Small and profitable. Quantifying returns to cattle value in rural Uganda.

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Abstract

A recent debate in the economic literature has questioned whether rearing cattle in developing countries is a profitable activity or not. By relying on a unique household panel dataset collected in 2015 and 2016 in rural Uganda, this paper explores the relationship between rates of return to cattle rearing, herd size and cattle value. I find positive annual median returns of +48% and marginal returns of +14%, but with one third of the sample still earning negative returns. I further explore the marginal returns of investing one additional dollar in cattle value by using an instrumental variable approach and show that marginal returns increase by investing in higher value animals. Yet, only farmers with low value cattle benefit from these positive marginal returns, while the effect is insignificant for those with already high value cattle, suggesting decreasing returns to cattle value.

Keywords: cattle, profits, Sub-Saharan Africa.
JEL codes: O12, Q12

Introduction

Rearing cattle is a common activity among farmers in developing countries. It represents a source of food and income, it can serve as draught power and provide manure for crops cultivation. The importance of keeping cattle is strongly advocated by poverty-reduction policies and programs which consider asset accumulation, typically in the form of livestock, as a way to reduce income variability.

Yet, recent empirical evidence on the profitability of cattle rearing has revealed a puzzling result of negative returns from raising cows and buffaloes in India (Anagol et al., 2014). Even if returns may vary a lot from dry to rainy years, being positive in rainy years and negative in dry years (Attanasio and Augsburg (2014), Gehrke and Grimm (2014)), several analysis have shown in the Indian context that the losses incurred in a bad year outweigh the gains obtained in a good year, leaving the puzzle unsolved.

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By using a unique household panel dataset on dairy farmers collected in two waves in 2015 and 2016 in rural Uganda, this paper makes an innovative contribution to the current literature. I, first, document the existence of positive median and marginal returns to cattle and, second, quantify marginal returns to cattle value with non-parametric and parametric estimates. Thanks to the large and balanced panel data, I estimate marginal returns while controlling for time-invariant effects at the household level. In addition, to solve the omitted variable bias associated with cattle value I use an instrumental variable approach. The main sets of results shows positive marginal returns associated with one more dollar invested in cattle value for the whole sample and, in particular, for farmers with low value animals.

The existence of positive annual median and marginal returns to cattle masks, however, important heterogeneities across farmers. While on average annual marginal returns are positive (+14%), there is still one third of the sample earning negative returns. Non-parametric and parametric estimates reveal that, while median returns increase with cattle value, there is a non-linear relationship between marginal returns and cattle value, with small farmers benefiting from the largest gains.

Moreover, building on the agricultural economics literature documenting returns to land decreasing with land size (Finan et al., 2005), I explore in a descriptive non-parametric way how returns vary along the herd size distribution. Also in this case results illustrate a relevant heterogeneity in profitability linked to herd size. Larger herds are associated with lower median profits, whereas there is an inverted-U shape relationship between profits per animal and herd size.

This study enriches the current literature by quantifying the marginal profitability of cattle associated with an increase in cattle's value, by using an instrumental variable approach. This is a main improvement compared to Anagol et al. (2014) and Attanasio and Augsburg (2014) who conduct only a descriptive analysis about total and per animal returns. This work differentiates also from Gehrke and Grimm (2014), who estimates marginal returns to cattle value using the introduction of the National Rural Employment Gurantee Act program (NREGA) in India at the district level and the amount spent at the sub-district level as instrumental variables for households' investment in cattle. Yet, the NREGA program has likely affected, among other things, the cost-opportunity of labour, which is a main input in cattle rearing, impacting returns to cattle not only through cattle value, casting doubts about the respect of the exclusion restriction assumption.

This paper uses a dummy for the gender of calves born between the two data collection rounds as an exogenous variation in calves and cattle's value.[1] In the Ugandan context, having a female calf is a positive productivity shock as the animal, once pregnant, will become a milking cow, providing a major and fairly constant source of income. A male calf, in turn, provides income only if the bull is used for breeding, a very rare event in our sample, as in this local context animals are not slaughtered for consumption and beef is not part of the common diet.

[1] Note that by cattle value I do not mean the initial price at which the animal was bought, but the current price the farmer would obtain if she were to sell it. In this way, the value of an animal is a proxy for its productivity at the moment of the survey.

Results from the 2SLS estimates show that one additional dollar spent on a single calf value increases marginal profits by \$1.2, marginal returns to calves by 10 percentage points and marginal returns to cattle by 0.3ppts. In particular, farmers owning animals of low value, below the 25th percentile of the cattle's value distribution, are the ones benefiting the most from a marginal increase in their calves value. One additional dollar increases profits by \$2.05 and calves' rates of return by 20.8ppts. In turn, the results are not statistically significant for farmers owning higher value animals, suggesting decreasing returns to cattle value.

These results represent an innovative contribution to the study of marginal returns to cattle, informing about the gains obtained from investing one additional dollar in animals' value. While measuring median returns simply illustrates whether rearing a certain number of animals is an overall profitable activity, quantifying marginal returns is particularly useful for farmers willing to further invest in the quality of their cattle in order to increase their annual returns.

Quantifying marginal returns to cattle and exploring their heterogeneity is a policy relevant matter, as several anti-poverty interventions distribute free cattle to poor households in developing countries. Yet, receiving a free animal represents a considerable income and asset shock, the returns to which can be very heterogeneous and dependent on initial conditions. The heterogeneity of returns is, however, somehow neglected by those asset transfer programs promoted by governments and NGOs that assume the transfer of milking cows to poor households a (good) way for improving nutrition and food security, while also relaxing their capital constraint, at least for the average beneficiary. And, so far, it has not been analysed in the economics literature neither. Quite interestingly, though, Bandiera et al. (2013) show that the effect of transferring animals to households not having any yet is more than ten times larger than for those at the bottom, probably because, as shown by Banerjee et al. (2011), the cost of maintaining livestock exceeds the regular income flows from these animals. It is only irregular sources of income (selling the animal itself or by-products, such as the animal's skin or calves born from the donated animal) that explain the increase in income from livestock activities found in their work.

It should not be taken for granted, indeed, that the poorest or smallest farmers would be the ones benefiting the most from this type of programs, as cattle rearing is expensive. For instance, evidence from the Rwandan "One cow per poor household" program suggests that the poorest beneficiaries are not able to provide enough fodder to feed the cow received and it is only the wealthiest farmers (among the eligible ones) who can afford the costs of rearing the animal (Klapwijk et al., 2014).[2] Similarly, Dercon (1998) shows that poor households may find it harder not only to invest in cattle rearing but to stay in the activity due to credit constraint and the need to smooth consumption. Program beneficiaries are likely, hence, to self-select into the decision of keeping the animal or selling it (Morduch et al., 2012).[3] Households may put

[2] Nonetheless, preliminary evidence documents an average positive effect of the program on food diversity and a decrease in the number of stunted children (Rawlins et al., 2014).

[3] Argent et al. (2014) show that those households that have managed to keep the cow received from the Rwandan "One cow per poor household" program for six years and that in addition have been trained in cattle rearing are still 56% more likely to be producing milk and experience a sixfold increase in their reported earnings from selling milk as compared to those benefiting only form the asset transfer. This might suggest that, for those ones not dropping out of the program, coupling asset transfers together with training might indeed assure a more long-term productive activity.

in place important substitution effects in reaction to receiving livestock, the loss from switching away from agricultural wage labour towards cattle rearing completely offsetting the gains from participating in the program.

Still, the existence of heterogeneous returns does not explain the puzzling result of negative returns to cattle, even if they concern only part of the distribution. One criticism could be that we are measuring profits in the wrong way, making important assumptions concerning the value of household labour, the prices of inputs, either not observable or imperfectly measured, and unobservable shocks affecting animals productivity. In addition, given that herd size and value, costs and outputs are all self-reported, measurement errors may be a serious concern. They may be correlated with herd size, as small farmers may consistently over-report their costs while large farmers may consistently over-report their revenues, or herd value, as small farmers may value much more their few animals than large farmers do. Even herd size and value may be measured with errors, the error increasing in the number of animals, being it potentially harder for farmers to recall the exact number of animals or their actual productivity the larger the herds are. While I will show that measurement errors with respect to revenues do not seem to be a concern, I am not able to completely rule out the existence of a measurement error bias with respect to herd size. I am, in turn, able to solve the potential bias associated with herd value by using an instrumental variable approach. The results on herd size are, hence, mainly descriptive, whereas the ones on herd value can be considered as causal.

In conclusion, this study makes three main contributions. First, it enriches the current debate on the profitability of cattle rearing by documenting the existence of positive annual median and marginal rates of return in the Ugandan context, in contrast to the negative returns found in the Indian context. Second, these results contribute to the agricultural economics literature, illustrating an inverse non-linear relationship between profits per animal and herd size, similar to the one found for landholdings. Third, this paper estimates marginal returns to cattle by addressing the endogeneity of cattle value with an innovative instrumental variable, the calf's gender, providing a causal interpretation of the effect of an increase in cattle's value on marginal returns.

The rest of the paper is organised as follows. Section 1 describes the data in detail and reports descriptive statistics about dairy profits and Rates of Return. Section 2 illustrates the empirical strategy used, in terms of non-parametric, parametric and IV estimates. Section 3 provides the main results. In the last section I draw the main conclusions.

1 Data and descriptive statistics

The data source is a household panel data collected in two rounds in 2015 and 2016 for a large-scale Randomised Control Trial implemented in rural Uganda, in the districts of Kamuli and Buyende in the Near-East region, that is one of the operation areas of the East Africa Dairy Development project, which aims to boost dairy productivity in Uganda.[4] For this study, we

[4] More information about the program can be found at http://www.heifer.org/eadd/index.html.

have sampled and interviewed five farmers in each of the 632 villages considered (see Appendix 1 for details about the sampling procedure). Out of an initial sample of 3122 farmers, I select those that at the moment of the first survey, or during the previous 12 months, had at least one head of cattle and that are present in both waves. The final sample consists of 2988 farmers.

This area is part of a much wider agro-pastoralist zone called "Cattle corridor", which runs from North-East Ethiopia through Kenya and down to South-Western Uganda. Farmers are cattle keepers and crop growers, but there is a variety of farming systems. Some, called "extensive systems", are characterised by large herds and vast grazing fairly arid areas. Cattle keeping is the main household activity, often passing over from one generation to the other. Others, called "intensive systems", are dominated by farmers with small herds, having an almost zero grazing pasture system, and engaging also in agricultural activities on rather small plots of land.

Yet, others are a hybrid between these two systems. The context of the present study is denoted as "semi-intensive". Herd size is medium-small, common grazing land is available to farmers and agricultural activity is widespread. On average, farmers own 6.5 heads of cattle, out of which one third is made of cows, the rest being mostly calves and heifers (Table 1). In the first data round, about 40% of farmers own a bull, while oxen are more rare (17%). The data do not provide detailed information on the use of each type of animal, but, interestingly, controlled mating using bulls is still fairly rare (8.8%). Even though few farmers own oxen, they appear to have the highest self-reported value of all cattle (265$), which might indicate their use in agricultural production as draught power. The animals owned by farmers are mostly naturally born (63%) or bought on local markets (45.6%), where only indigenous animals are usually sold, while artificial insemination and cross-breeding are extremely rare (0.4%). Animals are rarely sold, only one third of farmers report selling animals in the past 12 months, being mainly indigenous cows and calves.

While consumption of home-produced milk is the norm (on average farmers keep 3 litres per day for home consumption), market-oriented production is still fairly new in part because milk markets were lacking till few years ago. Indeed, even though 79% of the sampled farmers in the first round have produced some milk in the previous 12 months, only 52.7% have sold it and the majority declare to sell it to neighbours and friends (45%). Even though markets for milk are slowly becoming more widespread, only 38%, among those selling their milk, sell it on local markets to a private trader or consumer and 11% sell it to a fellow farmer who often acts as intermediary agent. One of the reasons for informal transactions being so common is the considerable price fluctuation from the wet to the dry season, making the transition cost of selling it on the market not affordable for many farmers.

In contrast to the "extensive systems", where herds are passed over from one generation to the other and used as bride price, in the present context households are used to keep cattle, but it is not a matter of family tradition. Focus groups discussions with farmers often indicated a fairly dynamic process, with farmers entering or expanding their activity according to perceived market opportunities. Cattle rearing is, indeed, not the only household productive activity, as in the first-round 73% were also crop-growers and 57.4% of sampled households had at least one member working off-farm, in 90% of cases being the household head. Sampled farmers have a longer experience with indigenous animals (14 years on average), but a shorter experience in rearing exotic and cross-breed animals (5 years on average). Upgrading animals breeds is important for milk production, as exotic/cross-breed animals are more productive, but they are also more fragile and need a lot of care treatments. Indeed, only 32% of households own this type of cattle at baseline.

Despite the richness of information contained in the data concerning dairy farming activities, I cannot exclude the existence of a random component in production due to unobservable shocks making profits fluctuating from year to year. A recent work by Attanasio and Augsburg (2014) has shown that local climatic conditions affect animals health through fodder's price, decreasing production in dry years. The years of our data collection were good rainy ones, meaning that the computed profits may reflect an upper bound.

Given the available data, I measure profits in the second data round (Π_{t+1}) and use the value of cattle as reported by farmers in both waves (P_t and P_{t+1}) to define the annual Rate of Return, while correcting for the 2016 inflation rate (4.2%), as:

$$RoR = \left\{ \frac{1 + \frac{P_{t+1} - P_{t-1} + \Pi_{t+1}}{P_{t-1}}}{1 + 0.042} \right\} - 1 \quad (1)$$

Rates of Return, profits, cattle value, costs and revenues are also measured at the animal level by dividing total amounts by the number of cattle heads owned, providing ROR for the average animal k:

$$RoR_k = \left\{ \frac{1 + \frac{P_{k,t+1} - P_{k,t-1} + \Pi_{k,t+1}}{P_{k,t-1}}}{1 + 0.042} \right\} - 1 \quad (2)$$

The data contain also the information about the value of each type of cattle (cows, calves, heifers, oxen and bulls), that I use for obtaining the average value of a single type of animal by dividing the total value of type j by the number of cattle in the j^{th} category. In this way, I can measure Rates of Return for the average animal k being part of category j:

$$RoR_{k,j} = \left\{ \frac{1 + \frac{P_{k,j,t+1} - P_{k,j,t-1} + \Pi_{k,t+1}}{P_{k,j,t-1}}}{1 + 0.042} \right\} - 1 \quad (3)$$

Note that profits cannot be measured separately for each cattle category, as inputs and outputs are aggregated at the cattle level.

Annual profits from rearing cattle are measured as the difference between outputs, expressed in terms of revenues obtained in the past 12 months from producing milk[5], selling animals, renting out animals and selling manure, minus the inputs invested in dairy farming, such as

[5] I include farmers that did not sell their milk and use the median price in their village to estimate the value of their milk.

animals health costs, wage of hired workers, household labour, expenses for buying animals and feeds costs.[6] Table 1 shows the main distribution statistics for the various inputs and outputs in both data rounds, which are described in detail here below.[7]

Outputs. Outputs consists in the value of home-produced milk, the revenues obtained from selling or renting out animals and selling manure.

- The information about milk production is separately asked for the dry and wet season, given the considerable production fluctuation over the year. For each season, farmers report the amount of milk produced on a usual day and the prices they were offered from each type of buyer they engaged with. In addition, in the midline data they report whether each cow in the cows roster was producing milk every day during each season and, if not, the number of months it produced milk. Table 1 shows that on average farmers produce around 2.1 litres of milk on an usual day in both waves. To obtain average daily revenues I multiply quantities and prices and then take the median across the two seasons. To recover average annual revenues in mindline data I multiply daily milk production in each season by the number of days a cow was lactating. In the baseline data there is no information about the actual lactating period of the animals, hence I multiply daily production by 205 which is the average lactating period also used by Anagol et al. (2014). Annual milk revenues amount at roughly 190$ in both data waves. This figure includes the imputed revenues for those that did not sell any milk. On average, throughout the year, each animal produces milk for a value corresponding to 40$ at baseline and 47.7$ at midline.
- Revenues from selling animals in the previous 12 months are higher than milk revenues (325$ in the first wave and 302$ in the second wave) and concern 45% of the sample.
- Information about from renting out animals and selling manure was only collected in the second round. They amount at 73$ in 2016 and concerned 20% of the sample.

Inputs. The costs that farmers undergo to rear cattle are all self-reported and include:

- Health costs: vaccination, artificial insemination, cross-breeding, health checks, curative treatments, deworming and spraying against ticks. All in all they correspond to 21$ on average for the whole year, 4.5$ per animal. Yet, these costs have almost doubled between the two waves, reaching on average $48 in 2016, $11.8 on a per animal basis.
- Wage of workers hired for taking care of the animals, including paying veterinary and extension agents, correspond to 12$ in 2015, but has increased to 16.7$ in 2016. In the first wave only 17% of farmers report having hired external workers for dairy activities in the past 12 months, while it concerns 21.6% in the second wave.

[6] The information about selling manure, renting out animals, and feeds costs were collected only in the second round.

[7] All monetary measures are expressed in US dollars. For the first round the exchange rate is 1$=3400 Ugandan Shillings, as in August 2015, while for the second round it is 1$=3337 Ugandan Shillings, as in September 2016.

- Household labour: in order to minimize the risk of measurement error, questions were designed following the method used in the LSMS-ISA questionnaires, which has proved to measure household labour more accurately than short questionnaires (Bardasi et al. (2010), Palacios-Lopez et al. (2015)). This means collecting information about several workers (at most three in our case) for each different task. Farmers indicated the number of days in the previous seven days and the number of hours for an average day that they (or someone in the household) spent herding, feeding, watering, milking the animals, selling the milk and cleaning the milking equipment. Some tasks tend to be performed only by one person, such as spraying against ticks, milking the animals, cleaning the milk equipments and selling the milk, while other activities, such as herding, watering and feeding the animals, are more often undertaken by several persons.[8] Summing together all the different tasks result on average in a bit more than a full day of work (assumed to be equal to ten hours). I value it by recovering the cost paid by the sampled farmers for hiring external workers. This local daily market wage corresponds to 0.8$ on average in the first wave and 1.03$ in the second wave. Considering household labour value only as part of the costs is reductive, though, as it represents also a wage earned from a working activity, meaning that part of it should in theory be accounted among the outputs.
- Expenditures for buying animals. They concern very few households in both waves. In 2015 only 12.4% of farmers bought heads of cattle in the previous 12 months, paying on average 200$, while in 2016 17.8% of the sample declared to buy animals, spending on average 220$.
- Information about feeds costs was collected only in the second round. They represent, on average the larger cost incurred in by farmers (78$ per year) and are supported by 70.7% of sampled households.

In order to account for cattle depreciation over time, I use the difference in cattle value between the second and the second round, divided by the first round value. Anagol et al. (2014) further compute the discount rate by including the average change in animal's value at each specific age. While I have the information on cows' age, I do not find in the data an inverse U-shaped relationship between animal's value and animal's age as reported by Anagol et al. (2014). In this context, cattle value seems to be completely inelastic to animal's age (see Figure 1). I, hence, consider a linear depreciation rate for all cattle heads given by the difference in values from the two data waves relative to the value declared in the first wave and further discount the Rates of Return by the 2015/2016 annual inflation rate (+4.2%).

[8] Given that the amount of time spent on different tasks by different household members was always provided by the same proxy respondent, the risk of underestimating the amount of household labour is larger than if it was self-reported by each household member (Bardasi et al., 2010). In order to have a better understanding of the labour intensity of cattle rearing we have preferred to collect information about the work-load of more than just one person, but due to practical reasons it was unfeasible to ask multiple persons to answer the questions on the various labour tasks. To limit the risk of measurement error, I replace as missing the amount of labour exceeding 10 hours of work per day and 7 days per week. In addition, I exclude outliers at the bottom and top 1%.

As reported in Table 1, cattle's value has increased across the two waves, both for overall herd and on a per animal basis. Figure 2 illustrates the density distribution of cattle value reported by farmers in each wave. This increase may partly be due to a significant change in herd composition. As Table 1 shows, farmers have increased the number of exotic cattle, more productive and more expensive, while they have decreased the number of indigenous animals. At the same time, they have almost doubled their number of cows and dramatically increased their number of oxen, which are both of high value as they are important sources of revenues.

A concern about the self-reported cattle's value information is that it may be measured with error, potentially correlated with herd size. Figure 3 shows, indeed, that the value of an average animal decreases with herd size. It could be that small farmers either buy more expensive animals, invest more in them, or assign to the few animals they have a higher value than large farmers. Splitting the sample according to the quantile of the average value reported by farmers for their single animals, shows, indeed, that those in the top quantile have a much smaller herd, that, however, yields much larger revenues per animal (Table 4). Those higher revenues are coupled with higher costs and, yet, allow farmers to earn much larger profits, both in total terms and on a per animal basis, and, similarly, larger Rates of Return. In particular, farmers in the top quantile of cattle value earn profits seven times larger and returns four times larger than those in the first quantile. The higher cattle's value reported by small farmers seems, hence, in line with a higher productivity of the animals. Nevertheless, the relationship may be bidirectional as farmers may value their animals differently according to the profits earned, transposing high profits on their animals value.

One of the main challenges in measuring profits in this context is the quantification of household labour costs, which constitute one of the main sources of costs. As a consequence, the choice of the market wage is not neutral. Gehrke and Grimm (2014) use half of minimum wage, corresponding to the average market wage for women in unskilled work activities, Anagol et al. (2014) and Attanasio and Augsburg (2014) use the daily wage reported in village surveys. As explained before, in this study I consider two ways for valuing household labour: zero value and the wage paid to hired dairy workers as reported by farmers in the sample. This makes the daily cost of household labour going from a minimum of \$0 to a maximum of \$1.03.

The bottom panel of Table 1 shows that average total profits are large and positive in both waves, even though they have decreased by 35\$ between 2015 and 2016, by \$39 if taking into account household labour costs. Adding household labour costs, indeed, decreases average profits, though they still remain large. An average farmer earned 174\$ in the first wave and 134\$ in the second wave, which correspond to 33\$ and 35\$ per animal per year. Excluding household labour costs results in total annual profits of 219\$ in the first wave and 183\$ in the second wave, corresponding to \$46 and \$49 at the animal level. Including or excluding household labour does not, hence, change much the figures, partly because households appear to spend few days working with cattle (50 in the first wave and 44 in the second wave) and partly also because the daily wage is very low.

These large profits translate in large annual rates of return. In contrast to Anagol et al. (2014), I find average returns of 83% when excluding household labour and of 74% when including it (Table 2). Given that the returns distribution is right-skewed, the median values are smaller. Median returns for the overall herd amount at 56% without household labour and at 49% when including it among the costs. Median marginal returns at the single animal level are 20% without household labour and 14% when taking it into account. Our preferred measure of RoR is the one including household labour costs, as excluding it is an extreme assumption of no labour opportunity-cost. This paper is particularly concerned with marginal returns, as they tell the profitability of investing one additional dollar in cattle's value, beyond what average returns can tell in terms of economic benefits associated to cattle rearing. In this regard, it is important to note the wide heterogeneity in RoR across households, as shown by Figure 4. Indeed, 37.4% (27.7%) of households earn negative marginal (total) returns when accounting for household labour costs, which slightly decreases to 32% (24%) when ignoring those costs. These are fewer than what Anagol et al. (2014) find in India (52% earning negative marginal returns), but very close to what De Mel et al. (2009) find for firms in Sri Lanka (30% earning total negative returns).

Table 3 provides a glimpse of the main characteristics of farmers according to their average rates of return. Farmers in the top quantile (column 5) have fewer animals than the average farmer in both waves, fewer exotic cattle heads and fewer cows. Yet, they earn larger milk revenues, both on a per animal basis and overall, and report revenues from selling animals, manure and hiring out oxen more than twice the average in the sample. Yet, they spend less for buying animals, but support substantial health, labour and feeds costs. In turn, those in the lowest quantile (column 1) have larger herds but of lower quality, resulting in lower revenues, despite incurring in much larger costs. These differences reflect the ones between farmers earning negative RoR as compared to those earning positive RoR, as reported in Table 5. Revenues are significantly lower in both data rounds for those farmers showing negative returns, having decreased over time, whereas for the other farmers revenues have substantially increased. In addition, they support higher costs that have increased across the two data rounds. Yet, their cattle's value seem to be stable across waves, whereas farmers earning positive returns have substantially increased it.

Two issues are worth mentioning here. First, cattle rearing is on average a profitable activity. Yet, returns are negative for a considerable share of farmers. Given that I observe the sampled farmers only at two points in time, I cannot say whether those farmers permanently earn negative profits and returns or not. For instance, there could have been some random productivity shocks affecting their dairy activity in 2015 and 2016. Yet, median rates of return of farmers reporting more than one shock in the previous 12 months are higher than those reporting only one shock (results not shown). While this suggests that earning negative profits is not fully explained by productivity shocks, I cannot rule out that those farmers are only temporarily earning negative annual returns.

The magnitudes of profits and returns may, at least in part, be due to measurement error in inputs and outputs. Moreover, it could be correlated with herd size, with small farmers over-reporting their costs while under-reporting their revenues, as argued by De Mel et al. (2009). The authors find that the correlation between self-reported profits and a measure of profits calculated by themselves as revenues minus expenses correlate very poorly, around 0.2-0.3. In our data we asked farmers what was the income obtained from selling milk during the last dry season, the last wet season and in the last month.[9] While these measures do not capture profits, they can be compared to my estimated measure of milk revenues (milk production times price reported), that was separately asked for both seasons.[10] The correlation of self-reported income with the estimated measure of milk revenues is very high for both the wet (0.68) and the dry (0.61) season at baseline.[11] The correlation between the income reported for the last month and the annual milk revenues, computed as an average between the dry and wet seasons, is, instead, quite low (0.36). This is probably due to the different phrasing of the questions, the high seasonality of production and the fact that "the last month" is not representative of the average month, meaning that we cannot just divide annual revenues by twelve. Reassuringly, the high correlation for the wet and dry seasons data suggests that measurement error is not a big matter for milk revenues. Still, I cannot rule out that it may affect the reporting of inputs expenses.

2 Empirical strategy

The main aim of this paper is to assess the profitability of cattle rearing and investigate the relationship between marginal returns, herd size and herd value. To do so, I, first, explore median and marginal returns over the whole distribution of herd size, using a non-parametric model. Second, I exploit the longitudinal dimension of the data by looking at variation in herd size and value within households across the two waves. Third, to quantify the causal effect of investments in animal's quality on marginal profits and returns I employ a 2SLS estimator using the gender of calves born between the two survey rounds as exogenous variation in cattle's value.

Parametric estimation. To explore the relation between herd size and profits I, first, regress total and per animal profits (Y_i and $Y_{a,i}$) on the total number of heads of cattle (L_i) owned by household i at baseline. I control for time-varying household characteristics (X_i) that might be correlated with herd size and returns, such as age of the household head, household size and the number of children under 15 years old living in the household. Given the large balanced panel dataset, I control for time-constant unobserved characteristics of households (λ_i) and time

[9] The exact wording is "How much income do you get from selling milk in a usual month of the wet (dry) season?" and "What was your income last month from selling milk?".

[10] For simplicity I conduct this exercise only with baseline data.

[11] I can refine the analysis by looking at the season in which the respondent was interviewed, so to reduce recall errors. For farmers interviewed in the wet season regarding their wet season income the correlation is 0.73, while for those interviewed in the dry season regarding their dry season income the correlation drops to 0.51. Regressing the self-reported incomes on four season dummies for long/short wet/dry seasons shows that the income reported for the dry season is more biased by the timing of the survey than the income reported for the wet season (Table 6). The simple fact of being interviewed in the long dry season translates into a higher wet season income compared to those interviewed in the long wet season (column 1). In turn, those surveyed in the short dry season report a lower dry season income compared to those surveyed in the long dry season (column 3). Indeed, those interviewed in the short dry season seem to underestimate their dry season income compared to all other farmers, as those surveyed in the other three seasons systematically report a higher income (column 4). These discrepancies may explain the lower correlation between the self-reported income and the computed revenues for the dry season.

trends (μ_t). Moreover, given that the primary sampling unit is the village, I allow for correlation between observations within villages using standard errors robust to heteroskedasticity and clustered at the village level (ϵ_v):

$$Y_i = \beta_0 + \beta_1 L_i + \beta_2 X_{i,t} + \lambda_i + \mu_t + \epsilon_v, \quad i = 1, ..., N \tag{4}$$

β_1 captures the relationship between herd size and profits. To explore the relationship between herd value and profits I run a similar specification where V_i is cattle's value:

$$Y_i = \beta_0 + \beta_1 V_i + \beta_3 X_{i,t} + \lambda_i + \mu_t + \epsilon_v, \quad i = 1, ..., N \tag{5}$$

I do not assume L_i, V_i and X_i to be uncorrelated and do not claim L_i, V_i to be exogenous. The aim is just to describe the correlation between Y_i and L_i or V_i, without any causal validity. The use of household and time fixed effects allow me to limit the risk of omitted variables bias, even though unobservable shocks might still bias the results.

2SLS regression on marginal returns. Controlling for household and time fixed effects in the parametric estimates helps netting out unobservable time-invariant factors that may be correlated with herd size, animal's value and profits. Yet, there may be other unobservable time-varying aspects contained in ϵ_v biasing the results. Those farmers having acquired higher quality cows may have, for instance, developed skills or adopted dairy technologies between the first and second round of data collection that make them rearing cattle in a more efficient way, leading thus to higher profits. The results would be upward biased in this case. In turn, they would be downward biased if, for example, farmers buying more expensive animals would put less effort and no further investment in cattle rearing, leading to lower profits. We could also argue that acquiring less expensive animals could be a strategic choice for those farmers willing to invest more effort and resources in cattle rearing. The money initially saved can be later re-invested in animal's health and feeds, increasing productivity and yielding higher revenues. This type of unobservable behaviour would not be captured by household and time fixed-effects, biasing the results. In addition, measurement error in cattle value would bias the results towards zero, whereas the risk of reverse causality, with, for instance, higher returns leading to higher cattle value, may bias the results upward.

To address those endogeneity concerns I apply a 2SLS estimator using the gender of calves born between the first and second round of data as instrumental variable. A female calf represents in this context a positive productivity shock as the animal will become a milking cow once pregnant, granting a constant source of revenue during the pregnancy period. A male calf, in turn, will become a bull, potentially exploitable for breeding other cows, though providing revenues on a less constant time period.[12] Using this instrumental variable means limiting the

[12] The use of bulls as a breeding method is not common as no farmer reports having used her own bull for cross breeding and only 14% declare having used the best breeding animals of a neighbour, which is presumably a bull.

sample to households with a calf born between the first and second data round, which represent 69% of the overall sample.[13]

I conduct the analysis using the cross-section dimension of the data without household and time fixed effects, given that I am interested in the impact on Rates of Return for which I only have one observation per household, being it measured over two data points. I regress returns and profits per animal at time $t+1$ ($Y_{i,t+1}$) on an average calf's value at time $t+1$ ($\widehat{V_{i,T+1}}$), instrumented by a dummy equal to one if between t and $t+1$ a female calf was born versus a male calf (C_i):

$$Y_{i,t+1} = \beta_0 + \beta_1 \widehat{V_{i,T+1}} + \epsilon_v, \quad i = 1, ..., N \tag{6}$$

where the first-stage regression corresponds to:

$$V_{i,T+1} = \beta_0 + \beta_1 C_i + \epsilon_v, \quad i = 1, ..., N \tag{7}$$

β is to be interpreted as the impact of an additional dollar on marginal profits and returns.

A female calf, as compared to a male calf, by raising animals' value may push farmers to invest in the adoption of dairy technologies and cattle management practices in view of future higher milk production. Given the higher value of their productive assets after the birth of a female calf and the consequent expectations of a higher productivity potential, farmers may decide to improve further their dairy activity. As a consequence, I expect the IV estimates to be larger than the OLS ones.

3 Results

Descriptive statistics provided in Table 2 have shown that median and marginal Rates of Return are largely positive, even though there is a considerable variation across farmers. In this section I, first, explore this variation in a descriptive way by assessing the correlation between returns and herd size with non-parametric estimates. Second, I take further advantage of the longitudinal structure of the data to control for household unobservable time-invariant factors that might drive the relationship between herd size and profits. Third, to solve the omitted variable bias that could still affect the estimates despite the use of fixed effects, I employ a 2SLS estimator to study the impact of an animal's value on its marginal returns.

[13] I consider only calves born between the two data rounds and do not include those born before the first round because the information reported in the questionnaire refers only to the last born calf. Female calves born before the first data round have probably become heifers by the second data round as calves are usually weaned when they are 7 or 8 months old, meaning that I should additionally include heifer's value, complicating the analysis as the data do not provide a roster of all animals owned.

Non-parametric estimates. Results from the non-parametric regression show that herd size is negatively associated with median Rates of Return (Figure 5).[14] The larger the herd is, the lower median returns are. The relationship looks fairly linear, slightly steeper for herds between the 50th and 75th percentiles. The relationship between herd size and marginal Rates of Return has, in contrast, an inverse U-shape, increasing up until the 75th percentile, levelling off between the 75th and 85th percentiles and decreasing afterwards. It increases slightly again in correspondence of the 95th percentile and decreases further on. These results holds whether or not we include household labour costs in the measurement of RoR.

Conducting the same exercise by type of animal shows that the increase in marginal returns to cattle is driven by the number of cows and calves (Figure 6). For those animals the positive relationship holds for almost the entire distribution until the 90th percentile (4 cows and 3 calves), meaning that the profitability of dairy farming associated with a larger number of cows and calves concerns the great majority of sampled farmers. Given the small number of heifers and bulls owned on average by farmers, it is not surprising to see an almost completely flat relationship between the number of those animals and Rates of Return per animal. For heifers the curve is decreasing until the 75th percentile and increasing only afterwards up till the 95th percentile, suggesting that the high cost associated with heifers is compensated only in large herds. For bulls the relationship with marginal Rates of Return is completely flat until the 95th percentile and then slightly increasing.

Turning to the relationship between cattle profitability and its value, non-parametric estimates confirm what already suggested by looking at Rates of Return across cattle value quantiles (Table 4). Figure 7 shows that both total profits and profits per animal increase with the overall value of the herd and the value of a single average animal in the herd. The increase in the first case is more pronounced for herds having an overall value below the median one, being flat for those between the 50th and 75th percentile ($706) and then slightly increasing again until the 90th percentile ($1030). With respect to profits per animal, the relationship is positive and steeper for animals having an average value below the 25th percentile, it is flat between the 25th and the 75th percentile ($170) and then it is positive again for those in the top 10 percentile of the distribution.

Parametric estimates. These non-linear relationships are confirmed also by parametric estimates obtained by controlling for household and time fixed effects. Table 7 reports the main regression results concerning total and per animal profits, including or excluding household labour costs. Results show that a higher number of cattle heads is on average positively associated with total profits. Yet, once we measure profits including household labour costs, the relationship is not any more statistically significant, meaning that an increase in herd size is not coupled by an increase in overall profits and, most likely, because it is offset by the higher labour costs associated with more animals. Turning to profits per animal, herd size appears

[14] To improve the figures readability I have limited the graphs to the 99th percentile of the herd size distribution, corresponding to 34 animals. In addition, I have marked the 50th, 75th and 95th percentiles with solid, dash, dot-and-dash lines, respectively.

to be associated with lower profits per animal, though the positive sign of the squared terms indicates that, again, the relationship is non-linear.

Distinguishing by type of animals (Panel 2, Table 7) shows that the positive association between herd size and overall profits is completely driven by the number of cows. Strikingly, these animals do not exhibit marginal decreasing profits, as additional cows are associated with higher profits per animal, even though at a decreasing pace. In line with the non-parametric results, calves are positively associated with total profits, tough the estimated regression coefficient is not statistically significant. All other categories of cattle are negatively correlated with profits per animal, suggesting decreasing marginal returns. Heifers, in particular, appear to be the least profitable type of cattle, being negatively associated with both total and per animal profits. This is expected as they are adult animals that are not yet producing milk and are not the ones usually sold out. A part from cows, no other type of cattle is positively associated with profits.

These results suggest that the higher up on the herd size distribution, the lower the profitability of additional heads of cattle is, in line with the existence of decreasing returns to cattle. Increasing herd size may not be the best way for increasing dairy profits, as the number of cattle heads is only weakly correlated with profits. It might be better to invest in herd composition, for instance by increasing the number of cows, as results in Table 7 suggest.

An alternative way for increasing profits might be to invest in the quality of farmed animals. According to non-parametric estimates (Figure 7), there seems to be a positive association between animals' value and profits, increasing in particular for farmers owning animals of low value. To further explore the association between profits and cattle value I conduct parametric estimates by regressing profits per animal on the average value of a single cattle head, while controlling for household and time fixed effects. To investigate the returns to cattle value by type of animal I also regress profits per animal on the value of the average cow, bull, oxen, heifer or calf.

Table 8 provides the results for the two measures of profits, one excluding household labour costs and the other including them. The various cattle value measures have been centred to their mean to simplify the interpretation of the linear term and reduce correlation with the quadratic term. Results show that animals of higher value significantly increase marginal profits. On average, one additional dollar invested in a single animal value is associated with \$0.08 more in profits per animal. The relation is non-linear, as shown by the quadratic term (column 1) and looses its statistical significance once household labour costs are accounted for (column 7).

Among the different types of cattle, only the value of cows and and calves is significantly associated with profits, but, again, not in a linear way. It is increasing for cows and decreasing for calves. One additional dollar in the value of an average calf increases profits per animal by about \$0.3, representing the largest contribution among the different types of animals. The relationship is decreasing as shown by the negative sign of the squared term.

To further explore linear patterns in the relationship between profits per animal and cattle value, I split the sample between farmers with value per animal above and below the median. Tables 9 and 10 show that, interestingly, the positive association between value and profits per animal is significant only for farmers with low value animals. For them, one additional dollar in the value of their average animal increases profits by \$0.1, the relationship being linear irrespectively of the inclusion or exclusion of household labour costs (Tables 9, columns 1 and 7). This linear positive relationship is confirmed also for cows and calves. In turn, for those above the median, the value of an average oxen and calf is significantly associated with profits per animal, but at a decreasing pace.

Parametric and non-parametric results suggest that animal's value is positively associated with marginal profits, but at a decreasing rate, as only the profits of farmers owning lower value animals are always significantly correlated with the value of an average head of cattle. This is in line with results from Gehrke and Grimm (2014), who find higher marginal returns at low levels of cattle value.

Instrumental variable approach. These results remain, however, substantially descriptive as there could be unobservable time-varying aspects that affect the relationship between cattle's value and profits, as discussed above. To be able to deal with endogeneity concerns and assess the causal impact of cattle's value on its profitability I exploit the sex of a recently born calf as an exogenous variation in the value of cattle. Provided the random assignment of calves' sex, I use as instrumental variable for each calf's value a dummy equal to one if the household had a female calf born between the two interview rounds and zero if it was a male calf. In the overall sample, 69% of farmers had a calf being born between the first and second round of interviews, corresponding to 2072 farmers. Among those, 812 (39%) had a female calf.

The higher value that farmers attach to female than male calves is graphically shown in Figure 8. A simple comparison of their two distributions shows that households having had a recently born female calf report higher values for their average calf than those having had a male calf. The distribution of the first group is always shifted to the right compared to the distribution of the other group.

More importantly, calves' value appears to matter for cattle rearing profitability. In line with previous parametric results, Table 11 (column 1) shows that the value of a calf is on average positively associated with profits per animal. One additional dollar in calf's value is associated with \$0.5 more in terms of profits per animal. The first-stage regression shows that this is due to the value attached to female calves, which raises the value of an average calf by \$9.8 as compared to those households having had a recently born male calf (column 2). Solving the endogeneity bias with a 2SLS estimator reveals that increasing an average calf's value by one dollar increases profits per animal by \$1.2. These results are in line with, though, as expected, larger in magnitude, than the OLS results. Controlling in addition for the average calf's value reported in the first data wave increases the effect to \$1.3. These results are confirmed when looking at the impact of calves' value on annual marginal Rates of Return measured at the calf level. Both the OLS and IV results are positive and statistically significant. The 2SLS estimates (column 6) indicate that one additional dollar spent on calf's value increases marginal RoRs by almost 10 percentage points. In all 2SLS specifications the instrumental variable as a good predictive power as shown by the F-test statistics reported at the bottom of Table 11.

To explore whether the increase in calves' value translates also into higher returns for the average cattle head, I conduct the same exercise by instrumenting the value of the average animal by the gender of a recently born calf. Table 12 shows that an average cattle head value is positively associated with marginal profits and Rates of Return (columns 1 and 5). This association is confirmed by the 2SLS results. One additional dollar spent on animal's value, instrumented by calf's gender, increases marginal profits by $0.3, which is extremely close to the magnitude previously found with parametric estimates (Table 8, columns 6 and 11), and marginal Rates of Return by 0.3 percentage points. Even though the magnitudes are lower than those found in Table 11, it is remarkable that an increase in calves value translates into higher herd value and that this ends up significantly increasing marginal profits and Rates of Return.

These results indicate that, on average, investing in higher quality animals increases marginal profits and Rates of Return already the year after. The effect is very large for calves, for which one additional dollar leads to an increase in marginal Rates of Return by 10 ppts, and it is still relevant for the average cattle head, for which one additional dollar spent on it leads to larger marginal RoR by 0.3 ppts.

Following the previous non-parametric and parametric estimates that have shown non-linearities in the relationship between profits and cattle value, I explore whether the increase in marginal RoR and profits is differential according to cattle's value quantile, as reported in the first data round. Ideally, non-linearities could be explored by including a quadratic term of calves and cattle value, but it would have to be instrumented as well, which is not possible given that the instrumental variable is a dummy and I cannot use its quadratic term. In alternative, I split farmers according to their average cattle head value, whether it is above or below the median value in the sample.

Table 13 shows that calves' value is still significantly and positively associated with profits and RoR in the OLS regression for both sub-samples. Yet, once we instrument it with the gender of a recently born calf, the estimates remains statistically significant only for the sub-group of farmers with an average animal value below the median (columns 3 and 5). One additional dollar invested in their average calf increases profits by $1.02 and ROR by 12.5 percentage points. This is in line with previous non-parametric and fixed effects regression results.

The instrumental variable has still a good predictive power for this sub-sample, whereas it looses its power for the other one, leading to non-significant results (columns 8 and 10). This suggests that the main set of results is explained by those farmers owning not very expensive animals and that there are maybe decreasing returns to calves's value. Moreover, the lack of predictive power of the instrumental variable for the second group of farmers might indicate that the birth of a calf is not an important productivity shock for them and that probably their animals' quality is already high enough that they would need to rely on other factors for increasing their marginal profits and returns.

To further explore for which group of farmers the main results hold, I look at farmers with an average cattle head having a value below or above the 25th percentile, as non-parametric results have shown that the relationship is particular strong for farmers with low value animals

(Figure 7). 2SLS estimates confirm, indeed, that farmers with low value cattle are the ones benefiting the most from an increase in their average calf's value (Table 14). One additional dollar increases profits per animal by $2.05 and calves' Rates of Returns by 20.8ppts, the magnitude being twice as large the one found for the overall sample in Table 11. For those owning cattle of high value there is no statistically significant effect once employing the 2SLS estimator. These results are in line with the existence of decreasing returns to cattle value as already suggested by parametric and non-parametric estimates.

As a placebo test for testing the robustness of the IV estimates, I conduct the same exercise using as instrumental variable a dummy equal to one if a calf was born between the two data rounds, irrespectively of its gender. Results reported in Table 15 show that the birth of a calf is associated with lower average calf value (column 1), while the 2SLS results are not statistically significant any more and the predictive power of the instrumental variable is very low. These results indicate that what matters is the gender of the calf, which significantly affects the animal's value, given its expected future productivity.

Mechanisms. Why does the average value of a calf or of a cattle head matter for profits and rates of return? What is the mechanism through which higher value animals increase cattle rearing profitability and returns? To answer these questions I turn to the components of profits, meaning revenues and costs. Using the 2SLS estimator I explore the impact of increasing the average calf value by one dollar on milk production, milk revenues and health costs.

IV estimates reported in Table 16 show that one additional dollar invested in the average calf's value increases milk revenues by $1.1 and daily milk production by 0.01 litres, the results holding even when controlling for the first data round levels (columns 2 and 4). This increase in production is likely due to larger investments in cattle health, as farmers spend $0.12 more for each animal's health on average. Looking at the different components of health costs shows that farmers spend more in health treatments (+$0.06), vaccination (+$0.04) and deworming (+$0.02). In turn, I do not find any statistically significant impact on the cost of household labour or hired workers (results not shown). These results indicate that an increase in cattle value pushes farmers to invest more in their cattle health conditions, increasing milk production and revenues, and, ultimately, profits and returns.

Conclusions

Drawing from a unique household panel dataset collected in two waves in rural Uganda, this paper documents the existence of positive annual median and marginal rates of return to cattle rearing in this context. Overall median returns are 48% and marginal returns are 14%.

Yet one third of the sample earns negative returns. There is, indeed, an important heterogeneity in returns across farmers. On the one hand, this depends on herd size. Non-parametric estimates show that median returns decrease with herd size, being much higher for small than large farmers, while marginal returns increase with herd size for small farmers, while decrease for larger ones. Moreover, parametric estimates using household and time fixed effects show that herd size is only weakly correlated with total profits, while negatively correlated with profits per animal, suggesting the existence of decreasing returns to herd size.

Instead of increasing herd size it may be more profitable, in this context, to, instead, raise animals' quality, either by improving herd composition or by investing more in one's cattle. One of the main contribution of this paper is to provide an identification strategy to conduct causal inference about the marginal returns to an increase in cattle's value. To do so, I employ an instrumental variable approach using a dummy equal to one if a female calf was born in between the first and the second data round, as compared to the birth of a male calf, as exogenous variation in the value of an average calf or cattle head. Female calves represent a considerable productivity shock, as they will become milking cows once pregnant, providing a fairly continuous and major source of income. Male calves, in turn, will turn into bulls, providing income only if used for breeding, as beef is not a usual component of the local diet.

Results from the IV estimates show that one additional dollar spent on a single average calf's value increases annual marginal Rates of Return by 10 percentage points. One additional dollar spent on a single average cattle head increases annual marginal Rates of Return by 0.3 percentage points. In line with non-parametric estimates and fixed-effect regressions results, the effects are explained by the sub-sample of farmers owning low value animals, which suggests decreasing returns to cattle's value.

In conclusion, these results contribute to the literature on the efficiency of farming by quantifying the marginal returns associated with a larger investment in cattle's value solving endogeneity biases common in the literature by using an instrumental variable approach. Further evidence suggests the existence of an inverse non-linear relationship between dairy profits and herd size. These results are important for farmers aiming at increasing their cattle annual returns by investing more in their animals' quality.

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Figures

Figure 1: Age profile of cows' value.

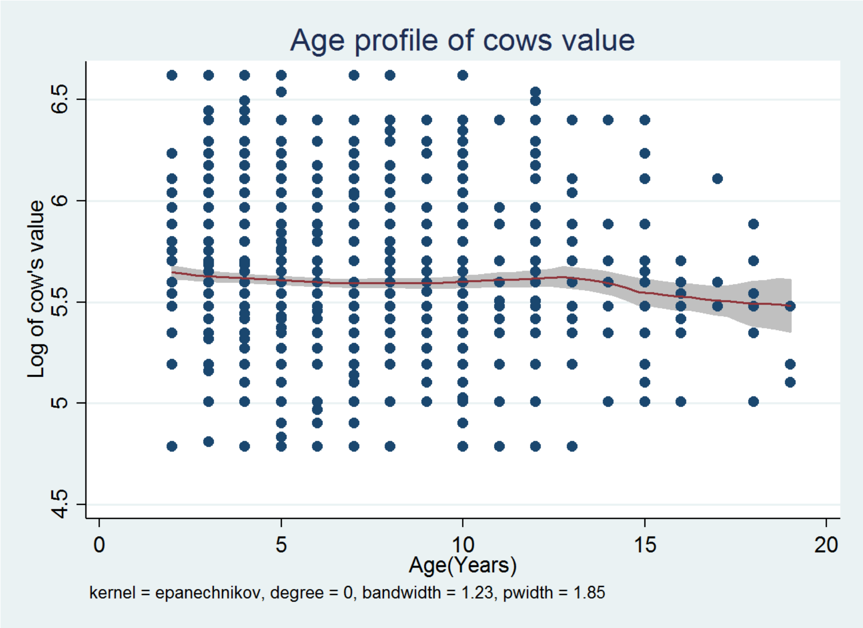


Figure 2: Distribution of total and per animal self-reported values of cattle measured in Wave 1 and Wave 2.

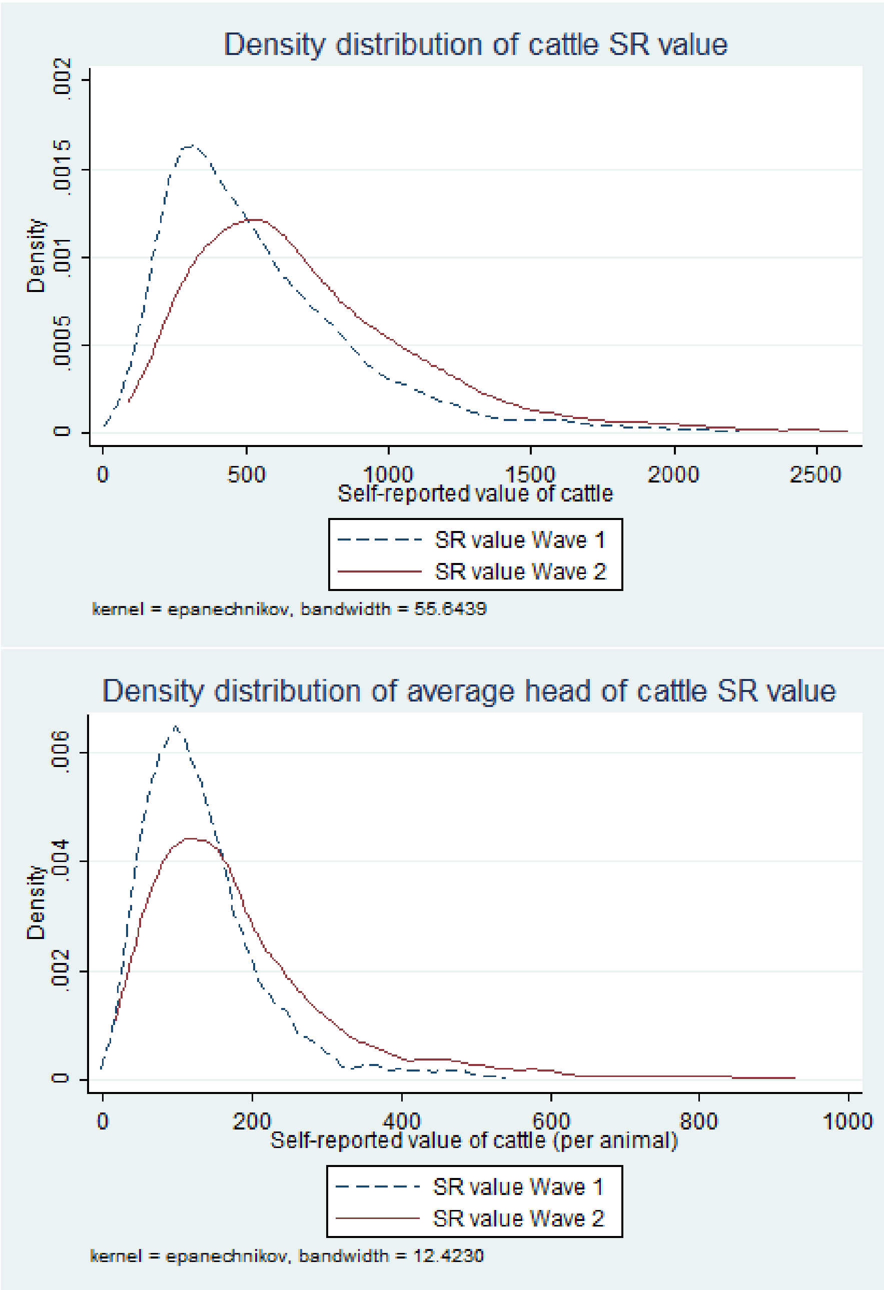


Figure 3: Self-reported value of an average cattle head vs herd size.

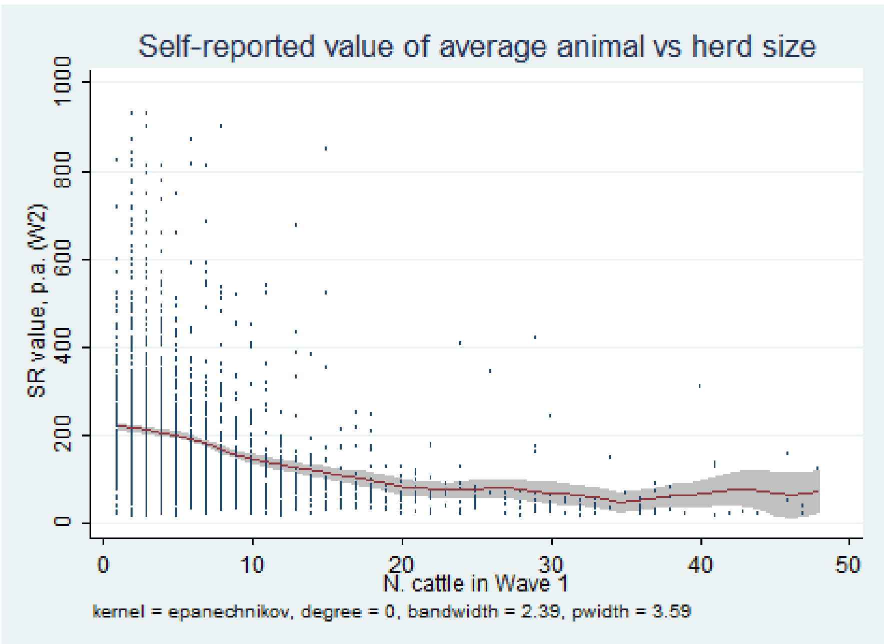


Figure 4: Distribution of total and per animal annual rates of return measured under different assumptions of household labour value.

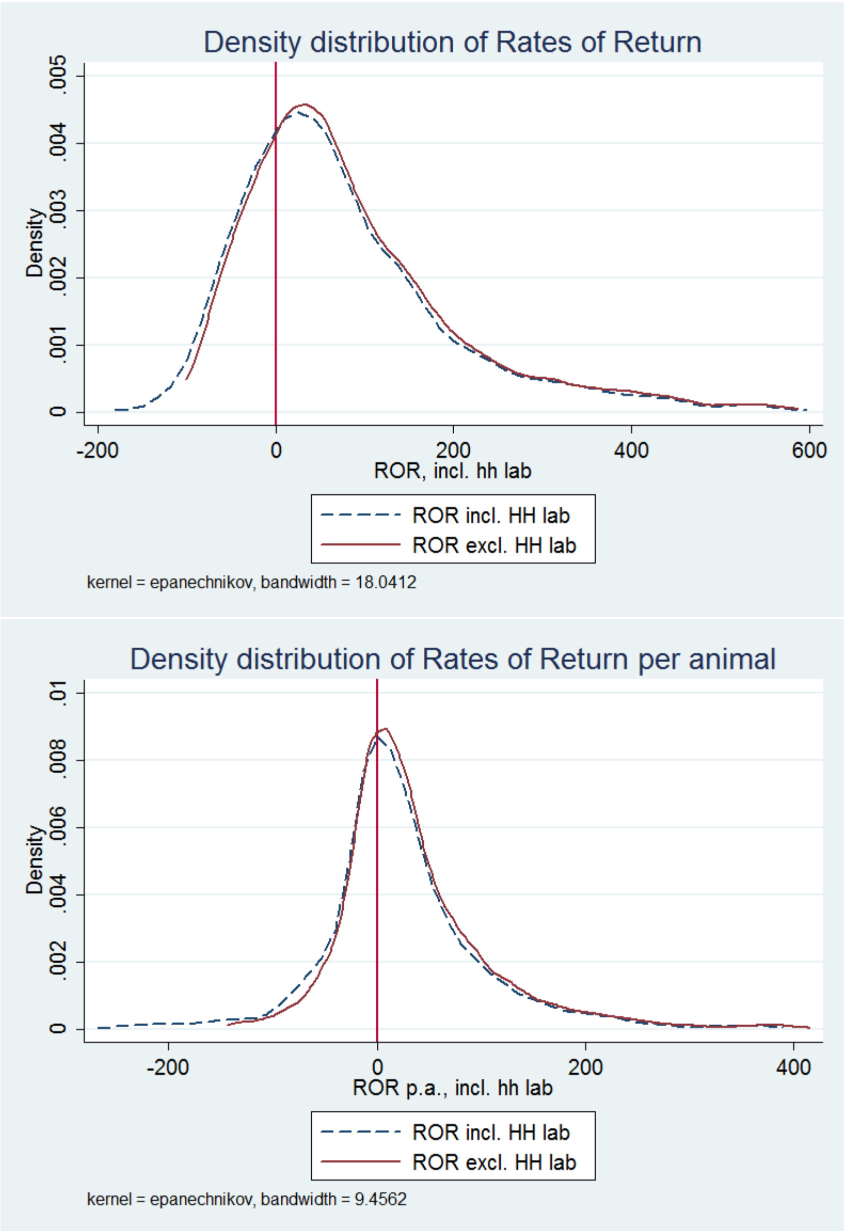
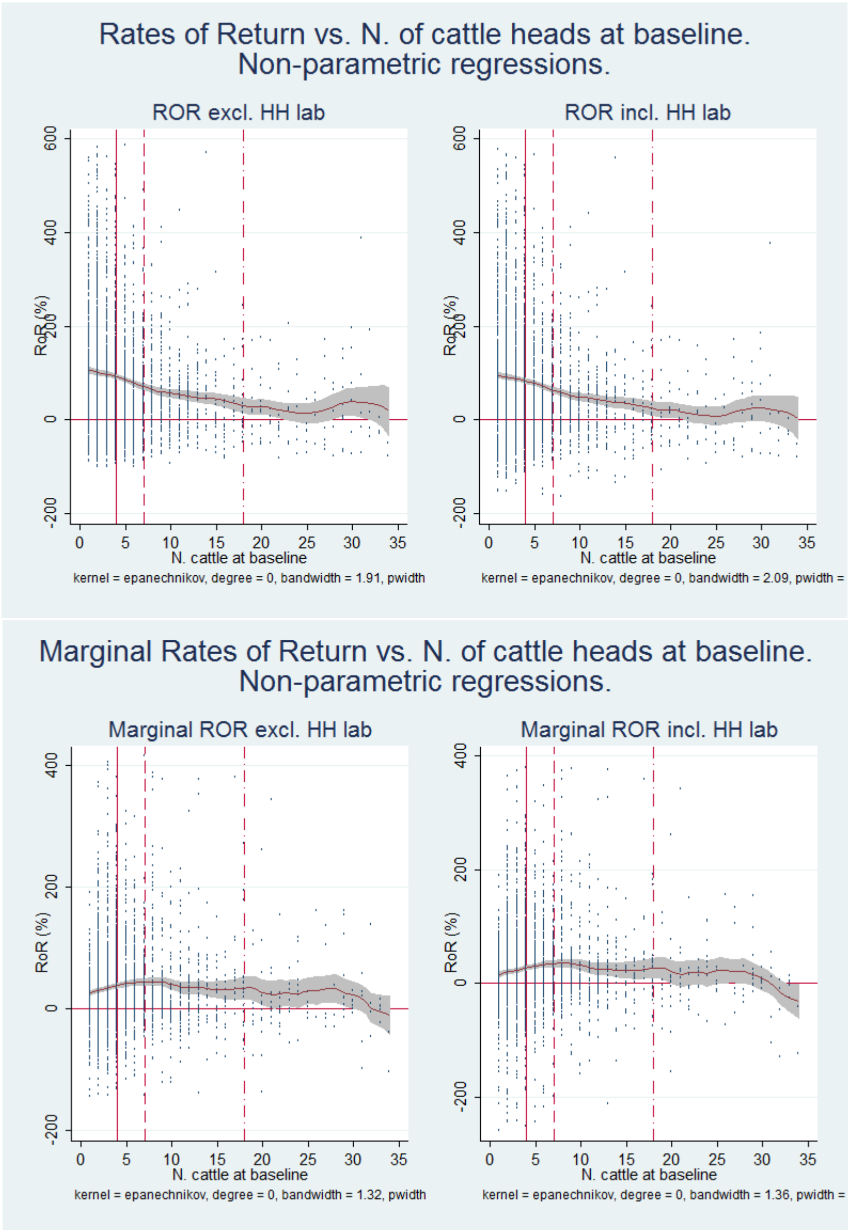
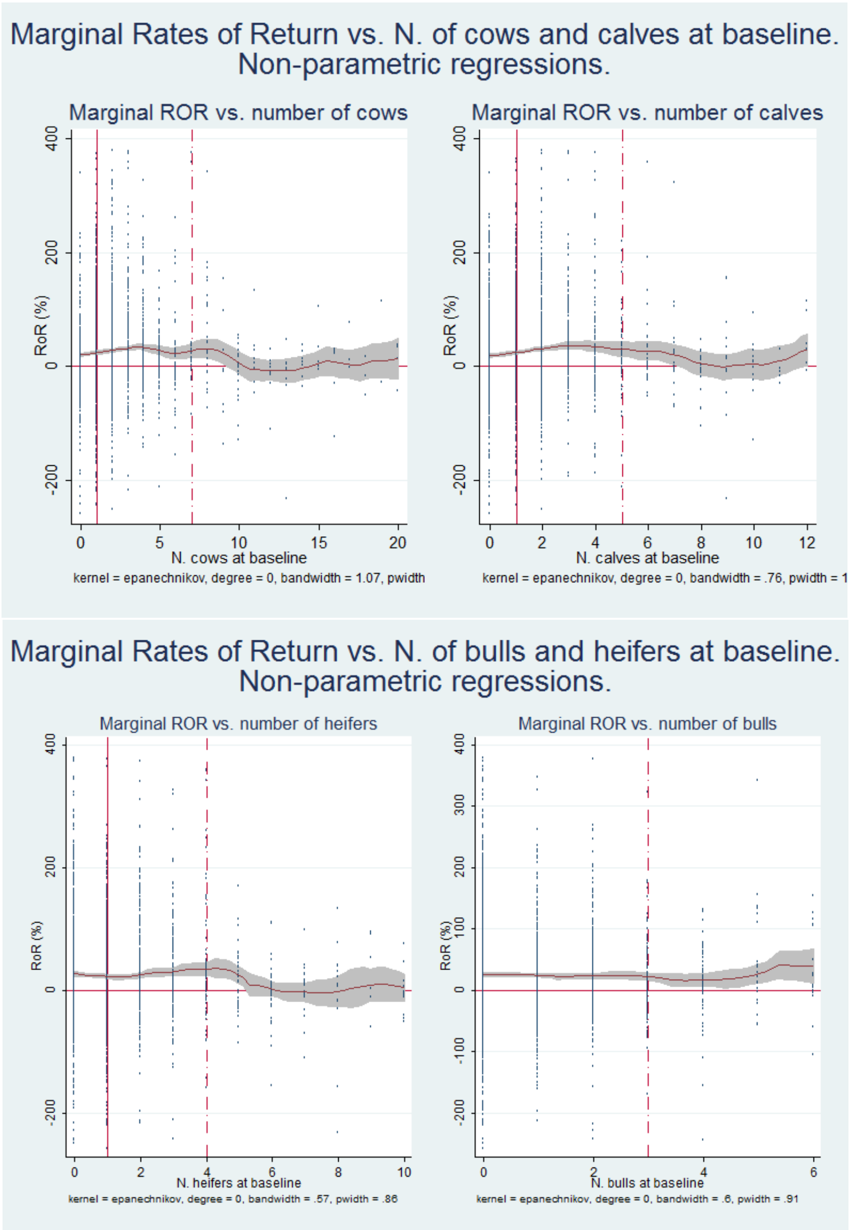


Figure 5: Non-parametric estimations of the relationship between total and marginal returns and herd size.



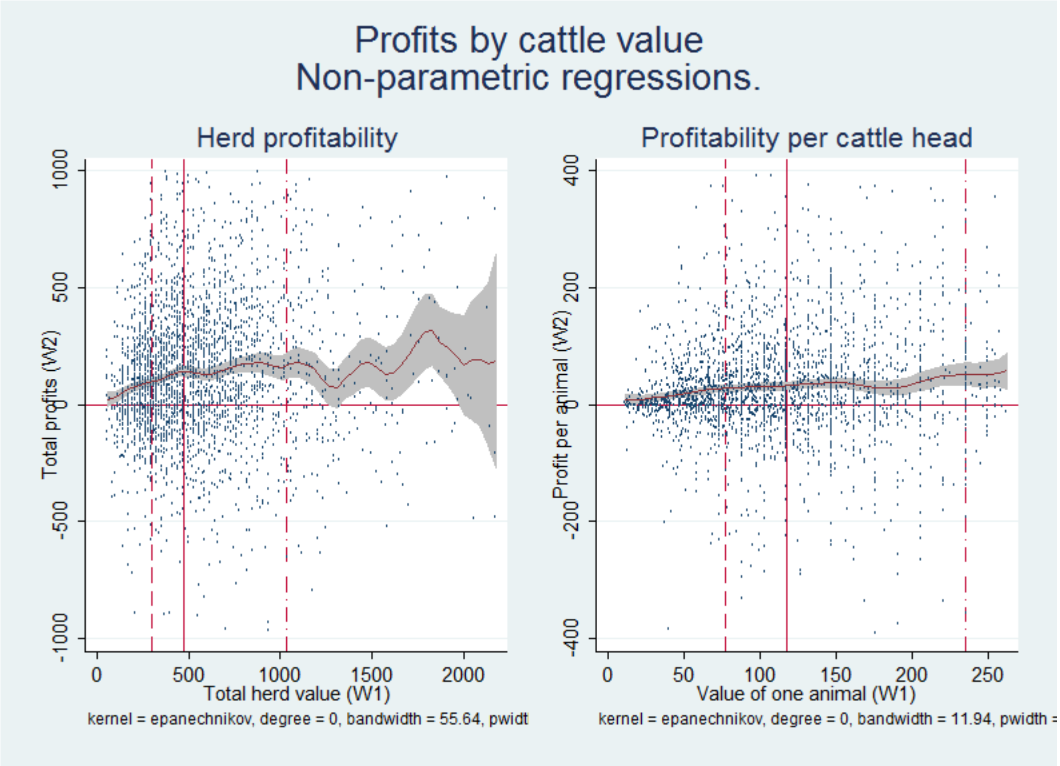
Confidence intervals at 95% level. Vertical lines indicate different percentiles of the herd size distribution. Solid line=50th percentile, dash line=75th percentile, dash and dot line=95th percentile.

Figure 6: Non-parametric estimations of the relationship between marginal returns and herd composition.



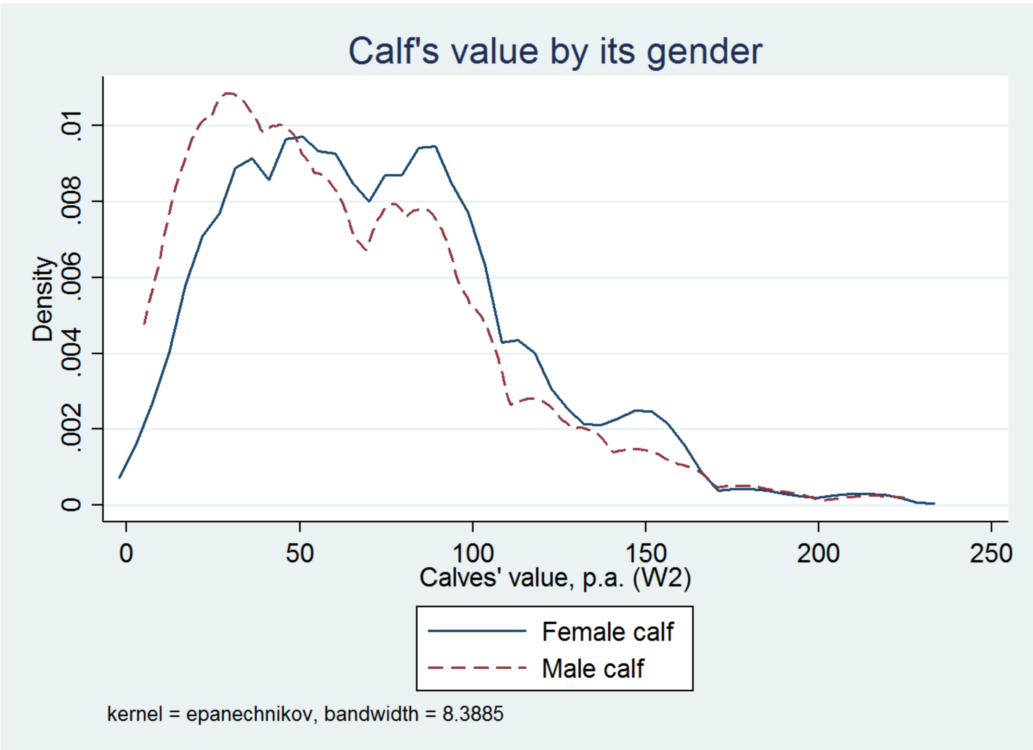
Confidence intervals at 95% level. Vertical lines indicate different percentiles of the herd size distribution. Solid line=50th percentile, dash line=75th percentile, dash and dot line=95th percentile.

Figure 7: Non-parametric estimations of the relationship between total and per animal profits vs. Self-reported value of herd and average cattle head.



Confidence intervals at 95% level. Vertical lines indicate different percentiles of cattle value distribution. Dash line=25th percentile, solid line=50th percentile.

Figure 8: Density distribution of a calf's value according to its gender.



Tables

Table 1: Herd composition, outputs and inputs descriptive statistics for waves 1 and 2 and means test across waves.

	Mean W2	Mean W1	Means-test	s.e.
Herd composition:				
N. cattle	6.320	6.529	-0.209	0.236
N. exotic cattle	1.453	1.230	0.224**	0.102
N. indigenous cattle	4.867	5.299	-0.432**	0.213
N. cows	4.564	2.380	2.184***	0.214
N. heifers	1.914	1.404	0.510***	0.072
N. bulls	1.444	0.806	0.638***	0.045
N. oxen	1.989	0.369	1.620***	0.038
N. calves	1.850	1.591	0.258***	0.070
Outputs:				
Annual milk production	2.114	2.075	0.040	0.063
Annual milk revenues	192.620	190.148	2.472	5.930
Price of milk	0.259	0.219	0.040**	0.017
Annual revenues from selling animals	301.915	325.255	-23.340**	11.179
Annual revenues from renting animals and selling manure	73.276	0.000	73.276***	1.354
Annual milk production, p.a.	0.565	0.422	0.143***	0.017
Annual milk revenues, p.a.	47.738	40.166	7.571***	1.607
Annual revenues from selling animals, p.a.	90.945	68.280	22.665***	4.265
Annual revenues from renting animals and selling manure, p.a.	13.482	0.000	13.482***	0.375
Inputs:				
Health costs for cattle	48.474	21.060	27.414***	1.077
Cost of hired labour	16.698	12.173	4.524***	1.139
HH labour cost	54.962	45.787	9.174**	3.612
Daily wage	1.035	0.807	0.227***	0.053
N. days of HH labour	44.133	50.729	-6.596***	2.232
Cost buy animals	220.238	200.553	19.685**	8.309
Feeds costs	78.639	0.000	78.639***	1.782
Health costs for cattle, p.a.	11.859	4.556	7.303***	0.267
Cost of hired labour, p.a.	2.608	1.353	1.255***	0.201
HH labour cost, p.a.	15.285	12.725	2.560*	1.361
N. days of HH labour, p.a.	13.530	13.666	-0.136	0.898
Cost buy animals, p.a.	57.719	48.764	8.955**	3.602
Feeds costs, p.a.	23.059	0.000	23.059***	0.647
Profits:				
Profit, tot., excl. HH lab	183.597	219.126	-35.530***	8.177
Profit, p.a., excl. HH lab	49.222	46.182	3.040	2.397
Profit, tot., incl. HH lab	134.514	174.049	-39.535***	8.733
Profit, p.a., incl. HH lab	35.428	33.697	1.731	2.688
Cattle's value:				
Cattle's value	716.744	554.225	162.518***	10.025
Cattle's value, p.a.	186.159	133.410	52.749***	2.958
Observations	5976			

Table 2: Rates of return.

	Mean	Median	S.D.	Min	Max
ROR, excl. hh lab	83.11	56.23	118.56	-99.67	586.52
ROR, incl. hh lab	74.22	49.57	118.78	-162.03	577.70
ROR p.a., excl. hh lab	34.85	20.58	71.95	-144.03	415.05
ROR p.a., incl. hh lab	25.00	14.87	75.85	-258.47	379.71
Observations	2821				

Table 3: Herd composition, inputs and outputs in the second data round, by Rates of Return quantiles.

	(1) RoR bottom 20th percentile	(2) RoR in 20th to 40th percentile	(3) RoR in 40th to 60th percentile	(4) RoR in 60th to 80th percentile	(5) RoR above 80th percentile	(6) Full sample
N. cattle (W1)	6.27	6.63	6.75	6.58	6.02	6.53
	(8.00)	(8.47)	(8.68)	(8.54)	(6.73)	(9.50)
N. cattle (W2)	5.62	8.45	7.77	6.48	4.15	6.32
	(7.23)	(10.14)	(9.16)	(6.89)	(4.87)	(8.70)
N. exotic cattle (W1)	0.81	1.27	1.37	1.28	1.16	1.23
	(2.25)	(3.24)	(4.56)	(2.97)	(2.25)	(4.20)
N. exotic cattle (W2)	1.02	1.89	1.77	1.71	1.18	1.45
	(2.38)	(4.10)	(5.15)	(3.05)	(1.75)	(3.68)
N. cows (W1)	2.27	2.35	2.44	2.37	2.26	2.38
	(3.35)	(3.50)	(3.74)	(3.61)	(2.94)	(3.96)
N. cows (W2)	1.82	2.78	2.58	2.21	1.52	2.16
	(3.07)	(4.27)	(3.45)	(2.49)	(1.69)	(3.60)
Annual milk revenues, p.a.	16.83	21.17	40.31	61.32	95.01	47.74
	(35.07)	(26.62)	(34.62)	(56.08)	(95.80)	(67.52)
Annual milk revenues	79.40	128.70	209.11	286.75	305.93	192.62
	(126.19)	(149.18)	(165.42)	(227.90)	(255.26)	(211.26)
Annual revenues from selling animals, p.a.	10.20	7.81	16.98	35.75	106.01	41.10
	(36.27)	(25.15)	(33.04)	(53.11)	(118.49)	(91.09)
Annual revenues from selling manure, hire out oxen, p.a.	2.04 (8.30)	1.42 (4.76)	2.42 (6.92)	3.86 (12.98)	4.39 (15.40)	2.80 (10.82)
Cost of buying animals, p.a.	25.12	7.58	5.15	4.94	7.50	10.65
	(48.85)	(21.79)	(17.09)	(19.83)	(30.22)	(33.49)
Health costs for cattle, p.a.	13.90	9.65	9.06	10.83	13.89	11.86
	(12.62)	(9.77)	(8.36)	(13.33)	(12.46)	(12.69)
Labour costs, p.a.	32.34	7.87	6.85	7.52	9.68	16.42
	(70.34)	(14.39)	(12.13)	(15.88)	(19.36)	(67.44)
Feeds costs, p.a.	37.73	16.34	14.05	15.47	20.42	23.06
	(44.12)	(21.44)	(19.60)	(20.18)	(26.14)	(35.37)
Observations	534	534	534	534	534	2988

Mean coefficients reported for each quantile of the Rates of Return distribution. Standard deviations in parenthesis. Rates of Returns are measured at the herd level accounting for household labour costs.

Table 4: Herd size, profits, returns, inputs and outputs in the second data round, by wave 2 per animal value quantiles.

	(1) Value in bottom 20th percentile	(2) Value in 20th to 40th percentile	(3) Value in 40th to 60th percentile	(4) Value in 60th to 80th percentile	(5) Value above 80th percentile	(6) Full sample
N. cattle	15.36	6.44	4.66	3.30	2.34	6.32
	(13.47)	(4.16)	(2.93)	(1.81)	(1.47)	(8.70)
N. exotic cattle	2.53	1.36	1.32	1.23	1.09	1.45
	(6.53)	(2.86)	(2.14)	(1.65)	(1.31)	(3.68)
Profit, tot., incl. HH lab	90.29	118.68	138.12	155.22	186.71	137.55
	(387.52)	(398.65)	(335.05)	(357.67)	(375.36)	(365.47)
Profit p.a., incl. HH lab	11.17	12.23	30.22	40.69	78.13	35.69
	(41.60)	(89.94)	(86.88)	(116.13)	(216.01)	(128.63)
ROR p.a., incl. hh lab	11.21	13.71	25.39	31.66	48.21	25.69
	(52.07)	(65.74)	(69.69)	(79.82)	(101.44)	(76.22)
Annual milk revenues, p.a.	22.85	35.56	47.68	63.77	72.94	47.74
	(26.36)	(37.29)	(53.22)	(66.81)	(110.66)	(67.52)
Annual revenues from selling animals, p.a.	10.96	16.87	25.39	36.31	105.96	41.10
	(23.43)	(32.82)	(53.48)	(61.71)	(144.68)	(91.09)
Annual revenues from selling manure,	1.52	2.68	3.43	2.41	3.88	2.80
hire out oxen, p.a.	(4.08)	(7.44)	(11.60)	(7.88)	(16.40)	(10.82)
Cost for buying animals, p.a.	3.57	7.08	8.73	10.66	22.61	10.65
	(9.17)	(19.88)	(20.25)	(31.86)	(56.18)	(33.49)
Health costs for cattle, p.a.	5.24	6.94	9.27	11.39	16.07	9.81
	(5.41)	(6.22)	(8.49)	(9.96)	(16.09)	(10.77)
Labour costs, p.a.	7.94	16.89	13.69	18.96	34.62	18.17
	(17.50)	(63.61)	(38.61)	(62.80)	(125.68)	(70.80)
Feeds costs, p.a.	11.10	16.68	19.46	26.91	36.66	23.06
	(17.91)	(23.29)	(26.06)	(35.94)	(52.00)	(35.37)
Observations	557	555	549	555	551	2988

Mean coefficients reported for each quantile of the average animal value distribution. Standard deviations in parenthesis.

Table 5: Characteristics of farmers earning negative ROR (G1) vs those earning positive ROR (G2).

	Mean G1	Mean G2	Means-test	s.e.
Daily median milk production, p.a. (W1)	0.335	0.457	-0.122***	0.023
Daily median milk production, p.a. (W2)	0.384	0.623	-0.238***	0.034
Annual milk revenues, p.a. (W1)	31.034	44.045	-13.011***	2.301
Annual milk revenues, p.a. (W2)	23.638	56.940	-33.302***	2.847
Revenues from selling animals, p.a. (W1)	18.677	22.189	-3.512*	2.024
Revenues from selling animals, p.a. (W2)	14.040	52.034	-37.994***	3.859
Health costs, p.a. (W1)	-4.150	-4.606	0.456	0.290
Health costs, p.a. (W2)	12.101	11.892	0.209	0.560
Hired workers cost, p.a. (W1)	1.396	1.337	0.059	0.186
Hired workers cost, p.a. (W2)	3.157	2.436	0.721*	0.436
HH labour cost, p.a. (W1)	10.079	10.310	-0.230	0.626
HH labour cost, p.a. (W2)	24.486	8.440	16.046***	1.945
HH work (days), p.a. (W1)	13.051	13.771	-0.721	0.592
HH work (days), p.a. (W2)	23.629	11.590	12.039***	2.258
Cost buy animals, p.a. (W1)	7.147	4.689	2.458***	0.840
Cost buy animals, p.a. (W2)	13.270	9.535	3.735***	1.441
Feeds costs, p.a. (W2)	30.629	19.470	11.158***	1.690
Cattle's value, p.a. (W1)	143.525	129.530	13.995***	3.464
Cattle's value, p.a. (W2)	148.546	200.664	-52.118***	5.786
Observations	2774			

Mean coefficients reported. The two groups are defined based on earning positive or negative Rates of Returns, that are measured at the herd level accounting for household labour costs.

Table 6: OLS. Bias in milk income reports according to survey season. First data round.

	Income reported for the wet season		**Income reported for the dry season**	
Bias in survey season reports with respect to:	*Long wet season*	*Short wet season*	*Long dry season*	*Short dry season*
	(1)	(2)	(3)	(4)
Long dry	3.580**	2.148		5.487***
	(1.53)	(2.17)		(1.38)
Short dry	-1.386	-2.818	-5.487***	
	(1.72)	(2.31)	(1.38)	
Short wet	1.432		-2.578	2.909*
	(2.02)		(1.68)	(1.66)
Long wet		-1.432	-1.709	3.778***
		(2.02)	(1.30)	(1.28)
Constant	18.018***	19.450***	15.417***	9.930***
	(0.92)	(1.80)	(0.99)	(0.97)
N	1297	1297	1296	1296
Dep. var. mean	18.9	18.9	13.4	13.4

Robust standard errors. Dependent variables expressed in US dollars.

Table 7: Fixed-effect regressions. Relationship between profits and herd size.

	(1) Profit, tot.	(2) Profit HH lab, tot.	(3) Profit, p.a.	(4) Profit HH lab, p.a.
1. Entire herd:				
N. cattle	6.213*	3.013	-8.163***	-5.596***
	(3.69)	(3.86)	(1.12)	(1.31)
N. cattle sq.	-0.099	-0.087	0.156***	0.102***
	(0.11)	(0.12)	(0.03)	(0.03)
t	-29.819***	-44.666***	3.396	-2.209
	(7.75)	(8.99)	(2.32)	(2.83)
N	5863	5863	5746	5748
Dep. var. mean	199	154	48	35.1
2. By type of animal:				
N. cows	51.334***	48.730***	11.574***	14.370***
	(13.05)	(13.89)	(2.78)	(3.40)
N. cows sq.	-1.634	-1.788	-0.528***	-0.684***
	(1.23)	(1.28)	(0.15)	(0.18)
N. bulls	-2.345	-11.758	-15.972***	-12.710***
	(14.75)	(16.41)	(3.58)	(4.43)
N. bulls sq.	-2.770	-1.374	2.009***	1.338
	(4.26)	(4.56)	(0.72)	(0.83)
N. oxen	10.110	-3.499	-7.160*	-4.862
	(26.23)	(27.72)	(4.34)	(4.58)
N. oxen sq.	-5.777	-2.042	0.147	-0.059
	(10.11)	(10.70)	(1.40)	(1.40)
N. calves	3.724	5.245	-15.265***	-10.587***
	(11.95)	(13.60)	(2.86)	(3.56)
N. calves sq.	-2.965	-3.836*	0.846**	0.409
	(1.84)	(2.10)	(0.36)	(0.41)
N. heifers	-25.210**	-22.453*	-18.959***	-16.754***
	(10.96)	(11.86)	(2.94)	(3.80)
N. heifer sq.	1.083	0.181	1.848***	1.615***
	(2.09)	(2.28)	(0.34)	(0.39)
t	-23.689***	-39.209***	5.688**	-2.174
	(9.03)	(10.34)	(2.88)	(3.68)
N	4998	4997	4894	4896
Dep. var. mean	193	150	47.2	34

Household and data round fixed effects. Robust standard errors clustered at the village level.

Table 8: Fixed-effect regressions. Profitability of animals based on their value at baseline.

	Profits per animal, excl. HH labour						Profits per animal, incl. HH labour					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
SR value of cattle	0.084**						0.038					
	(0.03)						(0.03)					
Squared term	0.000***						0.000***					
	(0.00)						(0.00)					
SR value of cows		0.061**						0.059**				
		(0.03)						(0.03)				
Squared term		0.000**						0.000*				
		(0.00)						(0.00)				
SR value of bulls			0.045*						0.042			
			(0.03)						(0.03)			
Squared term			-0.000						-0.000			
			(0.00)						(0.00)			
SR value of oxen				0.046						0.037		
				(0.05)						(0.06)		
Squared term				-0.000						-0.000		
				(0.00)						(0.00)		
SR value of heifer					0.038						0.033	
					(0.04)						(0.05)	
Squared term					0.000						-0.000	
					(0.00)						(0.00)	
SR value of calves						0.313***						0.221***
						(0.07)						(0.07)
Squared term						-0.002***						-0.001**
						(0.00)						(0.00)
N	5641	4807	2382	1285	3468	3510	5643	4808	2382	1285	3468	3509
Dep. var. mean	47.1	52.2	34.9	30.7	37	44.6	34.3	41.7	26	23.2	25.3	34.3

Cattle value measures centred by subtracting the mean. Household and data round fixed effects. Robust standard errors clustered at the village level.

Table 9: Fixed-effect regressions. Profitability of animals based on their value at baseline. Value below the median.

	Profits per animal, excl. HH labour						Profits per animal, incl. HH labour					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SR value of cattle	0.163***						0.115***					
	(0.04)						(0.04)					
Squared term	0.000						0.000					
	(0.00)						(0.00)					
SR value of cows		0.133***						0.120***				
		(0.03)						(0.03)				
Squared term		0.000						0.000				
		(0.00)						(0.00)				
SR value of bulls			0.081						0.066			
			(0.05)						(0.05)			
Squared term			-0.000						-0.000			
			(0.00)						(0.00)			
SR value of oxen				0.008						-0.037		
				(0.07)						(0.07)		
Squared term				0.001						0.000		
				(0.00)						(0.00)		
SR value of heifer					0.062						0.045	
					(0.05)						(0.05)	
Squared term					-0.000						0.000	
					(0.00)						(0.00)	
SR value of calves						0.438***						0.323***
						(0.08)						(0.08)
Squared term						-0.002						-0.001
						(0.00)						(0.00)
N	3413	3180	1050	560	1737	1723	3414	3179	1049	560	1736	1722
Dep. var. mean	39.9	45.3	33.2	25.6	35	35.1	30.8	37.5	27	19.4	27.6	27.1

Cattle value measures centred by subtracting the mean. Household and data round fixed effects. Robust standard errors clustered at the village level.

Table 10: Fixed-effect regressions. Profitability of animals based on their value at baseline. Value above the median.

	Profits per animal, excl. HH labour						Profits per animal, incl. HH labour					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SR value of cattle	0.040						0.005					
	(0.07)						(0.08)					
Squared term	0.000**						0.001**					
	(0.00)						(0.00)					
SR value of cows		-0.108						-0.116				
		(0.11)						(0.12)				
Squared term		0.001**						0.001*				
		(0.00)						(0.00)				
SR value of bulls			0.011						0.024			
			(0.06)						(0.06)			
Squared term			0.000						0.000			
			(0.00)						(0.00)			
SR value of oxen				0.356***						0.401***		
				(0.11)						(0.11)		
Squared term				-0.001***						-0.001***		
				(0.00)						(0.00)		
SR value of heifer					0.177*						0.176	
					(0.10)						(0.13)	
Squared term					-0.000						-0.001	
					(0.00)						(0.00)	
SR value of calves						0.404***						0.403***
						(0.12)						(0.12)
Squared term						-0.002***						-0.002***
						(0.00)						(0.00)
N	2185	1397	786	316	1213	1213	2186	1399	787	316	1214	1213
Dep. var. mean	60.4	69.1	37.5	36.9	41.2	52	46	56.3	29.4	29.9	28.6	41.7

Cattle value measures centred by subtracting the mean. Household and data round fixed effects. Robust standard errors clustered at the village level.

Table 11: OLS and IV regressions. Effects of calves' value on profits and Rates of Return.

	Profits, p.a.				ROR of calves, p.a.	
	(1) OLS	(2) First stage	(3) IV	(4) IV	(5) OLS	(6) IV
Calves' value, p.a. (W2)	.509***		1.19**	1.31**	2.34***	9.52**
	(.059)		(.47)	(.65)	(.31)	(4.1)
Female calf		9.84***				
		(2.2)				
Calves' value, p.a. (W1)				.00965		
				(.11)		
Constant	2.62	62.6***	-41.6	-47.1	17.5	-410*
	(3.4)	(1.4)	(31)	(33)	(18)	(238)
N	1754	1605	1605	1087	1161	1070
Dep. var. mean	36.9	66.2	37	31.3	157	154
First-stage F-test			19.3	12.3		15
p-value			1.3e-05	5.0e-04		1.3e-04

Sample made of farmers having a newborn calf between the first and second round of data collection.
Robust standard errors clustered at the village level.

Table 12: OLS and IV regressions. Effects of cattle's value on profits and Rates of Return.

	Profits, p.a.				ROR of cattle, p.a.	
	(1) OLS	(2) First stage	(3) IV	(4) IV	(5) OLS	(6) IV
Cattle's value, p.a. (W2)	.231***		.332*	.329	.154***	.33*
	(.032)		(.2)	(.31)	(.027)	(.2)
Female calf		20.9***				
		(5.2)				
Cattle's value, p.a. (W1)				.0498		
				(.15)		
Constant	-10.6**	154***	-10.7	-16.8	-4.58	-21.6
	(4.9)	(3.5)	(32)	(31)	(4.6)	(32)
N	2767	2004	2004	1972	2724	1972
Dep. var. mean	32.4	162	43.1	42.4	23.9	31.4
First stage F-test			15.8	7.29		16.9
p-value			8.1e-05	7.2e-03		4.5e-05

Sample made of farmers having a newborn calf between the first and second round of data collection.
Robust standard errors clustered at the village level.

Table 13: OLS and IV regressions. Effects of calves' value on marginal profits and returns. Analysis on sub-groups according to their average cattle value in Wave 1 with respect to the median value.

	Below median cattle's value (W2)					Above median cattle's value (W1)				
	Profits, p.a.			ROR of calves, p.a.		Profits, p.a.			ROR of calves, p.a.	
	(1) OLS	(2) First stage	(3) IV	(4) OLS	(5) IV	(6) OLS	(7) First stage	(8) IV	(9) OLS	(10) IV
Calves' value, p.a. (W2)	.312***		1.02**	3.53***	12.5**	.67***		1.78	1.55***	14.5
	(.061)		(.52)	(.41)	(5.1)	(.11)		(1.7)	(.46)	(26)
Female calf		9.51***					5.22			
		(2.7)					(3.3)			
Constant	8.86***	54.2***	-30.5	12.5	-465*	-3.09	76.9***	-91	-54	-1010
	(3.3)	(1.6)	(30)	(21)	(262)	(8)	(2.1)	(135)	(40)	(1916)
N	1027	950	950	804	745	727	655	655	357	325
Dep. var. mean	26.9	57.2	28.2	200	198	51	79.1	49.7	61	51.4
First-stage F-test			12.8		12.4			2.47		.315
p-value			3.9e-04		4.8e-04			.117		.575

Sample made of farmers having a newborn calf between the first and second round of data collection. Robust standard errors clustered at the village level.

Table 14: OLS and IV regressions. Effects of cattle and calves' value on profits. Analysis on sub-groups according to their average cattle value in Wave 1 with respect to the 25th percentile value.

	Below 25th percentile of cattle's value (W2)					Above 25th percentile of cattle's value (W1)				
	Profits, p.a.			ROR of calves, p.a.		Profits, p.a.			ROR of calves, p.a.	
	(1) OLS	(2) First stage	(3) IV	(4) OLS	(5) IV	(6) OLS	(7) First stage	(8) IV	(9) OLS	(10) IV
Calves' value, p.a. (W2)	.311***		2.05**	5.47***	20.8**	.532***		.954	1.86***	4.11
	(.076)		(.93)	(.71)	(8.6)	(.078)		(.86)	(.3)	(4)
Female calf		8.42**					6.59**			
		(3.4)					(2.7)			
Constant	5.27*	45***	-76.2*	-.895	-690*	3.99	72***	-26.8	-32.6	-189
	(3.2)	(1.9)	(44)	(27)	(370)	(5.4)	(1.6)	(64)	(23)	(280)
N	544	501	501	469	430	1210	1104	1104	692	640
Dep. var. mean	20.3	47.4	20.7	247	242	44.3	74.7	44.4	96.6	94.4
First-stage F-test			5.95		9.45			6.11		2.71
p-value			.015		2.3e-03			.014		.101

Sample made of farmers having a newborn calf between the first and second round of data collection. Robust standard errors clustered at the village level.

Table 15: OLS and IV regressions. Placebo using a dummy equal to one if a calf was born between the two waves, irrespectively of its gender.

	Profits, p.a.			ROR of calves, p.a.
	(1) First stage	(2) IV	(3) IV	(4) IV
Calf born	-13.3***			
	(4.2)			
Calves' value, p.a. (W2)		-.0897	.324	6.94
		(.62)	(1.1)	(7.9)
Calves' value, p.a. (W1)			.161	
			(.2)	
Constant	79.5***	42.9	2.83	-257
	(4.1)	(41)	(58)	(469)
N	1754	1754	1180	1161
Dep. var. mean	67.3	36.9	31.4	157
First-stage F-test		10	3.54	2.06
p-value		1.6e-03	.06	.151

Entire sample. Robust standard errors clustered at the village level.

Table 16: 2SLS. Exploring the channel through which an average calf value increases profits and returns.

	(1) Annual milk revenues, p.a.	(2) Annual milk revenues, p.a.	(3) Daily median milk production, p.a.	(4) Daily median milk production, p.a.	(5) Health costs for cattle, p.a.	(6) Health costs for cattle, p.a.	(7) Health treatment cost, p.a.	(8) Vaccination cost, p.a.	(9) Deowrm cost, p.a.	(10) Spraying cost, p.a.
Calves' value, p.a. (W2)	1.16***	1.1***	.0169***	.0171***	.125**	.103**	.0687***	.0453*	.0202*	.0249
	(.3)	(.29)	(.0037)	(.0036)	(.051)	(.048)	(.024)	(.024)	(.011)	(.024)
Annual milk revenues, p.a. (W1)		.215***								
		(.057)								
Daily median milk production, p.a. (W1)				.0543						
				(.061)						
Health costs, p.a. (W1)						-.247***				
						(.071)				
Constant	-22.5	-26.9	-.626***	-.661***	1.44	1.71	-1.11	-1.46	.611	1.58
	(20)	(17)	(.24)	(.21)	(3.4)	(3)	(1.6)	(1.6)	(.74)	(1.6)
N	1583	1553	1575	1545	1559	1550	1337	1010	1368	1526
Dep. var. mean	54.3	54	.49	.487	9.77	9.65	3.46	1.56	1.95	3.23
First-stage F-test	19.8	19.6	17.4	19	19.7	21.2	21.4	10	21.9	18.2
p-value	1.0e-05	1.2e-05	3.5e-05	1.5e-05	1.1e-05	5.2e-06	4.8e-06	1.7e-03	3.7e-06	2.4e-05

Dependent variables are measured at the animal level in the second data round. In columns 2, 4 and 6 I additionally control for the first round level of the dependent variable. Sample made of farmers having a newborn calf between the first and second round of data collection. Robust standard errors clustered at the village level.