,000	2,500	2,000
Median revenues:						
Milk	0	4,500	4,500	6,480	9,720	5,400
Calf	0	150	0	250	400	125
Dung	1,095	1,460	1,460	1,460	1,825	1,460
Total	1,095	5,895	6,013	8,643	11,580	7,030
Median costs:						
Fodder	5,652	6,850	6,850	6,850	6,850	6,850
Labor	7,300	7,300	3,650	5,475	3,650	5,475
Depreciation	−89	−46	−111	−68	13	−62
Insemination	0	68	102	136	136	68
Veterinary	0	80	0	100	100	50
Total	12,866	13,704	10,785	11,227	10,300	11,214
Median profit	−9,693	−8,121	−5,852	−3,868	1,377	−5,608
Median RoR	−973	−487	−269	−134	46	−268
			B. Buffaloes			
Animal value	3,000	7,000	10,000	12,000	10,000	8,000
Median revenues:						
Milk	0	0	7,560	10,800	14,040	8,100
Calf	0	0	225	450	500	50
Dung	1,460	1,460	1,825	1,825	1,825	1,825
Total	1,460	1,825	10,093	13,605	16,955	10,690
Median costs:						
Fodder	7,738	7,738	9,078	9,078	9,078	9,078
Labor	7,300	7,300	7,300	7,300	3,650	7,300
Depreciation	−653	−1,089	−423	−469	−441	−625
Insemination	0	0	136	136	136	68
Veterinary	0	0	50	100	100	50
Total	13,949	13,261	16,046	15,154	13,188	14,337
Median profit	−10,964	−9,281	−6,183	−802	2,998	−5,704
Median RoR	−321	−126	−65	−10	31	−65

Note. Median values of all input, output, and rate of return variables for cows and buffaloes. Data are first sorted on the basis of the estimated rate of return for the animal, and then within each quintile we present the median value of the variable as indicated in the row headings. Sample sizes of cows and buffaloes are 295 and 367, respectively.

they make provides a more accurate measure of profits than detailed questions on revenues and expenses.

Previous work in labor economics has found that workers in formal employment settings typically do overstate the number of hours worked (Stafford and Duncan 1977; Carstensen and Woltman 1979; Mellow and Sider 1983; Duncan and Hill 1985; Hamermesh 1990; Bound et al. 1994; Robinson and Bostrom 1994). Nonetheless, the fact that we find low median returns, even when we assume that labor costs are zero, suggests that overstating the amount of time spent on dairying is not the sole driver for our low estimated returns.

B. *Preference for Home-Produced Milk*

In a book aimed at British expatriates living in India entitled *Cow-Keeping in India* (1900), author Isa Tweed states, "The first advantage derived from keeping one's own cows is, you get pure milk. Pure milk is very essential to health. . . . If people do not think of their own health, . . . they should at least have some thought for the health of their families and friends, who may not be quite so anxious to suffer and die" (19).

Anecdotal evidence suggests that modern Indian households also believe, and perhaps rightly so, that home-produced milk is of higher quality than purchased milk. Reuters (2012) recently reported that much of the country's milk is either diluted or contaminated with chemicals, including bleach, fertilizer, or detergents. A government survey also found that 68.4% of milk sold in India does not meet basic health standards (Food Safety and Standards Authority of India 2011). This implies that households may value home-produced milk at a rate higher than the market value and therefore may be willing to receive low financial returns on dairy investments in exchange for the guarantee of having high-quality milk available for household consumption. Consistent with this hypothesis, we find that only 12% of our sample households actually sold milk in the past year.[29] This is also consistent with arguments about information asymmetries in the milk market in Ethiopia, in which children in households with cows (after controlling for wealth) consume more milk and have less stunting (Hoddinott, Headey, and Dereje 2014); similarly, earlier work argued that dairy cooperatives help mitigate information asymmetries in milk markets (Staal, Delgado, and Nicholson 1997).

Figure 3 presents a simulation of the median rates of return earned on cows and buffaloes if households valued a liter of home-produced milk more than their reported prices. Our survey question asked households for the average price of a liter of milk produced by their household. If there is an adverse selection problem in the milk market (say due to unobservable mixing of water with milk), then the prices our households report might be lower than the value of pure home-produced milk. Note that the average price of milk for cows and buffaloes is Rs 11.2 and Rs 11.7 per liter, respectively (table 1). The *x*-axis of figure 3 is a range of possible valuations for a liter of home-produced milk. We

[29] There are other potential explanations for why so few households sell milk. Another plausible explanation is that there is limited external demand for the milk produced in our sample villages; only 23% of our sample villages are visited by milk buyers, and only 8% have a milk cooperative.

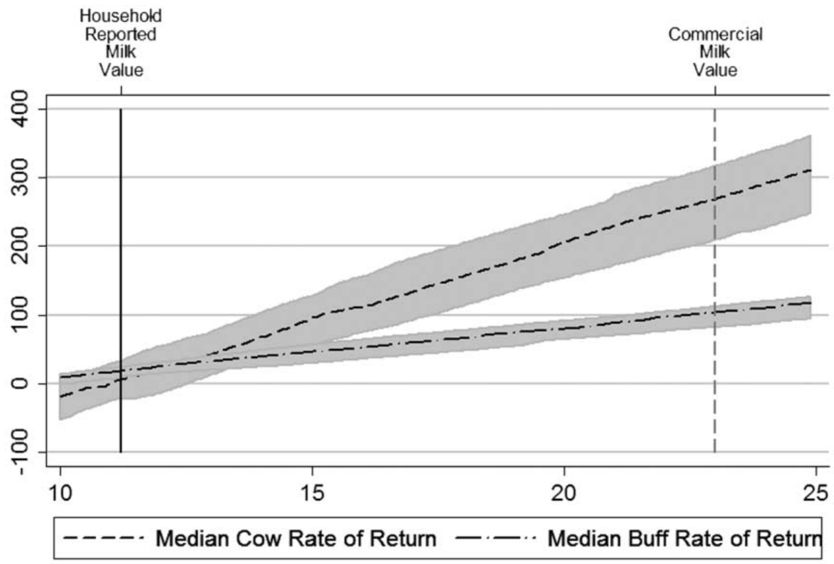

Figure 3. Rates of return and the value of home-produced milk. Assumptions: Labor valued at zero and fodder valued at feeding guide values. Figure shows how rates of return change with a household's valuations of home-produced milk. The *x*-axis plots possible values of home-produced milk. For each possible value on the *x*-axis we reestimate the median rate of return in the cows and buffaloes sample assuming labor is valued at zero and fodder at the the feeding guide values. These median rates of return are plotted on the *y*-axis (shaded regions are 95% confidence intervals). For reference, the solid vertical line is the mean self-reported price of milk produced by the house in the sample (answer to the survey question "What is the average price of [home-produced] milk per liter?"), and the dashed vertical line is the value of a liter of full-cream milk produced by India's largest commercial milk producer (Mother Dairy).

recalculate rates of return on each animal in our sample based on all of the possible values of the *x*-axis and then plot the median rate of return on the *y*-axis. The rates of return in this figure are calculated using the feeding guide fodder costs and assuming the value of household labor is zero.

In general, the figure shows that our return estimates are quite sensitive to the price of milk (i.e., if cow and buffalo milk was valued at Rs 15 per liter instead of Rs 11, returns increase to approximately 100% and 60% per year, respectively). The figure also shows that if households valued home-produced milk more than the price they reported in the survey (perhaps because they reported the price they could sell the milk for but not the value to the household as pure milk), then median rates of return may be substantially higher. It is interesting to note that the price per liter of full-cream milk produced by India's largest commercial milk producer (Mother Dairy) was Rs 23 per liter at the time of the survey, suggesting it is possible that the value of trusted quality milk is higher than the prices reported by our households. Estimating household preferences for home-produced versus market milk and testing for adverse selection in the milk market are interesting areas for future research.

A related explanation is that our estimates of price appreciation with age are downwardly biased because households report prices at which they could sell their cows, as opposed to how much they value their own cows. If households have private information about the quality of their cow's future milking potential, then it is plausible that the true price appreciation households experience is greater than the price appreciation as measured by prices that cows can be sold for. This bias is likely to be largest for cows that have not yet given milk, as once a cow has started milking, it is easier to prove its quality on the market. If price appreciation for young animals is in reality larger because of this adverse selection problem, then cows that have not yet given milk may have higher returns, and overall returns may not be as negative.[30] This explanation is potentially important in light of the fact that much of the negative returns when we exclude labor costs are concentrated in animals that have not yet given milk (figs. A5 and A6).

C. *Buffer Stock Savings and Preference for Illiquid Savings*

In developing countries, low-income individuals and small businesses are generally excluded from conventional financial institutions (Rutherford 2000). De Mel, McKenzie, and Woodruff (2009a) document that few poor households have formal savings accounts. However, as Rutherford (2000) emphasizes, low-income households do typically have some savings. This has led to the proliferation of a variety of forms of semiformal or informal savings channels, including deposit collectors, savings clubs, postal accounts, accumulating savings and credit associations (ASCAs), rotating savings and credit associations (ROSCAs), or saving at home.[31] These savings channels may help to meet the needs of the poor by offering convenient services in their neighbor-

[30] A related possibility is that households in our sample are in the process of increasing their herds, and so there are a disproportionate number of young cows that have low measured returns. While we do not have any reason to believe that cows in this sample are particularly young (e.g., there were no major asset transfer programs at this time), nationally representative data on the age distribution of cows and buffaloes are unavailable for us to verify this. Appendix fig. A4 now shows the age distribution of milking and nonmilking buffaloes and cows, respectively. Milking buffaloes and cows have ages centered around approximately 5 years and do not seem to have a preponderance of very young animals. Animals that were dry in the past year have an average age of approximately 3 years and also do not appear to have a preponderance of young animals.

[31] In West Africa, *susu* (deposit) collectors are paid up to 40% interest for providing a means of saving for rural households (Rutherford 2000).

hoods (as in the case of deposit collectors), allowing them access to loans (ASCAs and ROSCAs), and providing them with incentives to save (in the form of the social pressure present in savings clubs, ROSCAs, and ASCAs).

However, there are also disadvantages associated with these types of informal savings. The use of deposit collectors entails a negative interest rate. Interpersonal conflict or lack of trust may inhibit the creation of savings clubs, ROSCAs, and ASCAs, and keeping money in the home offers no shield against inflation and may lead to temptation spending. In the face of these shortcomings, households may find it desirable to save a portion of their income close to home in illiquid assets such as livestock, even if the returns to this means of saving are low, or even negative. This is consistent, for example, with the buffer stock motivation for owning bullocks, put forward in Rosenzweig and Wolpin (1993).

Evidence from Burkina Faso, however, does not support the buffer stock explanation, as even in droughts households were not likely to sell their cattle, but rather suffered extreme reductions in consumption rather than reduction in assets. This also implies a potentially very high return to owning cattle during droughts (Fafchamps, Udry, and Czukas 1998; Kazianga and Udry 2006).

D. Labor Market Failures: True Value of Marginal Time Is Zero

If labor markets are missing or imperfect, particularly for women, then the true opportunity cost of labor may actually be zero or close to zero (Bardhan 1984; Dasgupta 1993; Basu 1997; Mammen and Paxson 2000).[32] In many locations, the formal labor market for women is essentially nonexistent (Emran and Stiglitz 2006). Mammen and Paxson (2000) note that "there may be costs associated with women working outside of the domain of the family farm or nonfarm family enterprise. Custom and social norms may also limit the ability of women to accept paid employment, especially in manual jobs. Further, off-farm jobs may be less compatible with child rearing, creating fixed costs of working off-farm" (143). This implies that the household optimization treats the female labor endowment as effectively nontraded. One would expect that as the costs of women's time increases as they enter the workforce, the opportunity cost of tending a cow would also rise. However, if there are no opportunities for people to enter the workforce, then the opportunity cost of raising an animal is effectively zero, or at best the value of other home production opportunities.[33]

[32] For about half the households analyzed, women are responsible for tending the animals.

[33] This is based on the traditional assumption made in the literature that the value of an individual's time spent in any activity is equal to his or her wage rate.

E. Time-Varying Returns

We observe returns at a single point in time; if there is significant time-series variation in the returns to dairy animals, then it is possible that our low returns are due to an unusually poor year for cow and buffalo ownership. Attanasio and Augsburg (2014), in response to a working paper version of this article, find evidence supporting this explanation: cows and buffaloes in the Anantapur district in the Indian state of Andhra Pradesh have low returns (similar to ours) in two out of their three survey years (2009 and 2012) but positive returns in the good rainfall year 2008.

In our setting, the total rainfall in 2007 in our two survey districts Sitapur and Lakhimpur Kheri was 984.4 and 1,022.9 millimeters, respectively.[34] These 2007 values are quite close to the long-run average rainfall values of 943 and 1,056 millimeters in our two study districts.[35] In particular, the difference between the 2007 value and the long-run average value is 0.2 standard deviations for Sitapur and −0.14 standard deviations for Kheri. Appendix figure A6 plots the distribution of annual rainfall over the period 1901–2002 and shows that the 2007 rainfall values are close to the center of the distribution. These results suggest that our finding of negative returns is unlikely because of extreme rainfall in our particular survey year. Nonetheless, it is possible that the average returns to cows over a longer time period might be higher or lower than the returns calculated over a small number of years, and future work should attempt to estimate returns over longer periods.

F. Preference for Positive Skewness in Returns

Garrett and Sobel (1999) document theoretical and empirical evidence that positive skewness of prize distributions explains why risk-averse individuals may play the lottery. Similarly, skewness of returns distributions may explain why people may hold female cows and buffaloes, given that there is a small probability of making huge profits, although on average the animals yield negative economic returns. Our estimates provide evidence for positive skewness in returns. For example, table 2 shows that the top 20% of cows and buffaloes generate 220% and 96% median returns, respectively. At the same time, the

[34] These district-level annual rainfall estimates were downloaded from http://www.indiawaterportal.org/articles/district-wise-monthly-rainfall-data-2004-2010-list-raingauge-stations-india-meteorological. The source of these data is the India Meteorological Department. For the Kheri district, the annual total excludes November and December because these are not available in the data. These months typically have very low rainfall, and including average values for them does not change the results meaningfully.

[35] Annual total rainfall values for 1901–2002 for Sitapur and Kheri districts were downloaded from http://www.indiawaterportal.org/met_data/. The source of these data is the India Meteorological Department.

bottom 60% of cows and 40% of buffaloes make substantial median losses. This is consistent with the model of learning and types of enterprise presented in Karlan, Knight, and Udry (2012), which predicts that a majority of entrepreneurs will have low marginal returns to capital as they are not capable of running a larger business, but that a small proportion of entrepreneurs may have the skills to run large firms profitably.

G. Religious and Social Status Value

Hinduism may explain the results for cows, but not the results for buffaloes. In Hinduism, the cow is a symbol of wealth, strength, abundance, selfless giving, and a full earthly life.[36] As almost all the sampled households reported that they were Hindu, they may also derive spiritual returns from cattle ownership. The forgone returns compared to their next-best investment alternative would effectively be the cost of religiosity in this context. It also requires believing that the long-term social evolution of a religion could find an equilibrium in which individuals worship a loss-inducing investment; most economic models of religion predict that customs derived from religion either are beneficial or strengthen the group, and this seems to do neither (Bainbridge and Iannaccone 2010).

Cows (and buffalos) may provide social prestige. Ferguson (1994), albeit concerning Lesotho, argues that cattle are valuable because ownership of them (and the ability to lend them out) builds the social standing of the lender. Anecdotal evidence in the Indian context is that lending milk cows and buffaloes is rare, but it is possible that cows and buffaloes confer social status in other ways that we are not capturing. Again, similarly to the argument made with respect to religion, this would imply that the social evolutionary process has resulted in an equilibrium in which one gains social status from taking on unprofitable investments.

H. Female Preference for Saving in Cows and Intrahousehold Conflict

Ferguson (1994) also argues that men of the Basotho group in Lesotho, who typically work in South African mines, choose to save in cattle back in Lesotho because cattle are viewed as male property; women do not have the right to sell cattle, although they do have the right to spend cash saved at home.[37] This

[36] For a general review of the debate on why cows evolved to become holy in Hinduism, see Korom (2000).

[37] Ferguson (1994) also discusses how in Lesotho, cattle hold special value as gifts for bride-prices. In our context, this seems to be less important, as only 7.7% of cows and buffaloes in our data were acquired as gifts, 36% of cows and buffaloes are born into households, and 57% are purchased by the household.

creates an incentive for men in Lesotho to save in cattle, even if they earn a negative economic return. In our context women might have greater property rights over cows because they maintain the cows, and thus cows serve as a way for women to save that is less accessible by men. Such an explanation would be consistent with prior work that finds that women use inefficient savings vehicles as a way to protect income from men. For example, Anderson and Baland (2002) explain ROSCAs in Kenya as a method for women to shield savings from men, and Schaner (2015) shows in a field experiment in rural Kenya that a woman who has a higher discount rate than her husband is more likely to use a costly individual savings account as a way to protect her savings.

I. Correlational Evidence on Explanations

In this section we provide some correlational evidence on the plausibility of the variety of explanations we discussed above. The basic insight underlying our analysis is that if cows provide some indirect monetary benefits that we do not measure, then we should see that households that value those indirect monetary benefits less should have, on average, higher measured returns. For example, if households attach substantial value to cows as illiquid savings devices, then we should observe that households with greater access to illiquid savings devices should, on average, earn higher measured returns to cows; the reason is that, on the margin, households with alternative access to illiquid savings accounts will have a higher threshold return for owning cows because they do not value the illiquid savings benefits of cows.[38]

Table 4 presents our correlational evidence. The sample comprises all cows and buffaloes in our study. In column 1, the dependent variable is an indicator variable for whether the cow or buffalo produced a positive return in our sample, based on the return measure used in table 2 (labor valued at zero and the feeding guide values for fodder costs). Column 2 is the same specification with the continuous return variable as the dependent variable; the results are similar but substantially more noisy (we suspect the reason is measurement error in our continuous measure of returns).

In column 1, we find a positive and significant correlation between the number of adult males in the household and our positive return indicator variable, with each additional adult male correlated with a 4.1 percentage point increase in the probability of a positive return animal. We also find a negative but not statistically significant correlation between the number of adult females in the household and the household's returns; the adult male and female coefficients

[38] Appendix sec. 2 presents the simple conceptual framework that underlies our regression analysis.

TABLE 4
CORRELATIONAL EVIDENCE ON EXPLANATIONS

	Dependent Variable	
	Indicator (Estimated Return > 0) (1)	Estimated Return (2)
Number of children ≤ 12	.0024	1.98
	(.010)	(2.54)
Number of adult females	−.043	−8.98
	(.028)	(6.86)
Number adult males	.041*	7.61
	(.021)	(5.04)
Hindu	−.26	6.98
	(.38)	(92.6)
Hindu × cow	.092	−5.14
	(.20)	(48.2)
Owner has some primary or middle school	.083*	3.34
	(.050)	(12.1)
Owner has some high school or more	.090**	17.0*
	(.041)	(9.91)
Mean distance to banks (km)	.00016	.050
	(.00083)	(.20)
Distance to closest bank (km)	−.0023	−.68
	(.0027)	(.66)
Cow	−.068	9.66
	(.20)	(47.2)
ln(wealth)	.026	7.78*
	(.018)	(4.42)
Animal age	.27***	59.6***
	(.027)	(6.46)
Animal's age squared	−.014***	−3.04***
	(.0022)	(.53)
Mean dependent variable	.52	−18.5

Note. Sample is all cows and buffaloes. Dependent variables are defined on the basis of our return measure valuing labor at zero and fodder at feeding guide values. Excluded education category is an indicator for owners who have no formal education. Standard errors are in parentheses. $N = 543$.
* Significant at the .1 level.
** Significant at the .05 level.
*** Significant at the .01 level.

are significantly different (p-value = .06). One possible interpretation is that, relative to adult men, adult women provide low-cost labor to care for cows (the labor market failure explanation), and so on the margin, lower-return animals can be reared by households with more adult women. Another possibility is that adult men invest more in cows relative to adult women. Overall, these results suggest that understanding household dynamics and labor supply within the household may provide insights into the overall puzzle.

We hypothesize that if Hindus own cows for spiritual reasons, then on the margin they should earn lower financial returns on these investments. However, we do not find a statistically significant relationship between the household being Hindu and negative returns, for either buffaloes or cows (the Hindu and Hindu × cow variables). However, it is important to note that 95% confidence intervals on these variables include large correlations (there are only 67 non-Hindu-owned cows and buffaloes in the sample), so this is not a precisely estimated null result.

We find a positive and statistically significant correlation between households with heads with higher levels of education and our indicator for positive returns. The excluded category is an indicator for households in which the household head has no formal education. Relative to households with no formal education, household heads with some primary or middle school have an 8.3 percentage point larger probability of having an animal with positive returns. There does not appear to be an additional benefit in households in which the head has a high school education or more, as the point estimates on this indicator variable are 9.0 percentage points.

One prediction of the buffer stock savings explanation is that households with greater access to illiquid savings products should have higher returns because they do not need to hold low-return cows as illiquid savings devices. The best measure we have of financial access comes from our village survey, which included questions on the distance to banks. As a rough test of this idea, we include measures of the average distance to the closest agricultural, government, or private-sector bank, as well as the minimum distance to the closest bank. The coefficients on these variables are small and not statistically significantly different from zero.

As control variables we include an indicator whether the animal is a cow (instead of a buffalo), the log of household wealth, and the animal's age and age squared. We find that log household wealth is statistically significant in column 2. We also find that returns are increasing with age at a decreasing rate, which is consistent with the fact that animals are more likely to give larger quantities of milk as they get older.

The purpose of our regression analysis is not to provide causal evidence in favor of any of these particular explanations, but instead to just shed some light on how some of these explanations might be tested in future work in which exogenous variation in some of these factors is available. This regression analysis also does not present any tests of two of the candidate explanations we discuss primarily because of data limitations.[39] To test the preference for skewness hypothesis, we would need an independent measure of the household's risk

[39] Naturally we do not have a regression test for the possibility that our results are due to measurement error.

preferences (perhaps from hypothetical or real choices in gambles); our survey did not ask any questions that would allow us to derive a preference parameter for skewness. Testing the idea that returns are time varying requires data on the returns earned on the same cow over time, which our data do not include.

V. Further Research Questions and Policy Implications

Our goal here is not to determine conclusively why Indian households invest in cows and buffaloes despite the fact that economic returns to such investments seem to be frequently negative. Our goal, rather, is to put forward a puzzle, with the aim to motivate either better data, or better understanding of these markets or behavioral decisions, in order to explain the puzzle. With a better understanding of the driving market or behavioral failures, if any, one can then focus policies on specific market problems.

Evidence suggests that the poor are often willing to earn negative interest in order to access reliable saving services (see Dupas and Robinson [2013] for evidence on savings accounts with negative interest rates in Kenya and Rutherford [2000] for deposit collectors in West Africa). If livestock ownership is seen as a form of savings, the observed negative returns to cows and buffaloes provide additional evidence of the high demand for savings, and perhaps specifically for illiquid savings in order to avoid temptation spending. The question then turns to the supply side of savings: what are the constraints on the supply side that make cows and buffaloes better savings alternatives than what banks offer? With technological innovations such as mobile money, the transaction costs are plummeting for offering deposit accounts to consumers in developing countries, even in highly rural areas. Thus this is an area in which improvements in ability to store cash outside of the home may lead to more efficient allocation of capital, away from risky or low-return home investments. If the introduction of high-quality savings accounts leads to a reduction in cow and buffalo ownership, this would be evidence for the commitment to save explanations discussed above.

If indeed, as we find, owning cows yields low or negative returns, this is of critical importance for NGO and government programs that promote investment in cows with an aim of poverty alleviation. In particular, the results here are critical for programs that engage in livestock grants to help households start or expand income-generating activity from raising livestock (this is common among "graduation" programs, cited earlier, as well as many NGOs, such as Heifer International or other livestock grant programs). Our results suggest that merely transferring an asset alone may not be sufficient to generate higher income (beyond the value of the transferred asset). The heterogeneity in returns we observe may of course be due to heterogeneity in skills and knowledge on how to raise dairy animals profitably; this suggests the potential for training and monitoring to improve the returns for households. On the other hand, Ferguson (1994) argues that World Bank programs that attempted to formalize cattle rearing among the Basotho people in Lesotho failed because the Basotho primarily used cattle as a savings device and were not interested in upgrading their herds or reducing common grazing to improve productivity. Understanding why households choose to hold cattle at present is important for determining whether training and upgrading programs are likely to work.

Our results are also consistent with the finding in de Mel et al. (2009a) that female-owned enterprises in Sri Lanka have a marginal return to capital equal to zero. Fafchamps et al. (2014) also find that the returns to capital are equal to zero for female enterprises with less than the median level of profits prior to the capital infusion. Given that in our context the maintenance of dairy animals is managed by the women and children of the household, a similar mechanism or failure may drive the results in both our analysis and the above two papers.

Looking beyond cattle ownership, future research should analyze the returns from other assets, such as trees, tubers, and small livestock (Undurragaa et al. 2013). Anecdotal evidence suggests that a variety of low-performing assets are commonly held across the developing world, but more systematic analysis across countries and asset types, and with a focus on unpacking the mechanisms driving ownership and returns of such assets, would further our understanding of household finance for the poor.

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